

# **ICAST 2007**

**PROCEEDINGS**

**INTERNATIONAL CONFERENCE  
ON ADAPTIVE SCIENCE &  
TECHNOLOGY**

**10-12 DECEMBER 2007, GIMPA CAMPUS, ACCRA GHANA**

**TUTORIALS**

**SHORT COURSES**

**WORKSHOPS**

**SHORT COURSES, TUTORIAL & WORKSHOPS**

ID	Title	Instructor(s)	Activity Type & Duration
W1	Information Technology for Healthcare	Prof. Srinivas B. Mandalika, Int'l Institute of Information Technology, India	Half-Day Workshop
T1	Programming High Performance Computers with Message Passing Interface (MPI)	Dr Ekow Otoo, Staff Scientist	2-Day Tutorial
W2	Introduction to Scientific & Engineering Computing Using SCILAB™ <i>free software</i>	Dr A. Gyasi-Agyei, Central Queensland University, Australia	1 Full-Day Workshop
W3	Data collection and data management for community project formulation and evaluation	Rev. Tom Akuetteh Ndanu, University of Ghana Dental School, Korle Bu, Accra- Ghana	Half-Day Workshop
W4	Parcel-Based GIS System Development Concepts	Professor Frank Derby, Penn State University, Pennsylvania, USA	1 Full-Day Workshop
T2	Introduction to Preparing Scientific Papers Using LaTeX/TeX	Dr Ekow Otoo, Staff Scientist	Half-Day Tutorial
T3	Broadband wireless access over WiMax/IEEE 802.16: cost-effective cable replacement in the local loop	Dr A. Gyasi-Agyei, Central Queensland University, Australia	Half-Day Tutorial
SC1	<b>Transient and Lightning Protection:</b> Theory & Practice - including Building & Surge Protection	Professor Chandima Gomes, University of Colombo, Sri Lanka	Full-Day Short Course
SC2	Wireless Solution for Emergency Response for the Developing World	Mr. David Padi, United Nations Communications & Information Technology Services (CITS), New York, USA	Half-Day Short Course
W5	TCP/IP Protocol in Networking	Professor Willie Ofosu, Pennsylvania State University, USA	Half-Day Workshop
T4	The Basics of Cellular Telephony: From 2G to 3G	Dr Roch H. Glitho, Expert at Ericsson Canada & Adjunct Associate Professor- Concordia University, Canada	Half-Day Tutorial
W6	Liability Issues Facing the GIS community in the United States	Professor Salvatore A Marsico, Pennsylvania State University, USA	Half-Day Workshop
W7	Fundamentals of Geodesy in GIS and GPS Surveying Applications	Professor Frank Derby, Penn State University, Pennsylvania, USA	Half-Day Workshop

**ICAST 2007 WORKSHOP**

**Instructor:** Dr. Francis Derby  
**Title:** Development of Land Parcel-Based information System  
**Duration:** Half-Day  
**Contribution ID:** 152  
**Affiliation:** Penn State University, P. O. Box PSU, Lehman, PA 18627, [fwd3@psu.edu](mailto:fwd3@psu.edu), +1 570 675 9222

**Abstract:**

Land is one of the most essential commodities that humans need to exist. It is needed for all aspects of human life such as living, agriculture, commerce, mining, development and many more activities. Unfortunately ignoring minor additions as a result of earthquakes and volcanic activities, the total area of available land is finite. With population increases, there is strong demand for available as well as competition to access resources in land. Such demands have engendered the need to effectively manage land and to use available land to its most effective use for the benefit of mankind.

While striving to ensure good stewardship of the land, it has become necessary to maintain complete and up-to-date information about land. Availability of land related information ensures that informed decisions are made about the use of the land as well as resources in land. Parcel-based information systems are becoming essential in land management activities. Since land surveyors are the primary source for acquiring such information, the intent of this paper is to present a practical approach to land surveyors and land managers about the development of parcel based information system from existing survey data to support decision making and resource management processes.

**Intended Audience:**

This new workshop is an introductory course for surveyors, mappers, engineers, navigators geoscientists and GIS professionals who use GPS technology.

**Instructor's Bio:**

**Dr. Francis W. Derby** is currently an Associate Professor of Surveying and Geographic Information Systems at Penn State University. He holds a Diploma from the Kwame Nkrumah University of Science and Technology, Kumasi, B.Sc.(Hons.) degree in Surveying and Mapping Sciences from the University of East London and a Ph.D. from the University of Florida. Dr. Derby has extensive international experience in surveying and land information systems. He has worked as land surveyor in England, South America, East Africa and the Caribbean. He has also served as a World Bank consultant in Peru and Tanzania, and Technical Expert to the Commonwealth Secretariat of Great Britain (under the Commonwealth Fund for Technical Cooperation) in Dominica. During these assignments, Dr. Derby advised governments on land information management systems, cadastral systems and land records modernization. He has also implemented such systems in those countries. He has delivered several workshops in land surveying, land tenure, land registration, Land Information Systems (LIS) and Geographic Information Systems (GIS). His research interests include land tenure issues, implementation of Cadastral, Land, and Geographic Information Systems.

**Facility Requirements:**

1. Laptop projector
2. Flip Chart
3. Colored markers for writing on the Flip Charts



# Programming High Performance Computers with Message Passing Interface (MPI)

Ekow J. Otoo

*A Two-Day Post-ICAST'07 Tutorial, Accra, Ghana*

## I. OVERVIEW

This is a two-day tutorial on programming using the Message Passing Interface in C. It is being offered immediately following the ICAST'07 Conference in Accra. High Performance Computing (HPC), is the act in computer science of harnessing the simultaneous use of more than one CPU/Cores (sometimes up to tens of thousands as in Supercomputers), to execute a program in parallel. Examples of the various fields of applications of HPCs are: Simulation, Data Mining (including Statistical Information Gathering, Economic Modeling, Planning and Decision Making), Geophysics, Climate Modeling, Weather Forecasting, Bio-informatics, etc. A low cost approach to realizing HPC is the use of a cluster of workstations or PCs with each node running Linux as the Operating System (OS), and using a free software to implement the parallelism. Such a configuration is often referred to as a Beowulf cluster. It is a general cost-effective alternative to a traditional supercomputer. For most institutions in Ghana where the demand for high performance computing is needed, setting up a computing clusters should provide sufficient functionalities of an HPC. Some areas where cluster computing can be applied in Ghana to-day are in statistical information gathering and analysis, economic planning and modeling, weather forecasting, geographic information systems and simulations.

Associated with the use of an HPC is parallel processing and parallel application programming. A parallel program generally runs faster because there are more CPUs or cores running it. The standard mechanism for parallel programming is the Message Passing Interface (MPI). MPI used in conjunction with either FORTRAN or the C programming language is a set of library calls that allows an application to be run as a collection of processes that communicate through messages. Message passing with MPI is the major programming model in cluster computing and on large distributed-memory

systems in high-performance computing. MPI continues to be the dominant programming model on current as well as upcoming large-scale supercomputers, such as IBM BlueGene/L and BlueGene/P, Cray XT-3 and XT-4, as well as on Linux clusters of all sizes. Writing an explicit parallel program requires the programmer to rethink the way the problem is to be solved.

This tutorial provides an introductory overview of parallel computing with emphases on beginner's and some intermediate level concepts that are most relevant to the user. It should be suitable for new or prospective users, students and anyone seeking a general overview of parallel computing. It discusses software tools and hardware, with focus on standards, portability, and systems that are freely available. The tutorial provides training in parallel computing concepts and terminologies, using code examples in C to illustrate the concepts.

### *A. Objective and Goals*

The aim of this tutorial is to give people who already have some programming experience, an introduction into the basics of parallel programming. The focus is on the programming models of MPI with language support in C within the Linux OS environment. We recognize that most interested students may not have had prior experience in programming in C in a Linux environment. For this reason, a quick introduction to Linux and C programming will also be given. There will be hands-on sessions to allow users to immediately test and understand what the basic constructs of MPI are meant to do. Attendees will leave the tutorial with an understanding of how to develop parallel program in C using basic features of MPI and then subsequently follow-up with self-study tutorials that are freely available on the Internet to cover more advanced concepts.

### *Target Audience*

The tutorial is intended for programmers interested in learning how to program High Performance Computing

(HPC) systems such as Supercomputers and Clusters of Computers. Those who need to have an overview of parallel computing are also welcome. This includes new or prospective users of HPCs, managers, or persons needing a refresher on current systems and techniques.

### Prerequisite

Attendees **must** have some prior knowledge of programming in any high level programming language such as C/C++, FORTRAN, Java or Python. Familiarity with C will be an asset but a quick introduction to Linux and programming in C will be covered. No prior knowledge of MPI is assumed and the two-day tutorial will cover concepts at the beginners levels in MPI followed by some concepts at the intermediate level.

## II. CONTENT AND OUTLINE

The tutorial will spend about a quarter of the two-day sessions on introducing attendees to the Linux/Unix environment, the use of editors - Gedit, VIM/GVIM, compiling and running C programs and a coverage of a short C tutorial. Specific Linux distribution will be either the Ubuntu [1] or Knopix [2] depending on system's availability at the site. Coverage of the MPI topics will include: Fundamentals of the Message Passing; Getting Started with MPI - Compiling and Running a Sample MPI Program; Point-to-Point Communication - Blocking and Non-Blocking Message Passing; Collective Communication Routines; Derived Datatypes; Groups and Communicators; Virtual Topologies and Parallel Input/Outputs. Some methods of how to debug parallel programs will be discussed.

## III. HANDS-ON ENVIRONMENT AND MATERIAL

Attendees are encouraged to attend this tutorial with their own personal computers. The computer should have a CD/DVD reader if possible. CDs and DVDs with the essential editors and software - Linux, C, MPICH-2, PVFS-2, will be provided at this tutorial for personal installation and for the hands-on exercises. Provision will also be made to provide attendees access to PCs for the hands-on exercises **but this is not guaranteed**. There are numerous websites for resources and material for learning to use Linux/Unix, C and MPI. Some relevant lists will be given in the tutorial notes. Referenced material and sites used in the preparation of the tutorial include [3], [4], [5], [6], [7], [8], [9], [2], [1], [10].

## IV. ABOUT THE INSTRUCTOR

Egya Ekow Otoo is former Associate Professor of Computer Science. He attended Govt. Secondary Technical School, Takoradi and Adisadel College, Cape Coast, Ghana. He has a B.Sc degree in Electrical Engineering from KNUST, Kumasi, a Post-Graduate Diploma degree in Computer Science from the University of Ghana, Legon, an M.Sc. in Computer Science from the University of Newcastle-Upon-Tyne, Britain and a Ph.D. in Computer Science from McGill University, Montreal, Canada. From 1989 to 1997 he served as senior consultant to GIS Division, Natural Resource Canada, Ottawa and was also the lead developer of the Delta-X project, a system for managing and accessing digital Geo-Spatial databases. He served as the Chairperson of the Working Group II/3 - Technologies for Large Volumes of Spatial Data, of the International Society of Photogrammetry and Remote Sensing (ISPRS), Commission II, from 1992 to 1996. He has served as a member of the program committee on a number computer science conferences.

## REFERENCES

- [1] Ubuntu - The Linux-Based Operating System, "<http://www.ubuntu.com/>." [Online]. Available: <http://www.ubuntu.com/>
- [2] KNOPPIX: A bootable Linux live system, "<http://www.knoppix.com/>." [Online]. Available: <http://www.knoppix.com/>
- [3] W. Gropp, E. Lusk, and A. Skjellum, *Using MPI*, 2nd ed. Cambridge, Mass: MIT Press, 1999.
- [4] W. Gropp, E. Lusk, and R. Thakur, *Using MPI-2: Advanced Features of the Message-Passing Interface*. Cambridge, Mass: MIT Press, 1999.
- [5] Web Tutorial from the Ohio Supercomputer Center, "<http://www.osc.edu/press/releases/2006/pacs.shtml>." [Online]. Available: <http://www.osc.edu/press/releases/2006/pacs.shtml>
- [6] University of Cambridge, Engineering Department, "<http://www-h.eng.cam.ac.uk/>." [Online]. Available: <http://www-h.eng.cam.ac.uk/>
- [7] The Message Passing Interface (MPI) Standard, "<http://www-unix.mcs.anl.gov/mpi/mpich/>." [Online]. Available: <http://www-unix.mcs.anl.gov/mpi/mpich/>
- [8] Tutorial Material on MPI Available, "<http://www-unix.mcs.anl.gov/mpi/tutorial/>." [Online]. Available: <http://www-unix.mcs.anl.gov/mpi/tutorial/>
- [9] Open MPI: Open Source High Performance Computing, "<http://www.open-mpi.org/>." [Online]. Available: <http://www.open-mpi.org/>
- [10] Beowulf.org: Resources for Beowulf Class Cluster, "<http://www.beowulf.org/>." [Online]. Available: <http://www.beowulf.org/>

# Introduction to Preparing Scientific Papers Using L<sup>A</sup>T<sub>E</sub>X/T<sub>E</sub>X

Ekow J. Otoo

*A Half-Day Tutorial at ICAST'07, Accra, Ghana*

## I. OVERVIEW

Most paper submissions and presentations in the scientific community generally involve mathematical expressions, scientific notations and symbols that are not normally encountered in every day writings such as newspapers and novels. Publishers of scientific journals and conference proceedings expect authors to present their final manuscripts in sufficiently high quality that little or no further typesetting work should be necessary. The ubiquitous standard mechanism for preparing scientific papers today is Latex/TeX. Unfortunately the use of LaTeX/TeX has not been pervasive in higher institutions of learning and scientific communities of developing countries such as Ghana. Despite the fact that the software is open-source, free and has abundance of on-line tutorials for self study, hardly any mention or use of it is made in all the academic institutions in Ghana. There is the misguided myth that LaTeX/TeX has a steep learning curve, and as such, our talented engineering and science students, as well as maths and science instructors, shy away from it and elect to use MS Office and equation editor that is grossly inefficient tool for preparing scientific text. Learning to prepare documents and presentations in LaTeX/TeX is a first step towards communicating engineering and scientific knowledge and ideas to others. This tutorial introduces participants to the basics of LaTeX for preparing scientific publications that involve mathematical expressions. It also gives some expositions on macros that are specific to chemistry, physics and biology.

### *Objectives and Goals*

The objectives and goals of the tutorial are to:

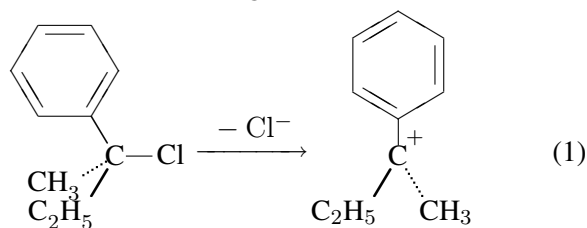
- introduce participants to the basics of LaTeX/TeX;
- show how specialized macros for specific domains are used;
- demonstrate the use of LaTeX for preparing slides for lectures;

- incorporate pictures into LaTeX documents;
- prepare bibliographic databases for citations in documents.

The tutorial is at the beginners level but presents sufficient elements of LaTeX/TeX to enable one to prepare documents that contain reasonable sophisticated mathematical expressions. At the end of this tutorial, one should be able to prepare documents with inserted Encapsulated Postscript (eps) and Postscript (ps) images, create a bibliography database for citations and generate a Portable Document Format (pdf) and postscript files. The LaTeX/TeX system is pretty large but a participant should be able to expand his/her understanding from the basics introduced and continue to typeset more esoteric expressions by following the abundant resources freely accessible from the Internet. In short, a participant should be able to typeset a document that contains mathematical expressions like:

$$\sum_{i=1}^n i^3 = \frac{n^2(n+1)^2}{4}$$
$$\int \frac{dx}{\sqrt{a^2+x^2}} = \ln(x + \sqrt{a^2+x^2}), \quad a > 0.$$

and extend this knowledge to producing chemical formula as shown below through further self-studies.



### *Target Audience*

The tutorial is intended for Science/Engineering students and lecturers and also those interested in pursuing careers in scientific publishing.

## Prerequisite

The tutorial will be at a beginner's level and slowly introduce sufficient material for preparing good quality scientific papers. No prior knowledge of LaTeX/TeX is required but familiarity with using a Personal Computer (PC) running Windows or Linux to type a simple document is required.

## II. CONTENT AND OUTLINE

The main topics to be covered in this tutorial will include: Use of a text editor - gedit, vim/gvim; Using proTeXt/TeXLive; document style formatting - chapters, sections, etc.; environments - tables, figures, lists ; mathematics - symbols, subscript, superscript, in-line maths, display maths, matrices; use of graphics; use of special packages; creating a .bib file, cross-referencing, citations; special TeX IDE and editors - TeXnicCenter, Texmaker;

## III. HANDS-ON ENVIRONMENT AND MATERIAL

Attendees are encouraged to attend this tutorial with their own personal computers. The computer should have either a CD reader or a USB port if possible. CDs and DVDs with the essential editors and software for LaTeX/TeX will be provided at this tutorial for personal installation and the hands-on exercises. Provision will also be made to provide attendees access to PCs for the hands-on exercises **but this is not guaranteed**. There are numerous websites for resources and material for learning LaTeX/TeX, and some relevant lists will be given. Some referenced material and sites used for the tutorial are [1], [2], [3], [4], [5], [6].

## IV. ABOUT THE INSTRUCTOR

Egya Ekow Otoo is a former Associate Professor of Computer Science. He attended Govt. Secondary Technical School, Takoradi and Adisadel College, Cape Coast, Ghana. He has a B.Sc degree in Electrical Engineering from KNUST, Kumasi, a Post-Graduate Diploma degree in Computer Science from the University of Ghana, Legon, an M.Sc. in Computer Science from the University of Newcastle-Upon-Tyne, Britain and a Ph.D. in Computer Science from McGill University, Montreal, Canada. From 1989 to 1997 he served as senior consultant to GIS Division, Natural Resource Canada, Ottawa and was also the lead developer of the Delta-X project, a system for managing and accessing digital Geo-Spatial databases. He served as the Chairperson of the Working Group II/3 - Technologies for Large Volumes of Spatial Data, of the International Society of Photogrammetry and Remote Sensing (ISPRS), Commission II, from 1992 to 1996. He has served as a member of the program committee on a number computer science conferences.

## REFERENCES

- [1] The Comprehensive TeX Archive Network, "<http://www.ctan.org/>." [Online]. Available: <http://www.ctan.org/>
- [2] H. Kopka and P. W. Daly, *Guide to LaTeX*, 4th ed. Reading, MA: Addison-Wesley Professional, 2003.
- [3] L. Lamport, *A document preparation system: User's guide and reference*, 2nd ed. Reading, MA: Addison-Wesley Professional, 1994.
- [4] F. Mittelbach and M. Goossens, *The LaTeX Companion*. Reading, MA: Addison-Wesley Professional, 2004.
- [5] S. Fujita, "Development of xymtex2ps for the postscript typesetting of chemical documents containing structural formulas," *J. of Comput. Chem., Jpn.*, vol. 4, no. 2, pp. 69 – 78, 2005.
- [6] The TeX User's Group Web Site, "<http://www.tug.org/>" [Online]. Available: <http://www.tug.org/>

### ICAST 2007 WORKSHOP

**Instructor:** Dr. Willie K. Ofosu  
**Title:** TCP/IP Protocol in Networking  
**Duration:** Half-Day  
**Contribution ID:** 169  
**Affiliation:** Pennsylvania State University, WILKES\_BARRE, Lehman, PA 18627, USA

#### **Abstract:**

Since the inception of networking computers together in 1972, the technology has grown exponentially with all areas of Industry gaining from the advantages the technology has to offer. One of the major factors in making this a preferred technology is the 7 layer Open System Interconnection (OSI) Model established by the International Standards Organization (ISO). The usefulness of the OSI is in allowing computers and peripheral equipment by different manufacturers to talk to each other.

The TCP/IP protocol suite provides the same facility as the OSI 7-layer model, and its 5 hierarchical levels correspond to the 7 layers of the OSI model. The topmost layer of the TCP/IP suite corresponds to the combined functionality of the three top layers of the OSI model. The suite assumes the presence of its bottom layer which corresponds to layers 1 and 2 of the OSI model. The functionality of the suite focuses on its three top layers, The Network layer, the Transport layer and the Applications layer. The Network and Transport layers span across the whole of the Wide Area Network.

Currently, the computer has become a tool that finds constant use in the home, in schools and in industry. The TCP/IP protocol suite forms a platform on which various applications are based, and the suite functions across the whole Internet. This workshop is intended to inform both the beginner and moderately advanced user who have the interest to learn how the TCP/IP functions in the network environment and how networks function as part of the Internet. The workshop assumes a basic understanding of data communications

#### **Instructor's Bio:**

Dr. Willie K. Ofosu is an Associate Professor at Penn State Wilkes-Barre, where he teaches Telecommunications, Information Communications Technology, Wireless Systems, Optoelectronics and Analog and Digital Electronics. He is a member of IEEE, ASEE, IET (England), and a Chartered Engineer (CEng) of England. His research interests are in RF components and antennas. He is currently involved in international activities in cooperation with some faculty members at Kwame Nkrumah University of Science and Technology in Ghana. He is an advocate of diversity in the educational environment. Dr. Ofosu received his Ph.D. from the Electronic Systems Engineering Department at University of Essex in England.

#### **Facility Requirements:**

1. PPT presentation facilities

**ICAST 2007 WORKSHOP**

**Instructor:** Dr. Francis Derby  
**Title:** Fundamentals of Geodesy in GIS and GPS Surveying Applications  
**Duration:** Half-Day  
**Contribution ID:** 180  
**Affiliation:** Penn State University, P. O. Box PSU, Lehman, PA 18627, [fwd3@psu.edu](mailto:fwd3@psu.edu), +1 570 675 9222

**Abstract:**

With modern development of satellite-based positioning and navigation techniques, surveyors, GIS professionals, engineers, navigators, and geoscientists are using Global Positioning Systems (GPS) technology for position fixing and many other applications. Aided by computers, there is the tendency for users to accept the computed results without adequate understanding of the underlying geodetic principles. These principles, although covered in geodesy textbooks, are usually replete with complex mathematical equations with minimal explanations.

This new workshop has been designed to explain the progression of ideas, concepts, and principles that are fundamental to geodetic positioning and navigation with GPS. Special efforts will be made to explain basic geodetic definitions, equations, formulas and algorithms.

This workshop will cover the broad areas of geometric, physical, and satellite geodesy. Topics which will be covered in this workshop include the shape and size of the Earth, coordinate systems, different types of heights, 3-D geodetic coordinate system, marine positioning, gravity and Earth's gravity models, World Geodetic System (WGS) 1984.

At the end of the workshop, participants will have a better understanding of geodetic principles in GPS technology and a better appreciation of the results obtained from GPS observations and computations.

**Intended Audience:**

This new workshop is an introductory course for surveyors, mappers, engineers, navigators geoscientists and GIS professionals who use GPS technology.

**Instructor's Bio:**

**Dr. Francis W. Derby** is currently an Associate Professor of Surveying and Geographic Information Systems at Penn State University. He holds a Diploma from the Kwame Nkrumah University of Science and Technology, Kumasi, B.Sc.(Hons.) degree in Surveying and Mapping Sciences from the University of East London and a Ph.D. from the University of Florida. Dr. Derby has extensive international experience in surveying and land information systems. He has worked as land surveyor in England, South America, East Africa and the Caribbean. He has also served as a World Bank consultant in Peru and Tanzania, and Technical Expert to the Commonwealth Secretariat of Great Britain (under the Commonwealth Fund for Technical Cooperation) in Dominica. During these assignments, Dr. Derby advised governments on land information management systems, cadastral systems and land records modernization. He has also implemented such systems in those countries. He has delivered several workshops in land surveying, land tenure, land registration, Land Information Systems (LIS) and Geographic Information Systems (GIS). His research interests include land tenure issues, implementation of Cadastral, Land, and Geographic Information Systems.

**Facility Requirements:**

1. Laptop projector
2. Flip Chart
3. Colored markers for writing on the Flip Charts

**ICAST 2007 WORKSHOP**

**Instructor:** Prof. Salvatore A Marsico  
**Title:** Liability Issues Facing the GIS community in the United States  
**Duration:** Half-Day  
**Contribution ID:** 190  
**Affiliation:** Penn State University, PO Box Lehman, PA 18627, USA, sam4@psu.edu

**Abstract:**

A Geographic Information System (GIS) provides an opportunity for its creators to articulate spatial information in a format which enables its users to visualize and solve complex spatial problems. The issues that arise from the use of the information associated with GIS are many. The workshop is participant focused and will discuss how the community can minimize exposure to liability by analyzing court cases from the government and private sectors in the United States of America. In addition, the participant will spend time addressing the legal theories of liability applicable to the government and private sectors.

**Instructor's Bio:**

Please see here <http://surveying.wb.psu.edu/psu-surv/salbio.htm>

**Facility Requirements:**

1. PPT presentation facilities

**ICAST 2007 WORKSHOP**

**Instructor:** Mr. David Padi  
**Title:** Wireless Solution for Emergency Response for the Developing World  
**Duration:** Half-Day  
**Contribution ID:** 198  
**Affiliation:** United Nations, NY

**Abstract:**

Today the developing world is no stranger to the problems of globalization: increase in organized crime, proliferation of illegal drugs and weapons, cross board migration and regional instability. These are just a few of the potential problems public safety organizations face. In response to these threats, the need for modern technological tactical tools to provide timely response for crises prevention and day to day management is vital. Designing a homogenous modern, secure, robust digital Terrestrial Trunked Radio based on TETRA Network infrastructure is an increasingly significant.

The goal of this workshop is to provide participant with basic understanding and limitations of conversional radio communications technologies. We will then identify and discuss key enhancement to the conventional radios system, this will lead to the proposed digital Terrestrial Trunked Radio Network for mission critical communication. The workshop will continue with an overview of the network services, and applications for efficient integration of IP voice and data transport solution. We will then discuss the combined features and benefit offered by digital Trunked Radio as an efficient communications system with integrated capabilities to transform operations.

**Instructor's Bio:**

Mr. Padi is a Communications Officer with the United Nations; he has over 24 years experiences in Telecommunications & Information Technologies (Network design & management). He contributed significantly with the design and development for the UN communications & information technology networks used by United Nations Peacekeeping Operations internationally.

From 1989 to date he continue to work on different technologies, including but not limited to complex networks consisting of Satellite Earth Stations, Wireless and Mobile Radio Communications Systems, Digital Private Automatic Branch Exchanges (PABx's), Digital Trunking Systems, Digital Microwave systems and Wide Area Network (WAN) to support Voice, Video and Data.

Currently stationed in UN Headquarters in New York, he supervises and provides useful and timely professional leadership to the UN field missions on design, policy development and implementation of communications & information technologies.

Holds both PgD and an MSc in Telecommunications Engineering from Coventry University, School of Engineering and Cable & Wireless College - United Kingdom, MSc degree in Information Technology from Aspen University, USA, specialized research in Advanced Microwave Systems & Satellite Communications engineering from The George Washington University, School of Engineering & Applied Science, USA.

**Facility Requirements:**

1. Laptop projector



### ICAST 2007 TUTORIAL

**Instructor:** Dr. Amoakoh Gyasi-Agyei  
**Title:** Broadband wireless access over WiMax/IEEE 802.16: cost-effective cable replacement in the local loop  
**Duration:** Half-Day  
**Contribution ID:** 201  
**Affiliation:** Central Queensland University, Australia, E-mail: gyasi-agyei@ieee.org

#### Abstract:

This is a half-day tutorial on broadband wireless access over WiMax/IEEE 802.16, which is a cost-effective cable replacement in the local loop. We will motivate the audience on how a wireless technology like WiMaX/IEEE802.16 can bring a relief to the unwired areas of the world for both local area and wide area communication services. Advantages of WiMaX/IEEE802.16 over its competing technologies in the last mile such as VSAT, xDSL and FTTH will be discussed. Topics to be discussed include

1. Overview broadband communications and WiMaX/IEEE802.16
2. Technical background and foundations of wireless broadband communications – wireless channels, OFDM and OFDMA, multiple-antenna technologies, service offerings
3. ISO/OSI layers implemented in WiMAX
4. WiMaX network architecture
5. WiMaX network performance issues

#### Intended Audience:

Any one interested in wireless communications, especially industry professionals, graduate students and ICT policy makers. No prerequisite will be assumed, but some background in ICT, radio propagation or electrical engineering will be beneficial.

#### Instructor's Bio:

Until 4<sup>th</sup> Jan. 2008 Amoakoh Gyasi-Agyei holds a Senior Lecturer position in Communications/Electronic Engineering at the Central Queensland University, Australia, where he has hosted distinguished professors, serves as the Program Advisor in Electrical/Electronic Engineering and the academic staff in charge of telecommunications engineering. In this position, Amoakoh works with both academic and general staff and students, and has supervised the projects of dozens of students in various areas in telecommunications, signal processing and computer networks. He graduated with a Ph.D. from Adelaide University, Australia in communications engineering and computer networking. He also holds Masters Degree in Communications Engineering & Technology from Chalmers University of Technology, Sweden and undergraduate degree in Electrical/Electronic Engineering from Hamburg-Harburg University of Technology (TUHH), Germany. Amoakoh has worked in several countries, including Research Scientist at Helsinki University of Technology (HUT) Finland within Nokia-sponsored R&D group, Visiting Assistant Professor at Yonsei University in Korea, and Visiting R&D Engineer at National University of Singapore. Amoakoh has experience from Ericsson in Sweden and Philips in Hamburg. He has consulted with industries, including BHP Billiton mines and Mackay Sugar in Australia. His R&D collaboration with Korean colleagues has led to a memorandum of understanding (MoU). He is a member of the IEEE and the IET. He served as the Treasurer for the IEEE Queensland Section in Jan 2004- Dec. 2006. He is a registered professional engineer with the UK Engineering Council. Amoakoh is the founding counselor of IEEE Student Branch at the Central Queensland University. Amoakoh has established many things, including the *International Conference on Adaptive Science & Technology* (ICAST). He serves on the editorial board of some international journals, including Hindawi Research Letters in Communications and the AJICT.

#### Facility Requirements:

1. PPT presentation facilities

## ICAST 2007 TUTORIAL

**Instructor:** Dr. Roch H. Glitho  
**Title:** The Basics of Cellular Telephony: From 2G to 3G  
**Duration:** Half-Day  
**Contribution ID:** 202  
**Affiliation:** LM Ericsson and Concordia University, Montreal, Canada and IMSP, University of Abomey-Calavi, Benin

### Abstract:

The world has witnessed a phenomenal growth of cellular telephony since the early 1990s. This growth is even more spectacular in developing countries where alternatives are fewer because of the low penetrations of fixed telephony and the Internet. Cellular telephony users in Africa now number more than 100 million, while only five years ago they were approximately 8 million. The first generation systems were analog and date back to the 1980s. The second generation systems (2G) are digital and their deployment began in the '90s. Third generation systems (3G) are digital but based on packet switching, unlike the two previous systems that are based on circuit switching. They are a product of the 2000s.

Several 2G systems have been standardized but the Global System Mobile (GSM) remains the most widely deployed system. The same applies to the Universal Mobile Telecommunication Systems (UMTS) when it comes to 3G systems. It is now customarily to refer to the General Packet Radio Service (GPRS) combined with GSM as 2.5G. It also customarily to refer to the Enhanced Data Rate for GSM Evolution (EDGE) combined with GSM as 2.75G.

This tutorial presents the basic of cellular telephony with a focus on 2G, 2.5/2.75G and 3G. The first part is devoted to the fundamentals of telephony and the essentials of wireless transmission. The classical hierarchical architecture of fixed telephony networks is reviewed and the signalling system No7 (SS7) is introduced. The wireless transmission techniques (ex: FDMA, TDMA, CDMA) are reviewed after that. In the second part we tackle 2G and 2.5/2.75G. The GSM architecture is described in detail and illustrated by call scenarios. GPRS and EDGE are briefly introduced. The last part of the tutorial deals with UMTS. UMTS relies on IP telephony. The essentials of IP telephony including the Session Initiation Protocol (SIP) and Media Gateway Controller Protocol (MEGACO) are presented. The functional entities and interfaces of UMTS are introduced along with call scenarios.

### Instructor's Bio:

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### Facility Requirements:

1. PPT presentation facility

### ICAST 2007 SHORT COURSE

**Instructor:** Dr. Chandima Gomes  
**Title:** Transient and Lightning Protection  
**Duration:** Half-Day  
**Contribution ID:** 204  
**Affiliation:** University of Colombo, Sri Lanka, Associate Professor, Patten University Sri Lanka

#### **Abstract:**

The aim of this short course is to provide a broad knowledge in building and equipment protection against surges generated by lightning and other sources (HEMPs and NEMPs are not covered) and the lightning safety of human beings. The course has been designed for senior engineers and scientists in power, communication, aviation, industrial, service, defense and research sectors.

#### Topics to be discussed

1. Fundamental Concepts of Lightning (required for engineers): Lightning initiation, attachment and return stroke, characteristics and statistics of lightning generated currents and electric fields, multiplicity, types of lightning, induced voltages, spatial and temporal distribution of lightning density, lightning measurements, triggered lightning, laboratory simulations, current models and field calculations.
2. Human safety: Statistics of lightning accidents, direct strikes and side flashes, step potential, touch potential, international guidelines, health hazards, recommendations for outdoor workers, safety devices
3. Lightning protection on structures: Basic concepts and international views, Rolling sphere, protective angle and mesh methods, Designing of air-termination and down conductor systems, Designing of earthing network, Equipotential bonding, Use of reinforcement steel and foundation earth for lightning protection, Materials, installation technologies and costing, Isolated protection systems, Bound charge problem on petroleum and chemical industries, protection of floating roof tanks, sparking of floating electrodes in fibrous, dusty, fume and other inflammable environments, protection of ammunition dumps, EMC concerns of sophisticated environments, Special issues of earthing, transient and anti-transient coupling, Site inspection and maintenance. (This presentation is based on IEC 62305 series, BS 6651 and NFPA 780)
4. Protection of low voltage power systems: Need for protection, Damage statistics, Coupling mechanisms, Protection scenario, Wiring systems, Lightning and switching impulses, Modes of protection, Peak current handling capacity, let-through voltage, MCOV, follow-current etc., Classes of surge protectors, Types of surge protectors, Zonal concept of protection, SPD selection criteria, Installation concerns, Low frequency earthing, Test impulses and testing procedures, Transmission of surges through signal lines, protection scenario, signal line protection devices, installation concerns, effective internal cabling, outdoor cabling, micro link connections, earthing of receivers, shielding and preventing cross-talk, high frequency earthing, Test impulses and testing methods, Location selection for IT and other sophisticated equipment, Shielding and bonding of network systems, Structural protection of towers, Surge filters for tower top equipment, Protection of the navigation warning light, Shielding and bonding of signal wires, sheath termination, earthing network and ring conductor, earth potential rise, Effects of towers to the neighborhood, site inspection and maintenance (This presentation is based on DIN V VDE V 0185-2:2002, IEC 62305-4/5, ITU-T K.20/21, and BS EN62305-4)

#### **Instructor's Bio:**

Details can be found on the Internet or Google Scholar.

#### **Facility Requirements:**

1. PPT presentation facilities

## **CONFERENCE DIVISION:**

Information & Communications Technologies  
(ICT)

Computer Science & Computer Engineering

# Adaptive Channel Loading MC-CDMA For 4G Wireless Networks

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August, 2007

**Abstract**—Multi-Carrier Code Division Multiple Access (MC-CDMA) is a promising candidate for the air interface of 4G wireless networks. In MC-CDMA systems, a number of sub carriers per user are used for the high-rate data transmission, and each data modulated by a different sub carrier is transmitted through a different frequency band. Each data undergoes a different channel condition and arrives with a different error rate at the base station. By transmitting message data based on the Channel State Information (CSI), a new data transmission scheme called “Adaptive Channel Loading MC-CDMA For 4G Wireless Networks” is introduced in this paper. Simulated results have shown that the scheme is able to effectively optimize resources in a downlink situation even in different noise environment.

**Index Terms**— ACL, 4G, MC-CDMA, OFDM, CSI,

## 1. INTRODUCTION:

Third Generation (3G) mobile communication technologies like CDMA2000, WCDMA are already in deployment in many countries. These are changing the way we communicate, conduct business, access information, and being entertained over the multimedia super highway. 3G services enable users to make video calls to the office and surf the net simultaneously, or play interactive game wherever they may be. Although bandwidth of current 3G technologies promise burst rates up to 384Kb/s and 2Mb/s for vehicular and indoor applications respectively, the average throughput per user is not expected to be more than 171Kb/s during the peak hours[1,8]. This bandwidth is adequate to meet the needs for voice, basic data communication and wireless internet access, but not enough for new interactive multimedia services such as multi-parity video conference. As such there is demand to develop a new physical layer that can give higher bandwidth. These future systems have been termed 4G (4<sup>th</sup> Generation) systems[2,3,9,10]. The main features of such a system will be greater capacity and access speed in the downlink. The vision of 4G wireless/mobile systems will be the provision of broadband access, seamless global roaming, and Internet/data/voice everywhere, utilizing for each the most appropriate always[4,11] connected technology. Multi-Carrier Code Division Multiple Access (MC-CDMA) is a promising candidate for the air interface of 4G wireless networks[5,6,12,13]. MC-CDMA is essentially an Orthogonal Frequency Division Multiplexing (OFDM) technique where the individual data symbols are spread using a spreading code in the frequency domain. The spreading code associated with MC-CDMA provides a multiple access technique as well as interference suppression. It is very efficient in spectrum usage and it is very effective in spectrum

selective channel. The 4G networks are predicted to provide packet data transmission rates of 5Mbps in outdoor-macro-cellular environments and up 20Mbps in indoor-micro-cellular environments. Figure 1 shows a rough sketch of this evolution trend towards 4G.

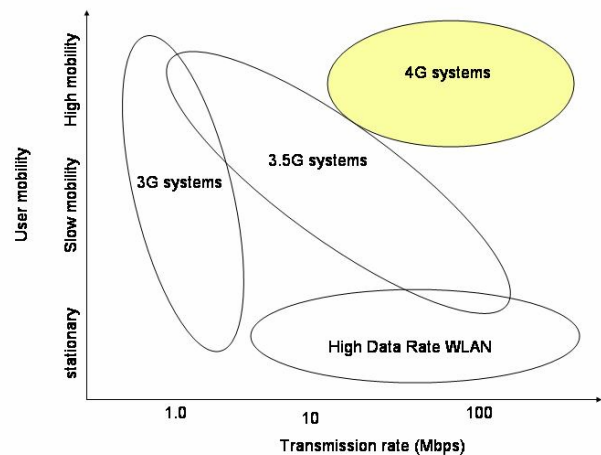


Figure 1 Evolutions towards 4G

In MC-CDMA systems employing adaptive modulation, the number of bits and energy allocated to a subchannel is decided based on the signal to noise ratio in that particular subchannel for a given probability of error. The algorithms used to calculate the bit and energy for all subchannels are known as bit and energy allocation algorithms or simply allocation algorithms. Thus in MC-CDMA systems with adaptive modulation, different number of bits are transmitted in different subchannels based on the channel conditions. If a subchannel has very low SNR than no bits are allocated to that subchannel and if a subchannel has high SNR more number of bits can be allocated to that subchannel. This is taken care by the allocation algorithms.

Recent studies by researchers have combined the principle of CDMA with OFDM which allows one to use the available spectrum in an efficient way and retain the many advantages of a CDMA system. If the number and spacing between the sub carriers are chosen appropriately, it is unlikely that all the sub carriers will be in deep fade and thus provides frequency diversity. This combination of OFDM-CDMA is a useful technique for 4G systems where we need variable data rates as well as provide reliable communication systems. In[7,14] this form of OFDM-CDMA or Multi-Carrier CDMA (MC-CDMA) was first proposed. A MC-CDMA system basically applies the OFDM type of transmission to a Direct Sequence (DS) -

CDMA signal. In conventional DS-CDMA each user symbol is transmitted in the form of sequential chips, each of which is narrow in time and hence wide in bandwidth. In contrast to this, in MC-CDMA due to the FFT transform along with OFDM the chips are longer in time duration and hence narrow in bandwidth. The multiple chips for a data symbol are not sequential but instead transmitted in parallel over many sub carriers. An interesting feature of MC-CDMA is that the modulation and demodulation can be easily implemented using simple FFT and IFFT operators.

Although OFDM is robust to frequency selective fading, it has severe disadvantages in sub carrier synchronization and sensitivity to frequency offset estimation. The other main issue with respect to OFDM is the presence of a large number of sub carriers which exhibits a non-constant nature in its envelope. The combining of OFDM and CDMA has one major advantage though. It can lower the symbol rate in each sub carrier compared to OFDM so that longer symbol duration makes it easier to synchronize[8,15] The MC-CDMA not only mitigates the ISI but also exploits the multipath[9,16] It has shown that MC-CDMA suffers only slightly in presence of interference as opposed to DS-CDMA whose performance decreases significantly in presence of interference. Multi-carrier CDMA spreads the original data stream using a spreading code and then modulates different carriers with each chip, i.e., spreading the chips in the frequency domain. A simple block diagram of a MC-CDMA system is as shown below in Figure 2a.

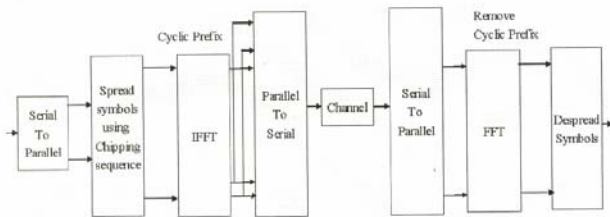


Figure 2a: Block Diagram of MC-CDMA System

The block diagram of a MC-CDMA transmitter is shown in Figure 2b The incoming data stream is first converted to a parallel stream and then spread in time using spreading codes. This ensures that the resulting spectrum has orthogonal sub carriers. The spreading code is represented as  $C(t)$  and the processing gain is  $N$ . The receiver block is shown in Figure 2c. The despreading is done in time after the FFT followed by a low pass filter and demodulation.

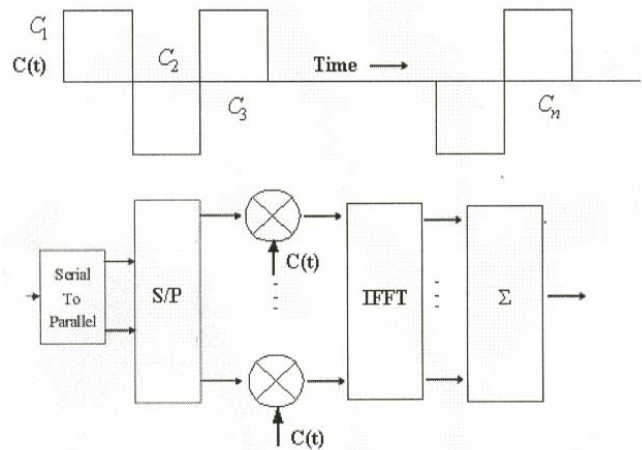


Figure 2b: MC-CDMA Transmitter

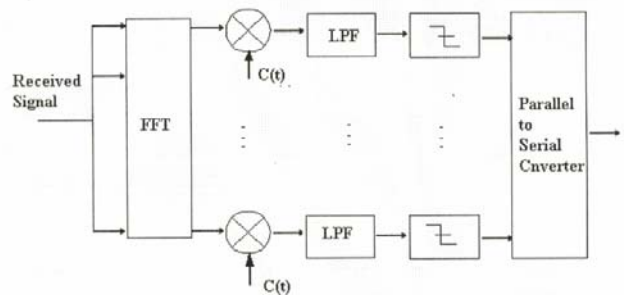


Figure 2c: MC-CDMA Receiver

## 2. ADAPTIVE CHANNEL LOADING ALGORITHM

1. Fix up the required probability of error,  $P_e$  and calculate the SNR gap for the given modulation technique, here QAM.
2. Fix up the maximum number of bits per subchannel,  $q$ , i.e. the maximum constellation size.
3. Find the incremental power matrix whose elements consists of the power required to transmit a one extra bit in the given subchannel using the subchannel gain and subchannel noise variance for all subchannels.
4. Initially set bits and power allocated to each subchannel to be zero
5. After the matrix has been calculated the algorithm works as follows
  - i) we search row 1 for the smallest  $\Delta P$  and if this happens to be for a particular subchannel 'p' we assign one more bit to it and also increment the power allocated to the particular subchannel by  $\Delta P(1,p)$

- ii) if total no of bits allocated to all the subchannels is greater than or equal to the desired no of bits to be transmitted in an OFDM symbol, come out of the iteration
- iii) else rotate the particular column corresponding to the 'p'th subchannel upwards by one row
- iv) go to step i) and repeat until the desired bit rate is achieved.

### 3. SIMULATION

- For a given bit rate and probability of error requirement, the algorithm allocates bit and energy to the subcarriers so that the total transmit power is minimum.
- The algorithm can be modified to achieve maximum transmission rate for a given power budget and  $P_e$ .
- Perfect channel information must be available for the algorithm to allocate bits and energy. Hence channel estimation is required.
- Algorithm uses M-ary QAM as a modulation method with different M for different subcarriers.

Available Channel Bandwidth, B	8 MHz
Maximum Channel Delay Spread, $t_d$	1 $\mu$ s
Guard Interval, $T_g$	4 $\mu$ s
$T_{os}$	32 $\mu$ s
$T_s$	36 $\mu$ s
Subchannel spacing, $f_d$	31.25 kHz
Number of Subcarriers, N	256
Size of IFFT and FFT, 2N	512
Sampling frequency, $f_s$	16 MHz
Cyclic Prefix Length, L	64

Table 1: Simulation Parameters

It is assumed that the perfect statistics of noise and channel are available and using the statistics we allocate bits and power to the subchannel using the bit loading algorithm. For simplicity, coding gain is assumed to be 0 dB and the data rate is fixed at 14.42Mbps (i.e. 512 bits per OFDM symbol time) for comparison with QPSK based static OFDM. Incoming bit stream is buffered and converted into N parallel bit streams using serial to parallel converter so that each subchannel gets the allocated number of bits. Then the bits are modulated using M-ary QAM constellation mapper to get N parallel complex subsymbols corresponding to N subchannels. The corresponding time domain symbols for the given spectrum are obtained by taking 2N point IFFT. The 2N parallel time domain symbols are converted to serial using a parallel to serial converter. The cyclic extension of the above-specified length (L) is added to the time domain symbols to account for ISI and to maintain orthogonality between the carriers and the resulting symbols are converted to analog and transmitted on the channel using a DAC sampling at a rate of  $f_s$ . The received signal is converted to digital using ADC with a sampling rate  $f_s$  and cyclic prefix is removed from the resulting signal. Then it is converted into 2N parallel streams using a serial to parallel

converter and the complex symbols are obtained by taking 2N point FFT. The symbols are demodulated using a M-QAM demodulator to get back the transmitted data stream.

### 4. SIMULATION RESULTS

A white noise spectrum is considered. The bit allocation for this case is given in figure 3. It could be seen from the figure that bit allocation is in accordance with the channel SNR.

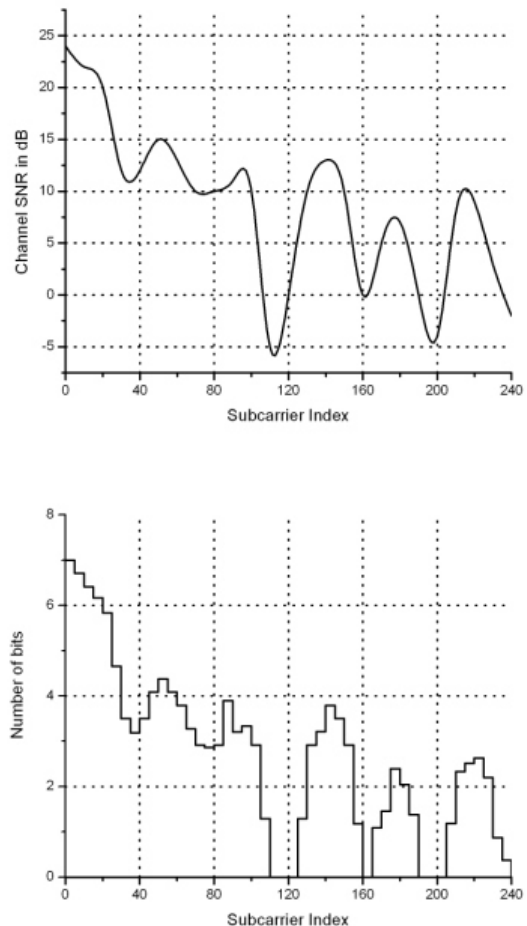


Figure 3: Bit allocation in a white noise environment

In addition to the white Gaussian noise in the channel we introduce narrow band interference in several subchannels. The effect of the narrow band interference is determined. The bit allocation for this type of channel is given in figure 4.

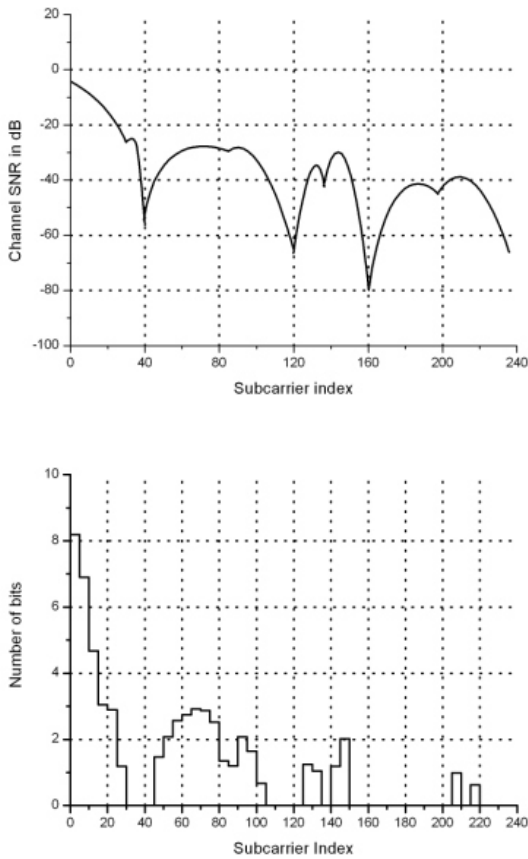


Figure 4: Bit Allocation in the presence of Narrowband Interference

In this case, the total transmit power to achieve the given requirement depends upon the position of occurrence of the narrowband interference. If the interference occurs in a subchannel, which has a good gain then the power loss will be more, because that subchannel would be used for transmission otherwise.

Here we consider a noise with an exponential spectrum. The bit allocation is given in figure 5. In this case the effective channel SNR is high in the intermediate subcarriers and hence more bits are allocated for these subcarriers. This can be inferred from the figure.

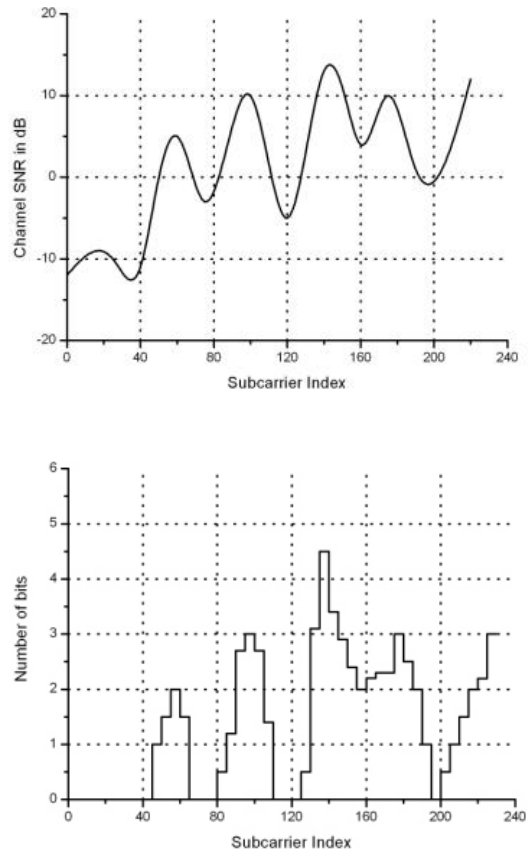


Figure 5: Bit allocation in the presence of noise with exponential spectrum

The algorithm is modified to achieve maximum bit rate for a given power budget and  $P_e$ . The BER plot is obtained for different transmit powers and is given in figure 6.

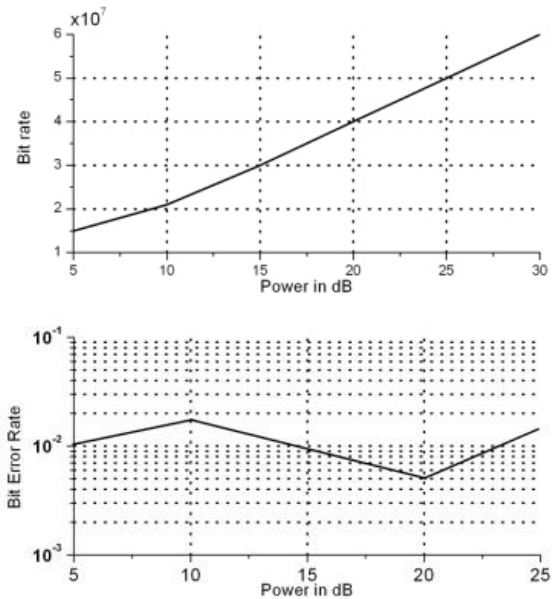


Figure 6: Plot of Bitrate for different power budget maintaining a constant BER



It can be seen from figure 6 that by increasing the total transmit power significant increase in bit rate can be achieved maintaining same BER and is clear that achievable bit rate increases proportionally to an increase in transmit power.

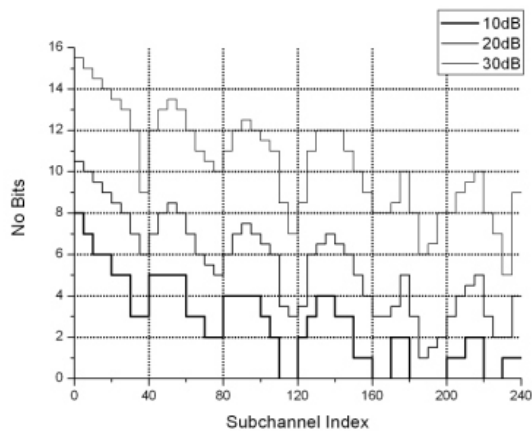


Figure 7: Bit allocation for different power budgets

The bit allocation for different power budgets is presented in figure 7. It can be seen from figure 7 that the number of bits allocated increases proportionally with increase in transmit power.

## 5. CONCLUSION

I have proposed an Adaptive Channel Loading MC-CDMA For 4G Wireless Networks for the downlink in a frequency selective fading environment. The main feature of the adaptive MC-CDMA strategy is the optimization of resources in a downlink situation, also it can provide flexible and high data rate in the downlink for multimedia applications. Extensive simulation studies were performed under various cases and from the simulation results we conclude that significant improvement can be achieved by using the Adaptive Channel Loading Algorithm. Hence, the blocking probability of the system can be reduced. Also the coverage area can be improved in a cellular system by using our algorithm. Even in adverse condition, the bandwidth could be maximized.

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# Text Manipulations And Spamicity Measures: Implications For Designing Effective Filtering Systems For Fraudulent 419 Scam Mails

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**Abstract** - An understanding of the nature of text categories and possible manipulations by Spammers to fool Spam filters within specific Spam corpus is imperative in the design of effective filters. This paper reports an ongoing research in training the text classification engine for the development of NiMFilter (Nigerian Mail Filter), a collaborative content-specific antispam system for filtering Nigerian Scam Mails. A total of 4000 mails partitioned into two equal halves were used for the experiment. These mails were harvested over a six months period. Existing corpus at the 419 coalition website, Nigerian Fraud Mail Gallery, Process Software Website and other Spam mails sent into our mail addresses constitute the manually identified Spam messages used for determining the Spamicities of text categories. Our ham messages consists of regular mailing contents common to the Nigerian e-mailer in order to enable us balance our filtering capacity. Findings show that Nigerian Spammers use some subtle manipulations such as word stemming, deliberate spelling errors, word toggles, insertion of underscores and a combination of American and British English to fool Spam filters. Using Bayesian probability, new text categories with high Spamicities were identified that can enhance the filtering abilities of upcoming and existing antispam systems.

**Keywords:** SPAM, Bayesian, Spammers, Filters, Nigeria, 419.

## I. INTRODUCTION

Several methods have been employed over the years in detecting and filtering Spam at the recipients end. Though, these techniques have attained certain level of success, there has not been a technique that has proved to be 100% successful as each one has one deficiency or the other. Spammers on the other hand, have not relented in modifying their methods in order to outwit Spam filtering programs. Techniques currently employed to prevent Spam generally revolve around the use Origin or address-based filters (which typically use network information for Spam classification) and content filters (that examine the actual contents of email messages)

Other data mining, machine learning and text classification techniques currently under research include memory-based approach [14], digest-based filters [4], density-based filters [16], Chi-squared filters [11], global collaboration filters [8] and artificial neural networks [1]. Social network techniques,

such as Reputation Network Analysis are also under investigation [6], gateway-based protection [12] and Sender and Receiver Addresses as Cues for Anti-Spam Filtering [3].

Spam filtering methods are also not mutually exclusive. A popular Spam filtering program, SpamAssassin uses a combination of Bayesian filtering, rule-based filtering and blacklist checking to calculate a Spam score for e-mail messages. Other authorities have also proposed a technique which revolves around using intrusion detection system (IDS) [13], Sender ID Framework [10] and DomainKeys [5]. . Dealing with Spam at the destination will not always yield the desired results as Spammers have evolved different measures to beat Spam filters at these nodes [9].

### *Origin-Based Filtering*

Blacklists can filter mail from mail servers or domains that have sent Spam or are suspected of doing so. The challenge is that the Spammers can easily move from a blacklisted domain to other domains. Whitelists allow users to specifically define trusted addresses that will immediately classify as legitimate all email received from those addresses. An appealing quality of whitelists is that for most users a whitelist would be significantly smaller and easier to maintain than a blacklist. The Achilles heel of a whitelist is that since the senders of email messages are not authenticated, Spammers who can lay their hands on or guess the addresses on a whitelist can phish and send Spam to addressees that allow mails from the whitelist.

Challenge/response systems are an advanced version of whitelists, allowing senders who are not on the whitelist to have their emails received. Incoming messages from addresses not on the whitelist trigger an automatic reply (or *challenge*) to the sender, requiring them to prove that they are a real user and not an automated mailer. One problem with the challenge response system is the issue of deadlock. If two parties who have never corresponded before both run challenge/response systems, the challenge sent by the recipient's system will be caught by the sender's challenge/response system and neither party will have the opportunity to provide an appropriate response.

### Content Filters

While origin-based filters such as whitelists and blacklists examine email headers and other network information, content filters detect Spam by looking inside the email and examining the message contents. Most content-based or Bayesian filters try to understand the text to various extents in order to identify Spam. A simple word filter, for example, could look to see if the message contains the words porn, please, million, lottery, transfer, *viagra* or *sex* or the phrases “next of kin”, “*buy now*” or “*you’ve won*” to determine whether it is Spam. Filters based on this technique are commonly called keyword-based filters.

## II. RESEARCH DIRECTION

The corpus of mails, generally referred to as Nigerian scam does not totally originate from Nigeria. An examination of routing data made available at the Nigerian 419 mail gallery and the 419 Mail Coalition [15] revealed that these mails are sent from different parts of the world. The common denominators are the bogus business proposals that appeals to the greed and gullibility of the psychology of an average would-be victim [2]. The perpetrators of these cyber crimes are now popularly called “yahoo boys”

We propose a Spam filtering system specifically targeted at Nigerian scam (419) mails aimed at preventing Spam messages from leaving the sending point. The system will operate by building a knowledge base for expert analysis of Spam mails from the source. A text categorization engine will be trained to identify specific words peculiar to the 419 scam problem. When implemented by an ISP or cyber café, it will detect and appropriately flag suspected spamming activities.

### Bayesian Training for Text Categories.

Rule-based filters were the most common type of Spam filter until 2002, when Bayesian filters became popular [7]. Bayesian filters work by analysing the words inside an email message to calculate the probability that it is Spam. This probability is based on not only those words that provide evidence that a message is Spam, but also on those words that provide evidence that a message is not Spam. Words that are not generally found in Spam messages contribute to the probability value in very much the same way as words that are frequently found in Spam messages.

The advantage of this technique is that, given appropriate time and training data, Bayesian filters can achieve a combination of extremely high accuracy rates with a low percentage of false positives. The low amount of false positives generated by a Bayesian filter is useful, as users generally regard the classification of legitimate emails as Spam as an order of magnitude worse than receiving Spam incorrectly classified as legitimate.

### Tokenizing Spam Constituents

The most important factor on which a Bayesian filters based its decision to flag a message as Spam or ham is the message content. This decision is aided by tokenizing the message in

the form of a table of text categories identified in Spam and non-Spam messages. These tokens are then compared with the ones in the Spam and non-Spam database tokens with which the antispam system has been trained in order to determine the Spamicities of the identified tokens. It follows then, that the ability of the filter designer to train the antispam with the right tokens and right Spamicities will enhance the efficiency of the filtering system. In most cases, words common to both ham and Spam possess low spamicity values. Our intention in this discourse is to identify a corpus of text categories common with the “Nigerian 419” mail corpus.

### Computing Spamicity

Once a filter has the list of tokens in a message, it computes the probability that the appearance of the word in a message makes the message Spam or ham as a factor of the frequency of occurrence of the same words in the token databases. This probability value assigned to each word is commonly referred to as *spamicity*, and ranges from 0.0 to 1.0. A spamicity value greater than 0.5 means that a message containing the word is likely to be Spam, while a spamicity value less than 0.5 indicates that a message containing the word is likely to be ham. A spamicity value of 0.5 is neutral, meaning that it has no effect on the decision as to whether a message is Spam or not. The neutral spamicity domain are occupied by words that commonly occur about the same frequency in Spam and non-Spam messages.

Expressed mathematically,

$$\text{Ham Probability} = \frac{\text{Token Frequency in Ham Messages}}{\text{Number of Ham Messages Used for Training Filter}}$$

$$\text{Spam Probability} = \frac{\text{Token Frequency in Spam Messages}}{\text{Number of Spam Messages Used for Training Filter}}$$

$$\text{Spamicity} = \frac{\text{Spam Probability}}{(\text{Ham Probability} + \text{Spam Probability})}$$

## III. DATA PRESENTATION AND ANALYSIS

In a previous research [2] almost 40% of mails emanating from public Internet access points in Nigeria are said to be scam mails. Since a major challenge in filtering is the level of precision and recall, we selected ham messages that fall into other categories of Internet correspondence peculiar to the Nigerian internet terrain. These constitute the major content that can produce false positives as they contend with Spam mails in the filtering system. Table 1 reveals the nature of manipulations some of the selected words are subjected to by Spammers in order to fool Spam filters. Tables 2 and 3 presents our observation of the changes in Spamicities as observed when some of the selected words were manipulated in one way or the other in Spam mails. The table in the Appendix presents carefully selected text categories in Nigerian Scam mails messages, their frequency of occurrence, Spam probabilities, ham probabilities and Spamicities in descending order

TABLE 1: TOKEN MANIPULATIONS AND THEIR FREQUENCIES OF OCCURRENCE

TC/M	NM	FSM	FHM
Beneficiary	Beneficiary (spelling)	13	0
Cooperation	Co-operation (hyphenation)	32	09
Date	Date of birth (compound/spelling)	34	0
Director	Directr (spelling)	23	0
	Dlrector (Toggle)	45	0
Discovered	Disc0vred (spelling)	35	0
Documents	DOCUMENT (Toggle)	21	0
Dollar	Dolar (spelling)	27	3
	Dollarrs (Spelling)	09	1
Fax	Faxnumber (compound)	53	5
First	Firstname ( <b>compound</b> )	3	23
Foreign	Foreing (Spelling)	27	1
	Foreign Account (compound)	45	15
Funds	Funds-transfer (compound/hyphenated)	65	05
	Fund-transfer (compound)	75	0
	Fun-transfer (Spelling error)	08	0
Invoice	Invoice (Spelling Error)	26	1
	Over-invoiced (Compound)	32	1
	Over-invoice (Grammar)	32	0
Joint	J0int (Toggle)	15	0
	Jonit-business (compound)	2	0
Lottery	LOTTERy (Toggle)	15	0
	Lotery	5	0
Mobile	MobiLe (toggle)	12	0
	Mobile-number (hyphen/Compound)	55	8
Next	Nxt (spelling)	5	0
	Next-of-kin	98	5
	Next_of-Kin (Toggle/underscore)	18	0
	Nextofkin (Compound)	27	0
Offset	Off-set (hyphenation)		12
Partners	Partiners (spelling)	23	0
	Pcitners (stemming)	19	
Personal	Personel (Word Manipulation)	12	0
	Persoal Account (Compound)	17	0
	Personals Account (Word Insertion)	21	0
Please	PLEASE (Toggle)	76	4
	Pleasee (Insertion/spelling error)	23	0
Position	Positon (spelling)	46	0
Risk	Risk-free (compound)	246	3
Successful	Successful (Spelling)	23	0
	SUccessful (Toggle)	34	0
Surprised	Surprized (British/American)	10	1
Swift	Swifte (spelling)	09	0
	Swift (Insertion/spelling)	03	0
	Swiftcode (compound)	05	1
	Swiftransfer (compound)	13	0
Telephone	Phone (shortened)	36	45
Top	Tp (Spelling)	21	0
	Top-Sectet (spelling,hyphenation)	45	0
	T0p Secret (Toggle/Compound)	5	0
Transferred	Trasfer (spelling)	14	0
	TRansfer (toggle)	29	0
	Transfered (British/American)	16	2
Venture	Venture (stemming)	16	0
Venture	Veture (spelling)	11	0
	Joint-venture (hyphen/compound)	76	4
Virtually	Virtualy (spelling)	21	1
	Vitually (spelling)	13	1
Win	Winn (insertion)	15	1
Worked	Worked-out (compound/hyphenated)	42	08
	Work-out (Compound hyphenated)	11	2

TCM = Token Compounded/Manipulate  
 NM = Nature of Manipulation  
 FSM = Frequency of Occurrence in Spam Messages  
 FHM = Frequency of Occurrence in Ham Messages

TABLE 2.0 : OBSERVATION OF THE CHANGES IN FREQUENCY OF OCCURRENCE FOR SELECTED TOKENS

S/NO	TK	OFSM	NFSM	OFHM	NFHM
1	Beneficiary	277	290	7	7
2	Cooperation	104	136	12	21
3	Director	291	359	13	13
4	Discovered	237	272	16	16
5	Documents	398	419	121	121
6	Dollar	676	712	93	97
7	Invoice	100	126	12	13
8	Joint	187	202	25	25
9	Lottery	765	795	2	2
10	Mobile	767	779	324	324
11	Next	895	900	234	234
12	Partner	34	76	12	12
13	Personal	102	114	30	30
14	Please	2800	2899	223	227
15	Swift	109	121	5	5
16	Transferred	134	193	56	58

**Key To Table Items**

TK = Token; OFSM = Old Frequency in Spam messages;  
 NFSM = New Frequency in Spam messages,  
 OFHM = Old Frequency in Ham Messages;  
 NFHM = New Frequency in Ham Messages,

TABLE 3: OBSERVATION OF THE CHANGES IN SPAMICITIES FOR SELECTED TOKENS

OSP	NSP	OHP	NHP	OS	NS
0.1154167	0.120833333	0.0029167	0.002916667	0.975352	1
0.0433333	0.056666667	0.005	0.00875	0.896552	1
0.12125	0.149583333	0.0054167	0.005416667	0.957237	1
0.09875	0.113333333	0.0066667	0.006666667	0.936759	1
0.1658333	0.174583333	0.0504167	0.050416667	0.766859	1
0.2816667	0.296666667	0.03875	0.040416667	0.879064	1
0.0416667	0.0525	0.005	0.005416667	0.892857	1
0.0779167	0.084166667	0.0104167	0.010416667	0.882075	1
0.31875	0.33125	0.0008333	0.000833333	0.997392	1
0.3195833	0.324583333	0.135	0.135	0.703025	1
0.3729167	0.375	0.0975	0.0975	0.792737	1
0.0141667	0.031666667	0.005	0.005	0.73913	1
0.0425	0.0475	0.0125	0.0125	0.772727	1
1.1666667	1.207916667	0.0929167	0.094583333	0.926232	1
0.0454167	0.050416667	0.0020833	0.002083333	0.95614	1
0.0558333	0.080416667	0.0233333	0.024166667	0.705263	1

**Key to table Items**

OSP = Old Spam Probabilities; NSP = New Id Spam Probabilitie  
 OHP = Old Ham Probabilities ; NHP = New Ham Probabilities  
 OS = Old Spamicities ; NS = New Spamicities

The Figures below show the effect of contribution of increased spamicity measures on the selected parameters.

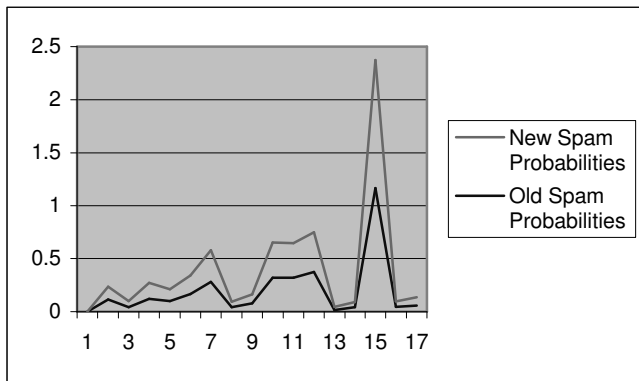


Fig 1: Contribution of increased spamicity measures on the selected parameters.

#### IV. DISCUSSIONS

To test our efforts theoretically, we composed the spam message below and tested the improvement of our filter based on the spamicities of the same tokens from Table 1 and Table 2. Our message and spamicity figures are presented below:

*My Dear Mr. James,  
Very best compliments. I'm your Partners friend (Mr. Kinlo) that met you in Abuja last week. Can you remember? High up the hotel at the New Sheraton Hotel Building. We discussed about your account, the one you claimed has since been abandoned with your previous outsourced service providers. I gave you a re-activation form in which it was specified that the only way we can receive your order is for you to swear an affidavit regarding ownership and provide the names and telephone numbers of your next of kin who will be the beneficiary in case of death. We solicit your cooperation in the provision of these required documents and information immediately you get back to Lagos. Please send them by courier with a letter addressed to The Director, Joint Concept Holdings, Bodija Shopping Complex, Ibadan. This will enable cut down on the long process of waiting for normal postage and be able to quickly transfer your data to the ministry of commerce for verification. On completion of the process, I will get back to you again through your e-mail address and telephone/mobile numbers. Next, an invoice will be issued and sent by courier for the new transaction at the earliest possible time for your swift transfer. Also provide your personal mailing address in your reply. Please refer to the top of this letter for our phone and mailing addresses.*

*Very Truly yours  
Tunjis Ajuomoba*

Simplifying Bayesian Rule gives

$$P = \frac{abc...n}{abc...n+(1-a)(1-b)(1-c)...(1-n)}$$

For Case (a) Old Spamicity Values we have

$$P = \frac{abc...n}{abc...n+(1-a)(1-b)(1-c)...(1-n)}$$

$$P = \frac{1.78676E-07}{1.78676E07+1.35858E-17}$$

$$P = 0.999999999923$$

For Case (b) New Spamicity Values we have

$$P = \frac{abc...n}{abc...n+(1-a)(1-b)(1-c)...(1-n)}$$

$$P = \frac{97627E-07}{97627E-07+0}$$

$$P = 1.0$$

Our calculations above are based on the 15 tokens in Table 5 below.

TABLE 5: SPAMICITY MEASURES BASED ON TEXT MANIPULATIONS

S/No	Token	Original Spamicity	Improved Spamicity
1	Kin	0.997472	1
2	Lottery	0.997392	1
3	Top	0.995529	1
4	Email	0.993583	1
5	Account	0.98367	1
6	Numbers	0.982801	1
7	Beneficiary	0.975352	1
8	Immediately	0.974359	1
9	Order	0.166667	0.166667
10	Abandoned	0.16	0.16
11	Friends	0.147887	0.147887
12	Compliments	0.138614	0.138614
13	Completion	0.114754	0.114754
14	High	0.065259	0.065259
15	Form	0.048276	0.048276

Product of Old Spamicities	Product of New Spamicities
1.78676E-07	1.97627E-07

Case (b) tells us outrightly without any benefit of thought that the mail is spam. There is an obvious improvement in total spamicity measures as a result of the increase in content spamicity made available by identifying possible text manipulations. The lessons learned when training the text classification engine based on our findings are as follows:

- All compound and hyphenated words should be tokenized. Hyphenations can be removed.
- Spell-checking will assist in removing deliberate errors, mixture of alphabets and texts (as in JOINT; note that zero is used instead of the alphabet O) and word-stemming by matching acceptable English words in the database with that on the mail.
- Convert all mails to upper or lower case to deal with text toggling.
- Underscores within mail contents should be removed except when referring to an e-mail address. All messages should be converted to either American or British texts using specific dictionary.

## V. CONCLUDING REMARKS

Our effort at developing *NiMFilter*, a hybridized antispam system for filtering fraudulent mails from the origin necessitates the adoption of the Bayesian model of filtering. We are therefore confronted with the usual challenge that Bayesian filters require the entire message to be received before analysis and are resource intensive since calculating Bayesian probabilities requires significantly more processing power than simply querying a list. Therefore any form of improvement on spamicity information, or the selection of tokens that aids the calculation of spamicities in order to quickly specify tokens with high Spamicities is a welcome development that will help filters achieve a higher precision, efficient recall and consequently low false positives.

## VI. DIRECTION FOR FUTURE RESEARCH

We intend to benchmark our filtering system with other non content-specific filters such as Procmail, PreciseMail and SpamAssassin in order to evaluate its performance in terms precision, recall and processor time usage.

## ACKNOWLEDGEMENT

We acknowledge with thanks Mr. Remi Oladipupo, Scholar, Computer Science Dept. University of Ibadan and Mr. Deji of FISALINK Systems, EKPOLMA, Nigeria for programming the Token Scanning Systems

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## APPENDIX

TABLE 1: SPAMICITIES OF THE IDENTIFIED WORDS IN DESCENDING ORDER

T <sub>K</sub>	F <sub>SM</sub>	F <sub>HM</sub>	S <sub>P</sub>	H <sub>P</sub>	SPM
Kin	789	2	0.32875	0.0008333	0.997472
Lottery	765	2	0.31875	0.0008333	0.997392
Top	2004	9	0.835	0.00375	0.995529
Email	4800	31	2	0.0129167	0.993583
Million	3006	21	1.2525	0.00875	0.993062
Win	796	7	0.33166667	0.0029167	0.991283
Account	2530	42	1.05416667	0.0175	0.98367
Invoiced	300	5	0.125	0.0020833	0.983607
Numbers	400	7	0.16666667	0.0029167	0.982801
Beneficiary	277	7	0.11541667	0.0029167	0.975352
Immediately	456	12	0.19	0.005	0.974359
Transfer	1103	30	0.45958333	0.0125	0.973522
Foreign	700	21	0.29166667	0.00875	0.970874
Private	805	30	0.33541667	0.0125	0.964072
Secret	309	12	0.12875	0.005	0.962617
Director	291	13	0.12125	0.0054167	0.957237
Swift	109	5	0.04541667	0.0020833	0.95614

Abacha	21	1	0.00875	0.0004167	0.954545
60%	402	21	0.1675	0.00875	0.950355
Banks	487	26	0.20291667	0.0108333	0.949318
Petroleum	302	17	0.12583333	0.0070833	0.946708
Proposal	607	36	0.25291667	0.015	0.944012
Code	201	13	0.08375	0.0054167	0.939252
Crude	275	18	0.11458333	0.0075	0.938567
Discovered	237	16	0.09875	0.0066667	0.936759
Equally	126	9	0.0525	0.00375	0.933333
Safekeeping	123	9	0.05125	0.00375	0.931818
Fax	1300	100	0.54166667	0.0416667	0.928571
Assist	295	23	0.12291667	0.0095833	0.927673
Interest	289	23	0.12041667	0.0095833	0.926282
Please	2800	223	1.16666667	0.0929167	0.926232
10%	205	18	0.08541667	0.0075	0.919283
Confidential	578	55	0.24083333	0.0229167	0.913112
NNPC	134	13	0.05583333	0.0054167	0.911565
Fortune	47	5	0.01958333	0.0020833	0.903846
Cooperation	104	12	0.04333333	0.005	0.896552
Late	653	76	0.27208333	0.0316667	0.895748
Invoice	100	12	0.04166667	0.005	0.892857
Joint	187	25	0.07791667	0.0104167	0.882075
Number	8073	1100	3.36375	0.4583333	0.880083
Dollar	676	93	0.28166667	0.03875	0.879064
30%	109	15	0.04541667	0.00625	0.879032
Central	113	16	0.04708333	0.0066667	0.875969
Lagos	176	25	0.07333333	0.0104167	0.875622
Assistance	100	15	0.04166667	0.00625	0.869565
Urgent	432	65	0.18	0.0270833	0.869215
Bear	79	12	0.03291667	0.005	0.868132
Relative	123	19	0.05125	0.0079167	0.866197
Family	200	32	0.08333333	0.0133333	0.862069
Arrangement	117	19	0.04875	0.0079167	0.860294
Date	756	126	0.315	0.0525	0.857143
Contacts	474	81	0.1975	0.03375	0.854054
Contract	195	34	0.08125	0.0141667	0.851528
CBN	120	21	0.05	0.00875	0.851064
Department	265	47	0.11041667	0.0195833	0.849359
Receive	124	22	0.05166667	0.0091667	0.849315
Lawyer	109	21	0.04541667	0.00875	0.838462
Approval	109	23	0.04541667	0.0095833	0.825758
Funds	1720	367	0.71666667	0.1529167	0.824149
Risk	407	89	0.16958333	0.0370833	0.820565
Business	907	214	0.37791667	0.0891667	0.809099
Cash	564	135	0.235	0.05625	0.806867
Abroad	276	67	0.115	0.0279167	0.804665

Oil	403	102	0.16791667	0.0425	0.79802
Confidence	294	76	0.1225	0.0316667	0.794595
Next	895	234	0.37291667	0.0975	0.792737
Strictly	367	97	0.15291667	0.0404167	0.790948
Free	400	106	0.16666667	0.0441667	0.790514
Solicit	458	123	0.19083333	0.05125	0.788296
Safe	367	99	0.15291667	0.04125	0.787554
35%	110	31	0.04583333	0.0129167	0.780142
Country	152	43	0.06333333	0.0179167	0.779487
Personal	102	30	0.0425	0.0125	0.772727
My	2700	802	1.125	0.3341667	0.770988
Documents	398	121	0.16583333	0.0504167	0.766859
Fund	700	221	0.29166667	0.0920833	0.760043
Partner	34	12	0.01416667	0.005	0.73913
Officer	300	107	0.125	0.0445833	0.737101
Western	34	12	0.01416667	0.005	0.73913
Telephone	328	123	0.13666667	0.05125	0.727273
Chamber	5	2	0.00208333	0.0008333	0.714286
Transferred	134	56	0.05583333	0.0233333	0.705263
Mobile	767	324	0.31958333	0.135	0.703025
Relation	206	97	0.08583333	0.0404167	0.679868
Birth	104	51	0.04333333	0.02125	0.670968
Position	400	200	0.16666667	0.0833333	0.666667
Response	208	105	0.08666667	0.04375	0.664537
Official	203	106	0.08458333	0.0441667	0.656958
Banking	154	85	0.06416667	0.0354167	0.644351
Nigeria	407	234	0.16958333	0.0975	0.634945
Share	207	122	0.08625	0.0508333	0.629179
40%	15	9	0.00625	0.00375	0.625
Security	178	107	0.07416667	0.0445833	0.624561
Immediate	203	123	0.08458333	0.05125	0.622699
Offset	21	14	0.00875	0.0058333	0.6
Union	21	14	0.00875	0.0058333	0.6
Promise	118	79	0.04916667	0.0329167	0.598985
Our	1600	1100	0.66666667	0.4583333	0.592593
Date	103	76	0.04291667	0.0316667	0.575419
Sir	978	786	0.4075	0.3275	0.554422
Investment	107	87	0.04458333	0.03625	0.551546
Faithfully	1198	1005	0.49916667	0.41875	0.543804
Name	1340	1145	0.55833333	0.4770833	0.539235
Abuja	14	12	0.00583333	0.005	0.538462
Brother	186	167	0.0775	0.0695833	0.526912
Dear	1288	1176	0.53666667	0.49	0.522727
Hope	203	198	0.08458333	0.0825	0.506234
Now	200	200	0.08333333	0.0833333	0.5

Your	3700	3865	1.54166667	1.6104167	0.489095
Madam	121	134	0.05041667	0.0558333	0.47451
Out	800	900	0.33333333	0.375	0.470588
Yours	1100	1298	0.45833333	0.5408333	0.458716
Affidavit	4	6	0.00166667	0.0025	0.4
Through	600	1000	0.25	0.4166667	0.375
Executive	18	31	0.0075	0.0129167	0.367347
Commerce	7	13	0.00291667	0.0054167	0.35
connectivity	23	49	0.00958333	0.0204167	0.319444
Highly	107	234	0.04458333	0.0975	0.313783
Cut	16	43	0.00666667	0.0179167	0.271186
New	304	1050	0.12666667	0.4375	0.22452
Order	100	500	0.04166667	0.2083333	0.166667
Abandoned	4	21	0.00166667	0.00875	0.16
Friends	21	121	0.00875	0.0504167	0.147887
Compliments	14	87	0.00583333	0.03625	0.138614
Completion	7	54	0.00291667	0.0225	0.114754
High	34	487	0.01416667	0.2029167	0.065259
America	5	76	0.00208333	0.0316667	0.061728
First	31	522	0.01291667	0.2175	0.056058
Form	56	1104	0.02333333	0.46	0.048276
Export	0	16	0	0.0066667	0

KEY: TO TABLE ITEMS

TK = Token, FSM = Frequency in Spam messages; FHM = Frequency in Ham Messages,  
 SP = Spam probability, Hp = Ham probability; TP = Total Probability, SPM = Spamicities

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# QUALITY OF SERVICES METRICS IN NIGERIAN INTERNET CAFES

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**ABSTRACT:** *The increasing need for quality internet service provision hinged on the quest for data privacy/security, speed of access, type of transmission medium, cost and overall staff efficiency among others remain paramount to the user of cyber-cafes in Nigeria and other developing countries. To evaluate these variables, data was collected using a self-designed questionnaire and found to fit chi-square adequately at 5% level of significance. It was however realized that there is no significant relationship between qualities of services provided and cost of services rendered, gender of user and, transmission channels. The staff efficiency, data privacy/security, speed of transmission and the quality of services provided are found to show significant relationship. A windows-based software tagged Cyber café Evaluator was also developed. The software accepts users' Quality of Service (QoS) ratings using them as parameters to evaluate service delivery. The program output makes useful suggestions on possible areas where there is need for service improvement.*

Keywords: *Quality, Cyber café, Internet, privacy, Speed, Security, Users, Windows, Transmission, Bandwidth*

## I. INTRODUCTION

The Internet and its technology continues to have a profound effect in promoting the sharing of information, making it possible for rapid transactions among businesses, and supporting global collaboration among individual and organization [5]. In Nigeria today, Internet services have become available even to mobile phone users with the introduction of WAP (Wireless Access Protocol) enabled handsets [3]. The Internet has also become a vital tool in the day to day running of business organizations and other institutions. It has helped to improve the methods and quality of services provided in all aspects of life such as commerce, health, education, sports, entertainment, news etc.

In the developed countries, a lot of people can afford to have the facilities for Internet access even in the privacy of their homes as well as in other public places. But in Nigeria and most developing countries, a larger percentage of the population cannot afford these facilities [1]. Cyber café's or Internet cafés therefore provide a popular and affordable way to access the Internet in these places in order to take advantage of the services made available on the web. Such services can be

summarized as the provision of opportunities for relaxation, socializing, communicating (e.g. internet phoning), research, News, sports and education.

### *Internet Growth in Africa*

As observed by Jensen [4] the Internet has grown rapidly in the African continent over the past few years. As at the end of 1996 only 11 countries in Africa had Internet access, but by November 2000 all 54 countries and territories had achieved permanent connectivity and the presence of full service dialup Internet Service Providers. The number of dialup Internet subscribers passed the million mark in the year 2000 and the sub-regional distribution of the Internet and its development clearly shows southern and northern Africa to be more advanced, followed by East and West Africa, then Central Africa.

In West Africa, Senegal and Ghana are the leaders in information technology (IT) followed by Nigeria, Benin, Burkina Faso, Cote d'Ivoire, Mali and Niger with Guinea, Guinea Bissau, and Sierra Leone at the bottom of the list. In spite of these developments on the African continent, Internet development on the continent has been confined to capital cities. The number of computers permanently connected to the Internet in Africa (excluding South Africa) is also said to be small. It has been equated to the number of computers connected to the Internet in a small eastern European country such as Latvia, which has a population of 2.5 million compared to 780 million in Africa, by UNICEF 1998 estimates [4]. Regional collaboration to address the need for improved ICT has increased in the sub-region.

The conference of African ministers of social and economic planning requested the United Nations Economic Commission for Africa to set up an expert group to discuss ICT in Africa which resulted in the development of the African information society initiative (AIS). Other initiatives include AfriLink (2001) by USAID aimed at facilitating African networking, and the Leylartd initiative, African Global Information Infrastructure project, which is a \$15,000,000 US government effort to extend full Internet connectivity to 20 African countries [7].

### *Development Of Information Technology (ICT) In Nigeria*

The first Information and Communication Technology (ICT) initiative in Nigeria started in the 1950s with focus on print and

electronic media. No major policy or other outcome was achieved because of strict government control. The full awareness of the importance of ICTs was absent. Only the private sector demonstrated ICT initiatives. The Obasanjo administration in 2001 established the National Information Technology Development Agency (NITDA) to serve as a bureau for the implementation of National Policy on Information Technology. NITDA is trying to increase the Internet penetration levels in Nigeria [2].

The Availability of on-line facilities to the populace on a private level is still very low. Therefore, one has to go to a cyber café even for rudimentary net access such as e-mail and net meeting, browsing etc. This notwithstanding, Nigeria today has been described by researchers as the West African Information Technology hub and one of the leading countries in the developing world as far as IT awareness and embracement is concerned [6].

### II. STATEMENT OF THE PROBLEM.

As a result of the foregoing, many Internet café's have been established for commercial use. However, users perception of the quality of services rendered by these cafes are plagued with various complaints. What follows summarizes the statement of the problem.

- (a) The speeds of the systems used for Internet access are quite inadequate for the user's needs.
- (b) Constant data transmission failure remains a threat to the users of cyber-cafes.
- (c) Cost remains a major consideration due to the low income of most café users in Nigeria, a developing country.
- (d) The overall staff efficiency with regards to their willingness to assist users when facing difficulties is also an issue that is concerning.
- (e) Data privacy/security of user information is not always guaranteed.
- (f) Persistent power failure, technical breakdowns and other environmental factors continue to plague the services rendered by the cyber cafes.

### III. SIGNIFICANCE OF THE STUDY

The paper intends to evaluate the services provided by these Cyber café's from the users' point of view, determine the level of satisfaction with the quality of services provided and proffer solution that would help improve the quality of these services.

### IV. RESEARCH INSTRUMENTS

A self-constructed questionnaire titled *Users' Evaluation of the Quality Of Services Provided By Internet Cafés* (UEQSPIC) was the main instrument used to collect data for this study. The questionnaire used contained 29 items grouped into 3 sections. Section A requests for the background information of the respondents, section B x-rays the service provided while section C evaluates the respondents' view of the quality of services provided by the cyber cafés. The users responded on 3-4 point Lickert scales depending on the questions asked.

### Study Population

600 Cyber café users, mainly consisting of students from tertiary institutions and other literate users in different cyber cafés across the country constituted the population of this study. A total of 500 responses were selected for the analysis because this number produced the feasibility stratification for age, sex, experience and hands-on-skills on computer among the sampled users.

### Method Of Data Collection

The researchers administered the instrument both by hand and through electronic mail correspondence. An on-line copy of the questionnaire was designed and setup.

### V. HYPOTHESIS, RESULTS AND DISCUSSION

Inferential statistics was employed using chi-square( $\chi^2$ ) to test for the significance of the formulated hypothesis on the group. All hypotheses were tested at 5 percent level of significance. The formulated hypothesis, chi square analysis, results and discussion are summarized in the table below.

Table 1: Decision Based on Observed and Computed Chi Square Analysis

S/NO	HYPOTHESIS	Computed $\chi^2$ value	Table Value (T) at 3 df	Decision at 0.05 level of sig.
H <sub>1</sub>	<i>H<sub>0</sub>: There is no significant relationship between the cost of services and the Perceived quality of services.</i>	1.69977	7.82	Accept the Null hypothesis
H <sub>2</sub>	<i>H<sub>0</sub>: There is no significant relationship between the speed of data transmission at the cyber cafe and the perceived quality of service.</i>	9.00363	7.82	Reject the Null hypothesis hence accept the alternative
H <sub>3</sub>	<i>H<sub>0</sub>: There is no significant relationship between user's gender and the perceived quality of service.</i>	3.13869	7.82	Accept the Null hypothesis
H <sub>4</sub>	<i>H<sub>0</sub>: There is no significant relationship between the staff efficiency at the cyber cafe and the perceived quality of service.</i>	8.67842	7.82	Reject the Null hypothesis hence accept the alternative
H <sub>5</sub>	<i>H<sub>0</sub>: There is no significant relationship between data privacy/ data security at the cyber cafe and the perceived quality of service.</i>	12.39115	7.82	Reject the Null hypothesis hence accept the alternative
H	<i>H<sub>0</sub>: - There is no significant relationship between the location of the cyber cafe and the perceived quality of service.</i>	3.69373	7.82	Accept the Null hypothesis
H <sub>7</sub>	<i>H<sub>0</sub>: There is no significant relationship between transmission channel used by the cyber cafe and the perceived quality of service.</i>	1.38504	7.82	Accept the Null hypothesis

From the table, it can be deduced that there is no significant relationship between qualities of services provided and cost of services rendered, gender of user and, transmission channels. Staff efficiency, data privacy/security, speed of transmission and the quality of services provided are found to show significant relationship.

## VI. THE CAFÉ EVALUATOR PROGRAM DESIGN

Based on the parameters used for the evaluations above, an interactive windows based program was developed tagged the “Cyber café Evaluator”. The Evaluator helps users evaluate the quality of service provided by a cyber café, based on the answers selected by the users from a list of questions. Depending on the answers, chosen by the users, for the questions asked, the software analyzes the answers and tells the user if the cyber café is up to standard, or if the cyber cafe needs improvement. It also identifies the areas that need improvement.

The program was developed using Visual Basic programming language, a versatile, event driven; object oriented programming language, which makes use of the graphic user interface (GUI) to achieve interactivity. The software is made up of three forms. The first form introduces the program and when the GO’ button on this form is clicked, it takes the user to the second form known as the ‘Evaluation Form’, which is the evaluator interface. This form consists of two sections. The first section is where information on the cyber café to be analyzed is entered.

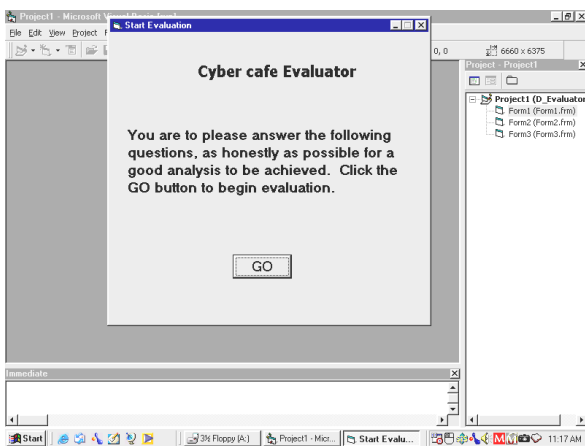


Fig. 1: Cyber Evaluator Interface

The second section consists of the questions and their answers, which are contained in combo boxes, where users can select according to how suitable they are to them. At the end of the questions are two command buttons. When the first command button captioned ‘Evaluate’ is clicked, the program evaluates the cyber café based on the answers given. The second button captioned ‘Exit’ is used to close the program.

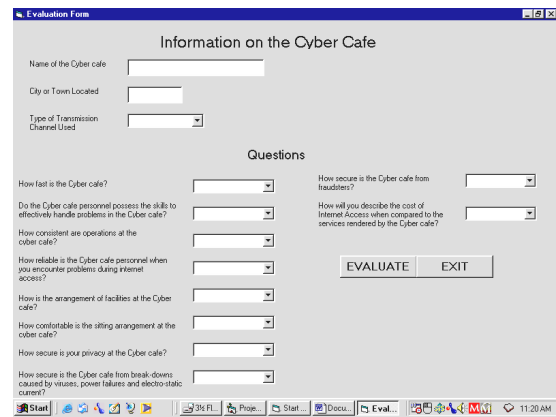


Fig. 2: Information Entry Interface

The third form called ‘the improvement list form’ is where the list of areas that need improvement, based on the answers from the users, are listed. Clicking on the ‘Ok’ command button on this form, returns you to the evaluation form to perform more evaluation or to exit the program.

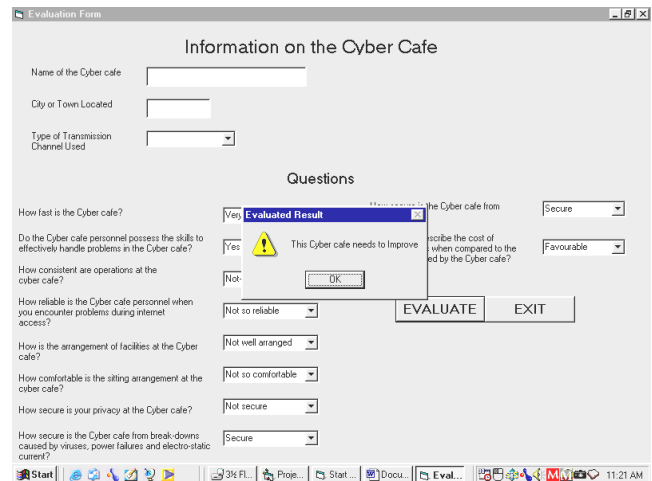


Fig. 3: Information Evaluation Interface

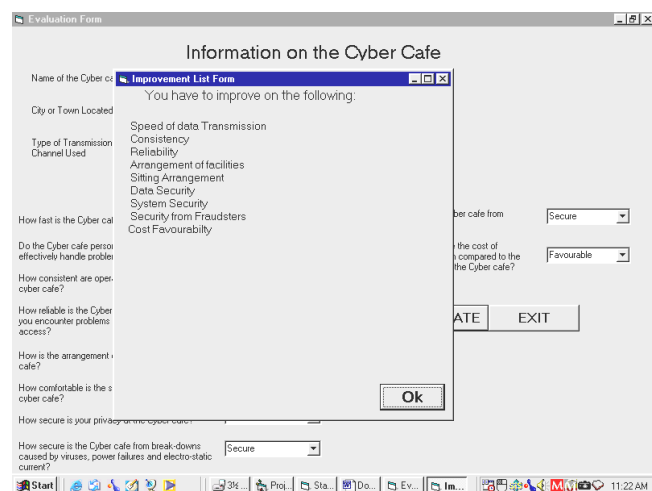


Fig. 4: Improvement Parameters Interface

## VII. SUMMARY OF FINDINGS

The research objectives are to determine the extent of usage of Internet facilities in Nigeria, appraise the level of satisfaction of users with Internet service provisions in Nigeria and to suggest measures that can be adopted to improve the quality of service of cyber cafés thereby improving user's satisfaction with their services in any instance of the problem situation in any developing country. What follows summarizes the findings from the research:

- (1) The level of awareness of Internet facilities and usage in Nigeria is on the increase.
- (2) More will have to be done in terms of the importation of equipments and facilities that meet with international standards.
- (3) The general level of consumer satisfaction with cyber café services in Nigeria is relatively low.
- (4) The factors responsible for these have been identified to include staff efficiency at the café, data privacy/data security and speed of transmission.
- (5) Other factors with insignificant effects are cost, mode of transmission, cost of services and location of cafés.

## VIII. CONCLUSION

The impact and development of information technology applications and dividends in our nation today rest much on information obtained from cyber cafes. Cafes serve as our own information highway "bus stops". Information ranging from news, education, entertainment etc are obtained from these facilities. In order not to dampen nor discourage the enthusiasm of teeming users of the Internet in our nation, Café facilities must be the types that will give users the seamless and quality services required of such ventures.

## IX. RECOMMENDATION

Given the factors identified as being responsible for the poor quality of services by the cyber cafes, efforts must be made to see to their improvement so as to make cyber cafés stay in business and encourage customers to keep coming. The points listed below will go a long way in achieving this.

- Also, cyber cafés could team up with fixed wireless operators to provide outlets for cheap Internet services.
- They could further team up with local and international distance learning programmes and serve as study centers, charge some form of

attendance or service fee and perhaps earn money on the processing of courseware.

- Another simple method too would be to form effective associations where experiences would be shared and lessons learnt and common interests pursued before regulators and service providers.
- Provision must always be made for the employment of technical staff such as computer or electronic engineers for the maintenance and servicing of computer systems being used in the cafes.
- Since data privacy is of serious concern to users, café-browsing points should be partitioned. Spyware, firewalls and antivirus should also be installed to ensure data security online.
- Speed of access can be improved by acquiring modern software and hardware facilities for café operations. A combination of wireless and VSAT access can in combination with wide broadband also help to improve on this.

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## Constructing Cascade Detectors with Linear SVM

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### Abstract

*This paper develops a cascade of linear SVM classifiers for fast object detection. The learning problem of every node in the cascade structure is described as a new quadratic programming problem in the frame of SVM, which makes every linear classifier achieve very high detection rate but only moderate false positive rate. The real experiment shows that this method enjoys good generalization capacity and much fast speed compared with the traditional SVMs.*

**Keywords:** cascade, object detection, support vector machine (SVM)

### 1. Introduction

Lots of methods are presented for machine learning, just as perceptron and neural networks, which are based on ERM (Empirical Risk Minimization principle). However, these methods with ERM are not assured to get the anticipant risk minimum in practical study system based on few examples.

SVM (support vector machines) is a new way for classification, proposed by Vapnik in the middle of 1990s. SVM use Vapnik-Chervonenkis dimension of the set of functions to construct the optimal separating hyper plane by the combination ERM and SRM (Structural Risk Minimization principle), and its capacity of generalization is much better than the other algorithms based on ERM. Therefore, statistical learning theory based on SVM is widely used in the research of pattern recognition, regression estimation and density estimation.

But there are some limitations to SVM. For example, training SVM is computationally complicated and needs abundant memory. In domains where the distribution of positive and negative examples is highly skewed (e.g. face detection or database retrieval), large numbers of negative examples certainly will affect the performance of SVM detector. Besides, for those non-separable cases, SVM introduces kernel functions to map input data to high dimension space that we called feature space, which causes a low speed during the detection of nonlinear SVM.

Cascade classifier is novel and efficient, and it is hierarchical, composed of several simple weak classifiers in a certain order. It can replace a complex integral classifier. Many modern approaches for classification focus entirely on the minimization of errors, but the cascade classification framework can be used to achieve extremely high detection rates and modest false positive rates so as to make a tradeoff between accuracy and efficiency. In other words, the new approach minimizes computational complexity and ensures high detection rates. In the cascade architecture illustrated in Fig.1, an input patch is classified as positive target only if it passes the tests in all the nodes.

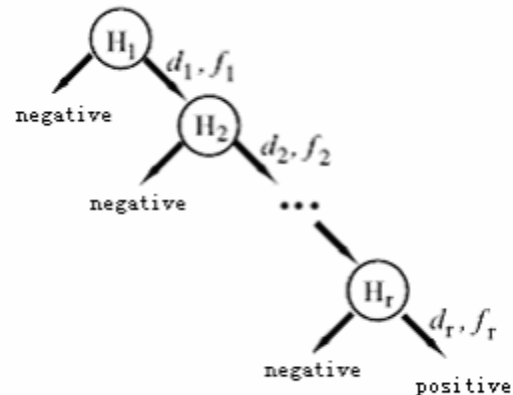


Figure 1. Illustration of a cascade with r nodes.

Viola and Jones introduced a new image representation called the “Integral Image”, which allows the features used by our detector to be computed very quickly. They proposed a learning algorithm, based on AdaBoost, which selected a small number of critical visual features from a larger set and yielded extremely efficient classifiers. Then they combined increasingly more complex classifiers in a “cascade”. Their algorithm is inefficient and needs a clear function to minimize the number of classifiers in the cascade<sup>[1]</sup>.

WU Jian-xin and his associates presented a mathematical characterization of the node-learning problem and described an effective closed form approximation to the optimal solution, which they

called the Linear Asymmetric Classifier (LAC). They first used AdaBoost or AsymBoost to select features, and used LAC to learn a linear discriminant function to achieve the node learning goal, and then combined the nodes into a cascade structure. Nevertheless, their method is based on ERM<sup>[2]</sup>.

Sami Romdhani and his team described a fast system for the detection and localization of human faces in images using a nonlinear SVM. They approximated the decision surface in terms of a reduced set of expansion vectors and propose a cascaded evaluation which had the property that the full support vectors expansion was only evaluated on the face-like parts of the image, while the largest part of typical images was classified using a single expansion vector. Subsequent stages with full support vectors expansion in their cascade are extremely complex<sup>[3]</sup>.

MA Yong and DING Xiao-qing proposed a face detection method based on a hierarchical SVM which was a combination of several linear SVMs and a nonlinear SVM. In the detection stage, the linear SVMs are used to quickly exclude most non-faces in the images while the nonlinear SVM is used to further verify possible face candidates. The architecture is very efficient<sup>[4]</sup>.

In this paper, we develop a cascade of linear SVM classifiers for fast object detection, based on both ERM and SRM. We establish the mathematical model for each node in the cascade, which minimizes the number of the weak linear classifiers and provides optimal performance of the whole classifier. The method not only improves the detection rates but also speeds up the process.

## 2. Appropriate Distribution of Samples for the Cascade Classifier

We present a cascade classifier for fast detection in domains where the positive samples and negative samples are unbalanced, which means the numbers of positive and negative samples are remarkably different, and lost positive objects during detecting phase would be a disaster, such as disease diagnoses and pedestrian detection. However, not all the unbalanced data can be classified by the cascade classifier presented in this paper. Since the separating hyper plane for every node in the cascade is linear, our algorithm is available if the positive samples are absolutely encircled by a convex manifold which covers no negative samples.

**Definition** Suppose  $x_1, x_2, \dots, x_n$  are  $n$  points in the Euclidean space of  $m$  dimensions.  $Q$  is the minimal closed convex set of  $x_1, x_2, \dots, x_n$ , as

$$Q = \{y \mid y = \alpha_1 x_1 + \alpha_2 x_2 + \dots + \alpha_n x_n, \sum_{i=1}^n \alpha_i = 1, \alpha_i \geq 0, i = 1, 2, \dots, n\}$$

$Q$  is also

called the convex manifold of  $x_1, x_2, \dots, x_n$  or the convex set yielded by  $x_1, x_2, \dots, x_n$ .

According to the definition above, the points in the convex manifold yielded by positive samples can surely be expressed by the linear combination of positive samples, vice versa. Therefore, none but those points which can't be expressed by the linear combination of positive examples are surely outside the manifold. We come to the conclusion that our method is not available unless there is no negative example that can be expressed by the linear combination of positive examples. Fig.2 shows the two cases of appropriate and inappropriate distributions. As we see, part (a) is the distribution that satisfies the method, but part (b) is not.

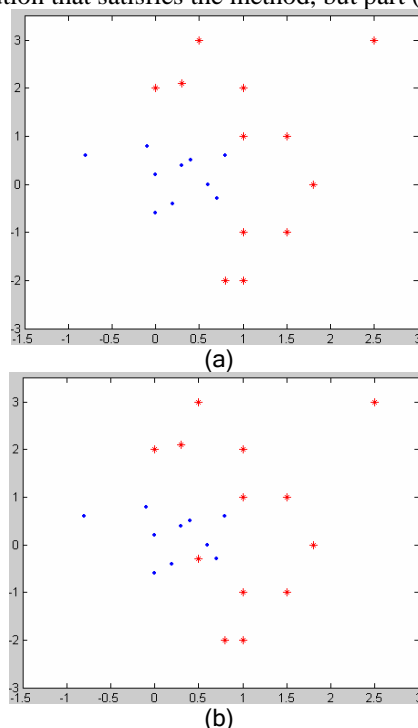


Figure 2. Examples of distributions

In practice, we can't ensure that none of the negative samples is covered by the convex manifold of positive samples strictly, which is impractical; instead, we allow few negative samples in the manifold, because there is false accept rate and false refuse rate in any approach for object detection. Further, there are other methods to remove these few negative samples.

## 3. Mathematical Model of the Cascade Classifier Based on SVM



Training the cascade detector with linear SVM which is essentially an ensemble of linear discriminant functions is radically a problem of node learning. Suppose different nodes are independent, and we should first set up the goals of node learning as follows:

- Each node is a linear classifier founded on SVM theory;
- Each node has a high positive detection rate and moderate false positive rate;
- For present negative examples set, the classifier at each node discards negative examples as more as possible so that the number of simple classifiers is optimal.

Suppose that the data set

$$X : \{x_i, y_i\}, y_i \in \{-1, 1\}, i = 1, K, l$$

and the former  $n$  samples are positive ones  $x_i^+$ ,  $y_i^+ = 1$ , for  $i = 1, K, n$ ; The later  $l - n$  samples are negative data  $x_j^-$ ,  $y_j^- = -1$ , for  $j = n + 1, K, l$ .

Slack variables  $\xi_j \geq 0, i = 1, K, l$  is introduced just like that in SVM, and then the mathematic model of every node is to solve the following quadratic programming problem:

Minimize:

$$\Phi(w) = \frac{1}{2}(w \bullet w) + C \cdot \sum_{j=n}^l \xi_j$$

Subject to:

$$\begin{aligned} (w \bullet x_i^+) + b &\geq 0, \quad i = 1, K, n \\ (w \bullet x_j^-) + b &\leq -1 + \xi_j, \quad j = n + 1, K, l \\ \xi_j &\geq 0 \end{aligned} \quad (1)$$

Here, the constraint on positive data is a little different from that of traditional SVM. This is the main difference between our optimization problem and SVM. The reason is that the cascade detector with linear SVM is constructed mainly to solve those problems where the positive and negative samples are asymmetry. As the positive data should be classified correctly at each classifier stage, the negative ones may be distinguished incorrectly. In the traditional SVM model, the constraints for the two class data are the same and it could hardly obtain the high detection rate of positive data.

Thus, the discriminant function for every node come to be an indicator function:

$$f(x) = \text{sgn}[(w \bullet x) + b] \quad (2)$$

Assembling these simple classifier, we can obtain a cascade framework. The algorithm can be formulated

as follows:

step 1. input the training data  $X_i$ , including

$n$  positive data  $x_i^+$  ( $y_i^+ = 1$ ) and  $l - n$  negative data  $x_i^-$  ( $y_i^- = -1$ ), into the quadratic programming problem (1), and then the vector of the separating hyper plane is given by the solution  $\begin{bmatrix} w_i \\ b_i \end{bmatrix}, i = 1, 2, K$ ;

step 2. substitute the negative examples into the first discriminant function:

$$f_i(x) = \text{sgn}[(w_i \bullet x) + b_i],$$

and the indicator vector of negative data is given

$$\text{by } y_i^-, y_i^- \in \{-1, 1\}, i = 1, 2, K;$$

step 3. the number of false positive data  $S_i$  is given

by calculating the number of negative data which satisfies the equation  $y_i^- = 1$ , and the false positive rate is given by  $\varepsilon_i = \frac{S_i}{l - n}$ , where

the initial number of negative data is  $l - n, i = 1, 2, K$ ;

step 4. set a maximal false positive rate  $\eta$  (e.g. 1%),

if  $\varepsilon_i \geq \eta$ , the false positive data (negative examples of misclassification) builds up the new negative data set  $x_{i+1}^-$ , and the positive set is unchangeable. The new training data set is make up of  $x_{i+1}^-$  and  $x_i^+$ , and then return to 1 until  $\varepsilon_i < \eta$ ;

step 5. if  $\varepsilon_i < \eta$ , end, and the separating hyper plane

is found:  $g_i(x) = w_i \bullet x + b_i, i = 1, 2, K$ . the cascade framework is obtained by cascading these simple classifiers.

## 4. Experimental Results

### 4.1 Experiment on Synthetic Data

The training data set consists of 99 two-dimensional points, including 19 positive data (blue) and 80 negative data (red), where the positive samples are encircled by the negative ones. We choose RBF kernel to train SVM classifier with radius of  $\sigma = 1$ , and choose the parameter  $C = 0.01$  to train the cascade SVM detector. Experiment proves the efficiency of the cascade classifier which optimizes not only the number of the elements but also the performance of the integer. Fig.3 shows the distribution of the data and the result of classification.

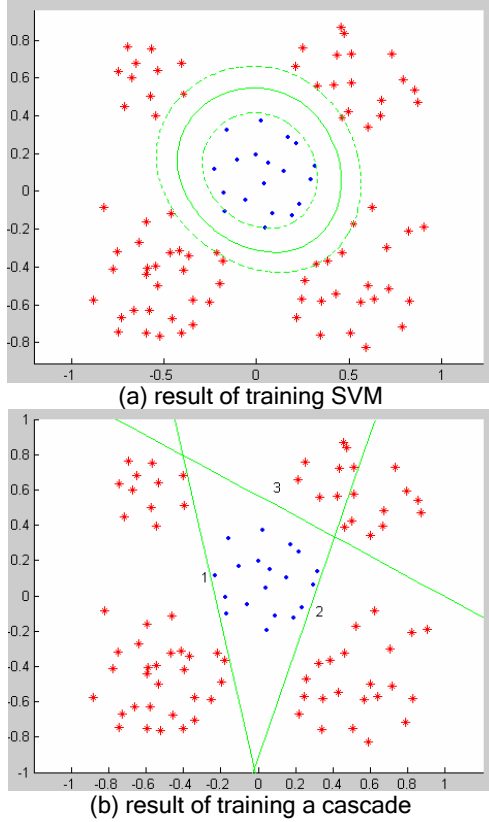


Figure 3. Results of SVM and a cascade with linear SVM

## 4.2 Experiment on a Real World Detection Task

This is a real world detection task rooted in lidar. The task is to detect grass by fusing the lidar data and image data.

It is well-known that lidar is widely used as an environment sensor of ground mobile robot because it has the merit of high angle resolution and range accuracy. But only distance information can't lead to an exact judgment to robot's surroundings. For example, the return signals from low wall and grass may be similar for lidar, but the two objects are very different for the robot's moving. Therefore, it is necessary to distinguish grass from other obstacles like walls by fusing the information of lidar and camera.

The fusion of two sensors data can be achieved by calibrating of camera. The result of projecting lidar points to image is shown in Fig.4 (a). The data set of 1432 points contains three features selected from fused data, where one feature is the height of object, and the other two are texture features. The training data set contains 200 points, including 112 positive data picked on the grass manually and 88 negative data picked from other obstacles. The remain 1232 points are test

data. We train the cascade classifier for the first time with the parameter of  $C=10$ , and then we train SVM classifier twice using RBF with radius of  $\sigma=1$  and  $\sigma=10$  respectively. The test results are showed in Fig. 4, where the places covered by black bars are detected grass region.



(a)result of projecting lidar points to image



(b)result of cascaded SVM



(c)result of SVM(RBF,  $\sigma=1$ )



(d)result of SVM(RBF,  $\sigma=10$ )



Figure 4. Results of SVM and a cascade with linear SVM

The test time is compared in the following Table 1:

T Table 1. Comparison of test time

	Test time(1320examples)
Cascaded SVM (four hyper planes)	0.001s
SVM (RBF, $\sigma=1$ )	45.0s
SVM (RBF, $\sigma=10$ )	46.6s

Traditional SVM classifier with the radius  $\sigma=10$  recognizes the grass correctly, but the white box and bushes are misclassified. The one with the radius  $\sigma=1$  recognizes the grass and box correctly, but the bushes are wrongly classified. And moreover, SVM costs much time to test the data because of its non-linearity. The separating hyper plane will be more complex with the increase of the training data so that the time it costs will also increase, which is bad for real-time object detection. The cascaded SVM provides correct classification for all the objects, which proves a better capacity of generalization. Furthermore, the new approach is extremely rapid; it costs less than 0.001s to test the data with four separating hyper planes. The speed is improved by several thousand times.

## 5. Conclusion

We have demonstrated that a cascade classification

framework with linear SVM can be used to achieve fast classification, high detection rates, and very low false positive rates. The classifier containing several simple linear classifiers can be applied to non-separable case with linear classifiers. The new algorithm is extremely efficient and easy to be carried out, compared to other algorithms.

There is a limitation of our method that the distribution of the data is required, namely, none of the negative samples is covered by the convex manifold of positive samples. However, it is sure that this algorithm will be improved and widely used in the near future.

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# An Empirical Analysis of Information Technology Choice to Empower Rural Women in Ghana

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**Abstract**— The paper reports the results of a survey of 1000 households selected from the ten regions in Ghana. In addition to estimating regional technology choice functions, the paper uses a pooled cross section technique to estimate an aggregate technology choice function for the country as a whole. Some of the principal factors included in the empirical model are households' incomes, levels of education, sizes of households, availability of cooperatives or community organizations, age, and marital status. The model was estimated using standard regression techniques that correct for possible heteroscedastic errors due to the differences in regional and households' attributes. Results confirm the existence of regional differences in the choice of information technology, and hence the need to fashion policies that reflect such differences.

**Keywords**—Rural women, ICT, radio, extension agent

## I. INTRODUCTION

In 2000, the nations of the world declared the “Millennium Development Goals (MDGs), a set of eight goals that directly address the problem of poverty alleviation. Seven of the eight goals – eradication of extreme poverty and hunger, universal primary education, gender equality and women’s empowerment, reduction in child mortality, improvements in maternal health care, combating HIV/AIDS, malaria, and other diseases, and environmental sustainability – are all directly associated with how careful policies and programs help to improve the overall well-being of women in society.

Ghana’s own poverty reduction program highlights the issues of women for policy initiatives because as [1] points out, “gender disparities are prevalent in Ghana and closing the gender gap and enhancing women’s participation in development is essential not only for building a just society, but is also a pre-requisite for achieving political, social, economic, cultural and environmental security among people on a sustainable basis” (Pg. 33). Both the MDGs and Ghana’s own Poverty Reduction Strategy Program (GPRP) emphasize the *empowering of women* as a goal to address the problem of poverty [2]. Both raise at least two broad issues. First, what is the content of empowerment programs, and second, how does

society obtains the participation of the *population affected* in designing and implementing empowerment programs. In

terms of content, the literature suggests that *information* is the key ingredient in designing women’s empowerment programs.

## II. PROBLEM STATEMENT AND OBJECTIVES

Ghana responded to the ICT challenge in the 2003 for implementation of the *Ghana Integrated ICT for Accelerated Development (ICT4AD) Policy* [3]. Several laws and policy initiatives have been introduced in support of Ghana’s ICT policy. These include the National Initiative Concerning the ICT and Education and Training, the African Information Society Initiative, and the Science and Technology Policy Research Institute. Despite these efforts, there are several problems affecting the ICT sector. First ICT policy planning and implementation is spread among several ministries, institutes, research centers, and private agencies. This increases the potential for conflicts and duplication of effort. There are concerns that the uneven access to education would translate to a ‘gender digital divide’ in Ghana unless explicit and credible policies are put in place to address the situation. There are also problems in making ICT available to a large segment of the population, especially for educational purposes in the rural areas due to lack of appropriate infrastructure. One way to address these shortcomings is to design and implement ICT programs that are consistent with the socio-economic status and characteristics of users. It is important to understand how much ICT users are willing to pay for alternative ICT delivery technologies to better design policies.

The overall objective of this study was to identify and assess alternative ICT strategies for empowering rural women in Ghana. The study uses results from a survey of 1000 households from the ten regions in Ghana to assess rural households’ willingness to pay for alternative ICT use in the delivery of information to households.

## III. METHODOLOGY AND STATISTICAL ESTIMATION

The data used in this study was based on a contingent valuation survey instrument developed and administered in several villages in the ten regions in Ghana. The survey was

divided into two main parts. The first part sought information on basic characteristics of households (age, education, dependents, occupation, expenditures, and membership in community organizations). The second part consisted of a bidding game for alternative information delivery technologies. Three main information delivery technologies were considered – community radio, private radio, and extension agent (printed material). The main distinguishing feature of these technologies was price. For example, information delivery by community radio was considered the cheapest since several households contribute to the purchase and maintenance of the system. Extension agents were the next cheapest of the three technologies considered because the government pays these agents. The idea was to explore the extent to which a part of the cost of extension information delivery could be shifted to households and lessen the burden on government. The most extensive delivery technology was the private radio since a household owns it individually and pays full amount for it.

Bidding took the form of a series of specific questions. For example, a respondent was asked whether she would be willing to pay GH¢0.10 (approx. US\$0.10) per year to use a community radio. If the response was ‘yes’ the question was posed again with an increase in the amount to GH¢0.20 (approx. US\$0.20). The process continued until a ‘No’ answer. The final amount to which the respondent answered ‘yes’ was recorded as the maximum willingness to pay to have the community radio installed in the village. For extension agents, the beginning bid was at GH¢0.50 (approx. US\$0.50), while for private radios, the beginning point was GH¢1.00 (approx. US\$1.00). Respondents were also asked to state an amount they were willing to pay for each of the information delivery technologies.

Data collection was a face-to-face interview where the interviewer had the opportunity to explain the purpose of the survey and the need to obtain truthful responses from the

respondent. There was no known sampling frame for the rural areas and no attempt was made to create a sample frame for the localities. The interviewers were quite familiar with the villages and based on their experiences understood the need to interview in a manner that did not impair the integrity of the effort. For example, respondents were cautioned not to discuss their responses with other households. There was broad agreement among field staff that respondents took the process seriously and were willing to offer truthful information to assist in achieving the objectives of the survey.

The survey data was estimated using a multiple linear regression statistical model of the form:

$$(WTP)_{ijt} = a_0 + a_1 (AGE) + a_2 (EDUC) + a_3 (MARS) + a_4 (DEPEND) + a_5 (EXPEND) + a_6 (MEMBR) + U_i$$

where  $(WTP)_{ijt}$  is the willingness to pay by a household (i) in region (j) for information delivery technology (t), AGE is age of respondent measured in years, EDUC is the educational level of respondent. MARS was the marital status of respondent, and was measured using a *dummy* variable equal to 1 if respondent is married, and zero if otherwise. DEPEND is the number of dependents of respondent, EXPEND is the aggregate of all expenditures reported by the respondent measured in Ghanaian Cedis, and MEMBR is the membership of respondent in a community organization. Membership was measured as a *dummy* variable, equal to 1 if the respondent belonged to a community organization and zero, if otherwise. The term U is a random error term assumed  $N(0, \sigma^2)$ .

#### IV. RESULTS

Table 1 lists the means of selected independent variables for the ten regions in the study, and the mean bids for extension services, community radio, and private radio. Mean household size and expenditures are also provided. Consistent with expectation, mean bids for private radio is highest, followed by mean bids for extension information, followed by community radio.

TABLE 1.  
MEANS OF INDEPENDENT VARIABLES COMPARED TO MEANS FROM GLSS 4

Region	Household Bids in Old Ghana Cedis			No. of Dependents	Expenditure Survey	Expenditure GLSS 4
	Extension Information	Community Radio	Private Radio			
Western	6182	3535.5	10404	2.79	5,025,25	4,677,000
Ashanti	8480	3360	22300	3.61	11054650	5,008,000
B. Ahafo	10030	3730	24305	1.77	4,180,710	3,544,000
Central	10180	3886	22450	3.74	5,153,510	2,977,000
Eastern	8909	4868	22696	3.33	8,549,222	3,736,000
G. Accra	10202	3656	21162	2.83	11,495,487	6,777,000
Northern	9520	3400	21069	4.43	3,335,400	2,837,000
Up. East	8595	3141	21262	3.04	4,059,460	1,793,000
Up. West	9980	3830	26200	5.67	2,070,160	2,462,000
Volta	7320	5200	11190	2.39	6,134,540	4,000,000

Source: Survey and GLSS 4, Table 9.2

Mean expenditure pattern for households also tracks the numbers from GLSS 4 [4]. However, in Greater Accra, Eastern, and Central regions, means from the survey are significantly different from the means based on GLSS 4.

Since the GLSS 4 is based on 1999 information, it could be that expenditures have changed significantly over the last five years. The means are sufficiently credible to provide a reasonable basis for the survey data analysis.

Equation 1 was estimated for all regions combined and then for each individual region using the Newey-West estimator. This estimation technique helps to address one of the common problems when one uses cross-section data. The socio-economic characteristics of households differ in important ways so unless the statistical procedure takes into account these variations, the estimated coefficients may not be efficient due to problems of *heteroskedasticity* and *autocorrelation*. The Newey-West estimation procedure takes into account the problems in using cross-section data to give consistent and efficient estimates. The results of the estimation procedures are presented below.

Tables 2a, 2b, and 2c present the results of regression analysis using the combined data set for all regions. Four observations were rejected so the total number of observations was 996 instead of 1000 (100 observations for each of the 10 regions). The overall explanatory power of the model was poor with an R<sup>2</sup> (Coefficient of determination) of 7.5% for the community radio regression, 6.9% for private radio and 8.4% for extension services. The low explanatory power of the models was consistent with what one would expect in regression analysis using cross-section data. Furthermore, there was statistical significance of several of the critical socio-economic factors that were hypothesized to influence rural women's willingness to pay for selected information delivery technologies.

Table 2a shows that older women, educated above the primary school level, with high expenditure levels, and were members of a community organization were more willing to pay for information delivered via a community radio. With the exception of the income factor that was statistically significant at the 10% level, all the other factors were significant at the 1% and 5% levels. The table also shows that younger women (below age 20) were not willing to pay for information delivered via a community radio. Results for information delivered via private radio (Table 2b) follow the pattern obtained for community radio but it is also found that married women were willing to pay for information delivered via private radio. This may be due to the fact that married households have higher income (combined income) and could afford the more expensive media for information delivery.

This observation is supported by the fact that the estimated coefficient for expenditures (.00011) in Table 2b is bigger than the estimated coefficient for expenditures (5.09E-06) in Table 2a. Also the expenditure factor in Table 2b is highly significant (1% level) compared to the significance level (5%) for the same factor in Table 2a. Table 2c reports the results of estimation for information delivered via extension agents. The pattern observed under the two previous results is observed for information delivery via extension agents. Here again, the principal factors were high education, high expenditures, membership in community organizations, age and marital status. The results show that younger women were not willing to pay for information delivered via extension agents. The only factor that was not found significant in explaining variation in the choice of information media was the number of dependents.

TABLE2A  
REGRESSION RESULTS FOR HOUSEHOLDS

WILLINGNESS TO PAY FOR COMMUNITY RADIO		
Variable	Coefficient	t-Statistic
Constant	3017.98	23.08
Age [Up to 20]	-704.62	-5.07
Age [Above 20]	180.84	2.69
Married	38.70	0.43
Dependents	-1.60	-0.10
Educ. [Primary]	-110.71	-0.84
Educ. [Above Primary]	187.74	2.05
Expenditure	5.09E-06	1.62
Membership	316.90	3.54
R-squared	0.075	N = 996

TABLE2B REGRESSION RESULTS FOR HOUSEHOLDS WILLINGNESS TO PAY FOR PRIVATE RADIO		
Variable	Coefficient	t-Statistic
Constant	12333.05	8.14
Age [Up to 20]	-5469.63	-2.54
Age [Above 20]	1041.34	0.81
Married	3433.88	2.47
Dependents	348.89	1.40
Educ. [Primary]	1204.46	0.73
Educ. [Above Primary]	5663.57	3.17
Expenditure	0.00011	2.82
Membership	4867.08	3.69
R-squared	0.069	N = 996

TABLE2C REGRESSION RESULTS FOR HOUSEHOLDS WILLINGNESS TO PAY FOR EXTENSION OFFICER		
Variable	Coefficient	t-Statistic
Constant	6707.23	17.23
Age [Up to 20]	-1855.98	-4.57
Age [Above 20]	395.12	1.95
Married	463.64	1.71
Dependents	48.58	1.059
Educ. [Primary]	-27.67	-0.089
Educ. [Above Primary]	473.32	1.82
Expenditure	1.43E-05	2.22
Membership	1298.57	5.20
R-squared	0.084	N = 996

## V. CONCLUSION AND POLICY RECOMMENDATIONS

The conclusion that could be drawn from this study is the need to analyze ICT use in empowering rural women within a broad context. No single socio-economic factor emerged as the dominant variable in planning policies and programs to introduce ICT use in information delivery to rural women. Likewise, no single information delivery technology emerged as 'the' technology to use in delivering information to rural women. The study results also point to a need to cast rural empowerment policies and programs within the broader poverty reduction policies of the government and also within

the attainment of the Millennium Development Goals (MDGs).

The results show that the attainment of the MDG vision would boost ICT use in delivering information to rural households since income was found to be consistently statistically significant in explaining rural women's willingness to pay for information. There are two important issues to address in the context of the relationship between incomes and ICT use to empower rural women. First, the relationship between ICT use and income must be seen as bi-directional. While high income makes it possible for rural women to pay for the information delivery technology of choice, the delivered information, in turn, is intended to empower women to be able to make those decisions that would improve their welfare and incomes [5]. These bi-directional effects are captured in the analysis by providing a 'feedback' loop in the theoretical framework that emphasizes the importance of 'learning' in the empowerment process. These observations lead to the conclusion that knowledge of the importance of incomes in ICT use in information delivery is not enough. There is also a need to emphasize the learning component that allows rural women to better utilize received information in decision making to further improve their incomes.

A second implication of the statistical significance of the income factor is the need to broaden policies to enhance the many possible sources of income available to rural women. Even though the popular view has been to focus on agriculture as the primary source of raising incomes of rural women, the survey results point to a need to broaden the scope of an income policy in rural areas. The field survey results show that the majority of women (45.8%) reported "trading" as the primary source of income while 23.9% reported "farming" as their primary source of income. About 7.7% reported "dressmaking" as their primary source of income while 4.1%, 2.7%, 2.6% reported "hairdressing," "teaching," and "office work" respectively as the primary source of income. A sizable percentage (11.2%) reported no income source.

by extension agents since the historical mission of these agents are the delivery of "agriculture-related" information. The results may also explain the popularity of private radio because radios may complement such activities as 'hairdressing', 'dressmaking,' 'office work,' and 'trading.' The key is for policy and program planners to better understand the dynamic in the rural sector and to recognize shifts in economic activity that may be counter to the historical pattern of economic activity.

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The distribution of women's sources of income is beginning to put flesh on some of the results obtained in the study. For example, the distribution may help explain why several households were not willing to pay for information delivered

# AN ENTERPRISE APPROACH TO SYSTEM DEVELOPMENT

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**Abstract** - With the current invasion of information technology into every aspect of human life with a view to reduce redundancy and improve efficiency, the need for its application into an enterprise cannot be over emphasized. Most systems developed for business are done for individual applications which do not interact, giving rise to duplication of functions. This paper takes a look at an enterprise approach to system development which integrates business processes into a singular whole.

**Keywords:** Enterprise, Architecture, Stand alone

## I. INTRODUCTION

When project teams work under the assumption that they can do anything they want, chaos normally results. Functionality and information will be duplicated,. Units and systems components will not integrate well as there will be conflict within the system components causing the system to fail completely or not function optimally. Although each individual unit may function excellently,as a whole (an integrated system) they may have serious challenges. Only a few software systems exist in isolation. Rather, systems must co-exist with several and sometimes hundreds of other systems to achieve a common united goal which creates the functional ability of any specified entity. Different unit applications must cooperate effectively with the other systems within the establishment. Therefore an application must be developed so that it does not cause adverse effects on your other systems, and ideally it should be built to take advantage of and to enhance a shared infrastructure.

An enterprise system is defined as the use of software and computer system architecture principles to integrate a set of enterprise computer applications [1]. This is shown in fig. 1

In todays competitive and dynamic business environment, applications such as supply chain management software, customer relationship management software, business intelligence software and integrated collaboration environments have become imperative for organizations that need to maintain their applications and others in order to realize financial and operational competitive advantages.

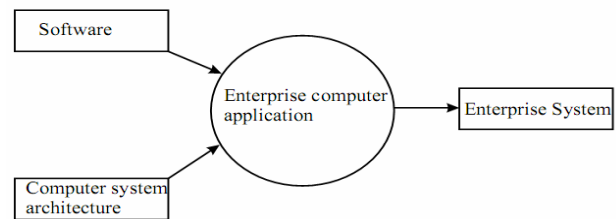


Figure 1. Enterprise Definition

Enterprise system tends to transcend the simple goal of linking applications. It attempts to enable an innovative way of leveraging organizational knowledge to create further competitive advantages for the enterprise.

When different standalone systems are supposed to function together, there is always the possibility of compatibility problems such as not being able to share their data effectively, and regular human intervention in the form of decision making or data entry. This constitutes a bottleneck to the entire system operation. However with properly deployed enterprise systems architecture, organizations are able to focus most of their efforts on their value creating core competencies instead of focusing on workflow management. Business architecture shows the business models, service, organization and strategy that forms the basis for choice of other enterprise architecture. Reference [2] classified enterprise systems into business, application, information and technology. This is however depicted by fig. 2 below. An enterprise processes information and information technology assets as a vehicle for aligning business and IT in a structured and therefore, more efficient and sustainable way which has presently attracted significant attention. Enterprise Architecture (EA) is a conceptual blueprint that defines the structure and operation of an organization.

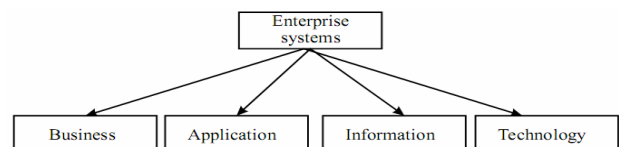


Figure 2. Enterprise Systems Classification

The intent of enterprise architecture is to determine how an organization can most effectively achieve its current and future objectives.

- Business classification describes how the operations and functionalities that make up the system work to achieve its daily activities.
- Application classification describes how the various system functionalities collaborate to meet organization standards.
- Information classification describes and shows the document files, databases, images, presentations, and spreadsheets required by the organization for effective functioning
- Technology classification describes the hardware, software (system software and application software), and networking solutions for the organization.

## II. BENEFITS OF ENTERPRISE ARCHITECTURE

Reference [3] purported advantages of having an enterprise architecture to include: improved decision making, improved adaptability to changing demands or market conditions, elimination of inefficient and redundant processes, optimization of the use of organizational assets, and minimization of employee turnover. The Enterprise Architecture offers several other key benefits. The six most important benefits include:

### A. Links InformationTechnology (IT)

As a comprehensive framework, an Enterprise Architecture identifies how IT assets directly enable business processes collaborate, and how those processes execute a system's mission. IT assets are reflected in the Information Architecture.

### B. Improves Interoperability and Integration

By defining standards and specifications for tasks, the systems will "talk to each other"; the job of integrating multiple systems becomes easier. This leads to other benefits such as:

- making accurate information available whenever and wherever needed;
- reducing the time required to implement systems; decreasing the cost of implementing systems (primarily lower labor costs – you don't have to redefine interface standards with each implementation); and
- increasing the likelihood of systems interoperating correctly the first time.

### C. Enables Agility

When there is the need to quickly respond to some sort of change in the environment, there has to be a ready reference that informs on what impact that change will have on each of the components within the Enterprise Architecture, and how to ensure the components continue to operate smoothly through change management. The Enterprise Architecture also enables faster design of new systems and extensions to existing systems by pre-defining ground rules and standards.

As we migrate to a service orientation, user applications will increasingly be delivered as a composition of reused services allowing faster adaptation to new business requirements.

### D. Reduces Costs

Economies of scale in purchasing, reduced training requirements, fewer support staff and simpler upgrades are all examples of cost reductions offered through enterprise architecture. It reduces support costs by establishing a less complex environment (due to technical homogeneity) which is easier to support and results in faster repairs.

### E. Improves Security

Through the development of security standards, the risk of intrusion, loss (tangible and intangible), and system downtime are all reduced.

### F. Reduces Technical Risk

The Enterprise Architecture can reflect a technology infrastructure that is based on industry standard solutions. Doing so increases the availability of support services. It also ensures maintaining a pace of technology currency that is consistent with its business context and risk profile.

## III. ATTRIBUTES OF ENTERPRISE SYSTEM

Reference [5] describes Enterprise systems as having the following attributes:

- **Accessibility:** service or resource is always accessible and available when needed.
- **Scalability:** it has the ability of handling load increases and it also provides the required quality.
- **Platform:** the ability to access system functions through different platforms and user languages.
- **Portability:** having the ability to run on different hardware and operating environments.
- **Manageability:** the ability to ensure that the system continues to work with optimum performance and security standards.
- **Maintainability:** the ability to convert flaws in the existing functionality without impacting existing functionality.
- **Leveragability:** the ability that stored data, programmed logic, and other systems resources available anywhere in the enterprise, should be accessible from everywhere in the enterprise.
- **Reliability:** the assurance of the integrity and consistency of the application and all of its transactions. The ability to provide a required reliability service level depends on the close coordination of the hardware, networking, operating system, storage subsystem, application framework and application software.
- **Security:** the ability to allow access to application functions and data to some users, and deny other users access to them.
- **Interoperability:** the ability of the system to share data with external systems and interface with external systems.



- **Popularity:** the assurance that since other people are using the same technologies, there will be a sufficient talent pool to maintain it, and if there are problems, the manager who selected the technology would not be hurt politically within his organization.

#### IV. PURPOSES OF ENTERPRISE SYSTEM

Enterprise systems can be used for different purposes.

1. **Data (information) integration:** ensuring that information in multiple systems is kept consistent.
2. **Process integration:** linking business processes across applications.
3. **Vendor independence:** extracting business policies or rules from applications and implementing them in the enterprise systems, so that even if one of the business applications is replaced with a different vendor's application, the business rules do not have to be re-implemented.
4. **Common facade:** An enterprise system could be a front-end cluster of applications, providing a single consistent access interface to these applications and shielding users from having to learn to interact with different applications.

#### V. ENTERPRISE SYSTEM LIFE-CYCLE.

The enterprise life cycle is the dynamic, iterative process of changing the enterprise over time by incorporating new business processes, new technology, and new capabilities, as well as maintenance and disposition of existing elements of the enterprise [4]. This is depicted in figure 3.

#### VI. ENTERPRISE APPLICATION AREAS

Enterprise systems can be applied to virtually every core business area as shown in Figure 4.

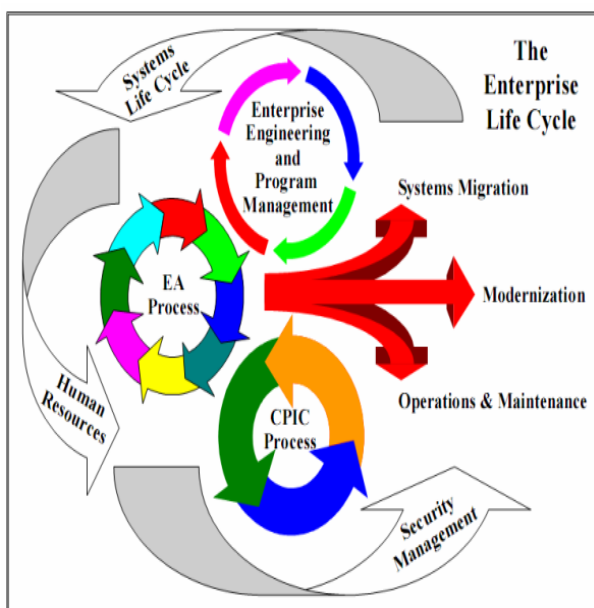


Figure 3. Enterprise System Life Cycle [4].

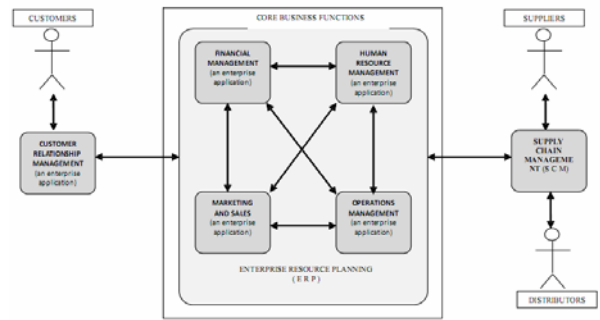


FIGURE 4. ENTERPRISE APPLICATIONS [5].

#### VII. ENTERPRISE SYSTEM PATTERNS

##### A. Integration Patterns

There are two patterns that enterprise systems implement:

1. **Mediation:** Here, the enterprise system acts as the go-between or broker between multiple applications. Whenever one of the applications is modified (new information created, new transaction completed, etc.), an integration module in the enterprise system is notified. The module then propagates the changes to other relevant applications.
2. **Federation:** In this case, the enterprise systems system acts as the overarching façade across multiple applications. All access from the 'outside world' to any of the applications are front-ended by the enterprise systems. The enterprise system is configured to expose only the relevant information and interfaces of the underlying applications on behalf of the requester.

Both patterns are often used concurrently. The same enterprise systems could be keeping multiple applications in sync (mediation), while servicing requests from external users against these applications (federation).

##### B. Access Patterns

Enterprise systems support both asynchronous and synchronous access patterns, the former being typical in the mediation case and the latter in the federation case.

##### C. Lifetime Patterns

An integration operation could be short-lived (e.g. keeping data in sync across two applications could be completed within a second) or long-lived (e.g., one of the steps could involve the enterprise systems interacting with a human workflow application for approval of a loan that takes hours or days to complete) [5].

#### VIII. STAND-ALONE SYSTEM FLAWS

A stand-alone application can easily be viewed as a closed system with no pre-built functionality for future integration. This class of systems depend solely on its modules. The cost of building several stand-alone systems far outweighs the cost of building and maintaining an enterprise system. Some other flaws present with standalone system include:



- Applications are built separately
- Each system has its own files and databases
- Repetition of data items
- Loose and awkward integration of all applications

## IX. CONCLUSION

The benefits and technologies supporting an enterprise based approach to application development are vast and when put to full use has immeasurable benefits. This paper has identified core aspects of an enterprise design approach with advantages over standalone design methods.

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## Cellular Telephony as Enabler for Anywhere, Anytime On-Line Address Books: An Open Architecture

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*Abstract-The growth of cellular telephony is truly explosive, especially in developing countries where it is the prime telecommunications infrastructure due to the low penetration of fixed telephony and the Internet. To fully exploit telephony, address books are indispensable. Most cellular telephony users in developing countries rely solely on the rather primitive off-line address books that come with the phones. Loss of a phone often turns into a 'painful' ordeal, especially since backup mechanisms, such as synchronizing with computers, are seldom used. Computers and phones with synchronization abilities are not affordable by most end-users. This paper proposes an open architecture for providing anywhere, anytime on-line address books in settings where end-users rely solely on the off-line address books provided with cellular phones. The address books are stored on-line in a repository in the cellular network. They can be downloaded into new phones when replacement phones are purchased. Short message service (SMS,) a widely deployed cellular telephony service, is the prime interaction mechanism between the off-line and the on-line address books.*

**Keywords-** Cellular telephony, GSM, on-line address books, Short Message Service Center (SMS-C), Short Message Service (SMS), Signaling System No7 (SS7)

### I. INTRODUCTION

The world has witnessed a phenomenal growth of cellular telephony since the early 1990s. This growth is even more spectacular in developing countries where alternatives are fewer because of the low penetrations of fixed telephony and the Internet. Cellular telephony users in Africa now number more than 100 million, while only five years ago they were approximately 8 million [1].

Address books are an indispensable and integral part of telephony. They allow callers to store and easily retrieve the telephone numbers of their professional and personal contacts. Address books may also contain other convenient information such as civil addresses and professions. We are all familiar with the tick off-line address books (known as phone directories) supplied by fixed telephony service providers -- books that are nowadays also on-line and accessible via the Internet. However such books are usually not available in mobile telephony settings.

Most cellular phones come with mechanisms that allow end-users to manage their own address books. Relevant information can be stored on and retrieved from these phones. In this paper we designate these address books as off-line address books.

The loss of a phone can become a nightmare, especially in developing countries where backup mechanisms (e.g.

synchronization with computers and Internet on-line address books) are not common practices. Computers and Internet access are still too costly for most end-users.

This paper proposes an open architecture for providing anywhere, anytime available on-line address books in developing countries where most end-users rely solely on their off-line address books. The architecture relies on the cellular network, since it is the prime telecommunications infrastructure in most of these countries.

On-line address books can come to the rescue when phones are lost because they can be automatically downloaded to the newly acquired phones. They are stored in a repository in the cellular network and the end-users interact with the repository using a widely deployed cellular telephony service, the short message service (SMS).

The next section gives background information on cellular telephony and SMS. The third section reviews the state-of-the-art in light of the system design goals and end-user requirements. The novel open architecture is introduced next, followed by our conclusions.

### II – BACKGROUND

Cellular telephony adds mobility to fixed telephony. The first generation systems were analog and date back to the 1980s. The second generation systems are digital and their deployment began in the '90s. Third generation systems are digital but based on packet switching, unlike the two previous systems that are based on circuit switching. This paper focuses on second-generation cellular systems, which are now the most widely deployed. We use the Global System Mobile (GSM) as our archetype, as it is the most widely deployed system in developing countries. SMS was added later to GSM to allow the exchange of short text messages.

#### A. GSM

This sub-section introduces the GSM architecture, which is made of three layers. The main components are briefly described. For a detailed overview please consult reference [2]. At the lowest layer of the architecture we have the mobile station (MS), which is the actual cellular phone. It is made up of two main components: a subscriber identifier module (SIM) combined with a mobile equipment (ME) unit. It may also have storage capacity. The SIM uniquely identifies the subscriber and the ME provides the radio interface to the second layer, the base station subsystem (BSS). The off-line address book that comes with the phone is stored on / retrieved from either the SIM or the storage available on the phone.

The BSS is made up of the base transceiver station (BTS) and the base station controller (BSC). The MS communicates with the BTS. Several MSs can be connected to the same BTS and several BTSs are connected to the same BSC. The BSC manages the BTSs. At the highest level of the architecture we have the network sub-system (NSS). The mobile switching centers (MSCs) are telecommunication switches that have additional functionality for mobility management. Several BSCs can be connected to an MSC. The MSCs are connected to several databases including the home location registry (HLR) and the visitor location registry (VLR). The HLR stores information on the network subscribers while the VLR stores information on the subscribers (of other networks) who are currently present in the network. Figure 1 provides an illustration.

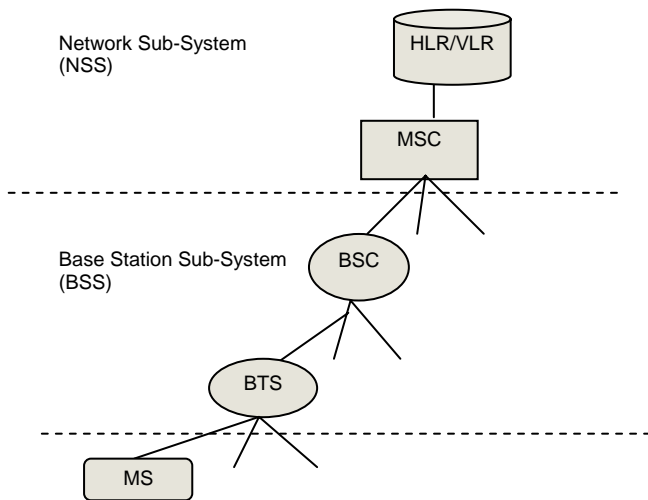


Figure 1 - A simplified GSM architecture

### B. SMS

SMS was a later addition to GSM. Call signaling in GSM is based on signaling system No7 (SS7). SS7 is an out-signaling system that relies on a dedicated packet switched network. Reference [3] gives an overview.

Figure 2 contrasts a simplified SS7 protocol stack to the classical 5-layer TCP/IP stack. The application part in case of GSM is called mobile application part (MAP). It runs on top of a network service part called message transport part (MTP). MTP3 corresponds to the IP layer, MTP2 to the data link layer and MTP1 to the physical layer. The TCP layer has no equivalent in SS7.

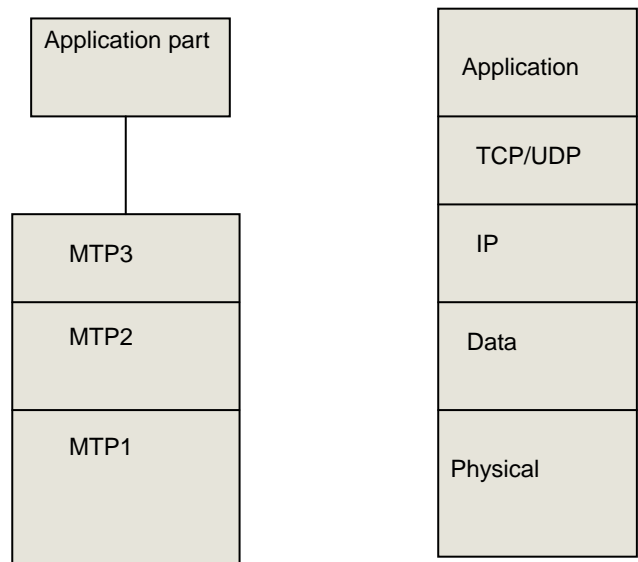


Figure 2 – Simplified SS7 stack versus 5-layer TCP/IP stack

After the introduction of GSM, network operators realized that the spare capacity in the SS7 network could be used to transport short text messages, not more than 160 characters long. However, longer messages can be sent thanks to fragmentation and re-assembly.

The only node that was added to the GSM architecture to implement SMS is the short message service center (SMS-C). It is a store-and-forward messaging server and is connected to the MSC. An SMS sent from user 1 in network 1 to user 2 in network B may cross several SMS-Cs before reaching the SMS-C of network 2. SMS are stored on the MS (either on the SIM card or on the phone storage) before delivery. They are stored only for a limited period of time. For more information on SMS the reader can consult reference [4].

## III – DESIGN GOALS AND STATE OF THE ART

We envision on-line address books as a value added service offered to subscribers by cellular telephony service providers. We successively introduce the system design goals, the requirements for subscriptions, usage and interactions with the system. We then use the system design goals and the requirements to critically review the state of the art.

### A. System design goals

Our first goal is to design a system with developing countries as the prime targets, which means that the specifics of these countries must be taken into account. This implies, among other things, that the system should be able to cater to low-end and medium-end phones that have limited storage capabilities.

Another goal is to have an open architecture that can be easily deployed in any GSM network. The system should not be tailored to a specific equipment brand. Little or no change should be made to the existing GSM functional entities. Although new functional entities may be introduced,

these entities should interact with the standard GSM entities whenever possible.

We will also design the system to meet the classical goals such as scalability, reliability, fault tolerance, etc. For example, the system should scale in terms of subscribers and also in terms of address book size.

### B. Requirements for subscription

The end-user shall have two options when subscribing to the service

#### Option 1: The entire address book on-line

In this case the entire content of the address book is duplicated on the on-line repository offered by the cellular network operator. End-users can directly manipulate their on-line and off-line books by creating and modifying entries on their phones. Synchronization with the on-line address book is done automatically and transparently.

#### Option 2: Parts of the address book on-line

Some subscribers may wish to duplicate only parts of their address books on-line, potentially thus motivated by the charging model. If for instance the service is charged per entry stored, some subscribers may decide to duplicate on-line only the entries they consider critical. It is obvious that in such cases, only the parts that have been duplicated can be downloaded to new phones when phone losses occur.

### C. Requirements for usage

After subscription end-users shall be able to:

#### Save on the on-line address book

Only subscribers who have selected the second option have access to this operation, because it is performed automatically for those who selected the first option. Subscribers can use this function to select from the local address book the entries that will be stored on the on-line address book.

#### Modify the on-line address book

Like the previous operation, only subscribers who have selected the second option have access to this function – again, it is done automatically for the others. Subscribers can explicitly modify (or remove) entries that are stored on the on-line partial address book.

#### To download and transfer address books

The “download” operation allows subscribers to download parts of or the entire address book they have on-line. The “transfer” operation allows them to transfer parts of, or their entire on-line address book to other subscribers.

### D. Requirements on interaction mechanisms

The preferred interaction mechanism shall be SMS, since it is already in general use in developing countries. However, for convenience, the end-user shall also be able to interact via a Web page if she/he wishes

#### Interacting with SMS

The end-user registers by sending an SMS (with a pre-defined format) to a pre-defined phone number. The same applies to the other operations: save, modify/remove, download and transfer.

#### Interacting via a Web page

All of the above operations can also be done via a Web page offered by the network operator.

### E. Critical review of the state of the art

A few cellular telephony service providers already offer some services that are close to the anywhere, anytime on-line address books we have in mind. An example is the “SOS SIM repertory service” offered by Bouygues and for which subscribers pay a monthly fee [5].

With this service, all the entries of the off-line address book saved on the SIM card are automatically backed up on a server in the Bouygues network. The backup is done in the few hours following the last modification. Actually, the entire address book is backed up on the server after each change and the server keeps the history. When the subscriber loses her/his phone, she/he can select the version of the backup she/he wishes and receive it on the newly acquired SIM card.

This service meets neither our system design goals nor the end user requirements. The architecture is not open. It is tailor-made for Bouygues and cannot be easily deployed in other GSM networks. The second option of our subscriptions requirement is not supported. Interactions via a Web page are not possible. Furthermore, only the addresses saved on the SIM card are backed up.

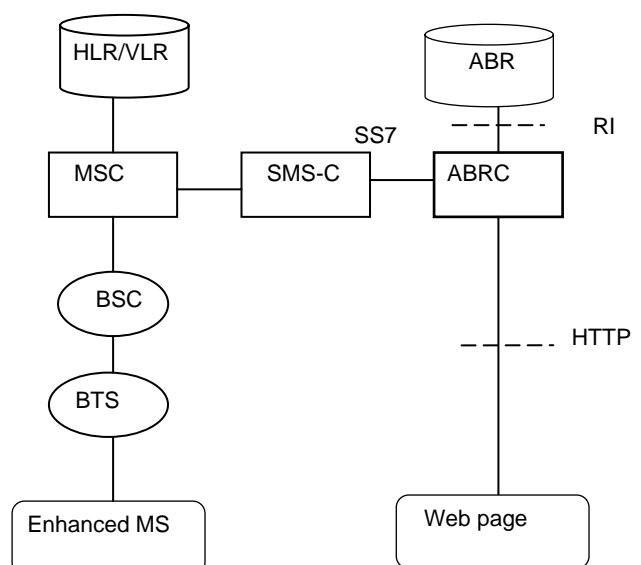
There are tools on the market that can help end-users back up their off-line address books. An example is the “MySIM copier” [6], which allows the end-user can copy her/his off-line address book on a backup SIM card. Such tools are not readily available in developing countries. Furthermore, both SIM cards could be lost. There are many other tools that require the use of personal computers. However, as already stated, personal computers remain too costly in these settings.

## IV – PROPOSED ARCHITECTURE

The functional entities and interfaces are presented and illustrated by scenarios. The technical challenges are discussed subsequently.

### A. Functional entities and interfaces

Figure 3 depicts the overall architecture.



There are two new functional entities: the address book repository (ABR) and the address book repository controller (ABRC). The ABR stores the actual on-line address books. It may be implemented as a centralized or a distributed database. The address book repository controller (ABRC) controls the ABR. It can be accessed via 2 interfaces: SS7 when the end-user interacts via SMS, and HTTP when the end-user interacts via the Web page. It interacts with the ABR via the repository interface (RI) (e.g. SQL). Only one existing functional entity is modified, the MS.

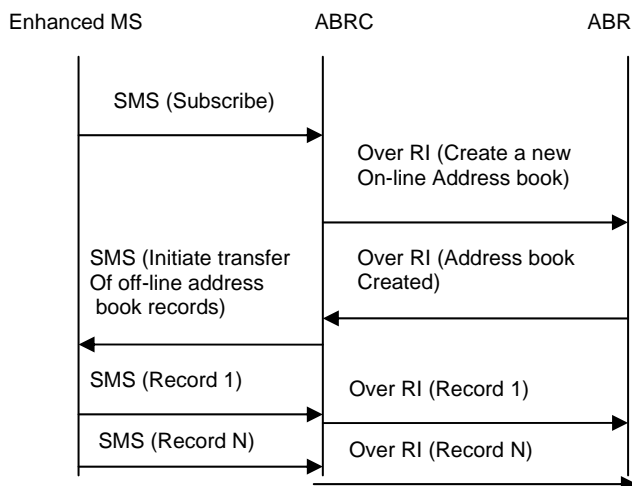
Thanks to these enhancements of the MS, whenever an end-user (with subscription option 1) modifies her/his local address book, the MS automatically generates an SMS, which is sent to the ABRC in order to trigger synchronization. Thanks to the same enhancements, whenever an end-user makes a change to the on-line address book (or the parts of the book that are kept on-line) via the Web page, the off-line address book is updated accordingly.

### B Illustrative scenarios

Two scenarios are discussed.

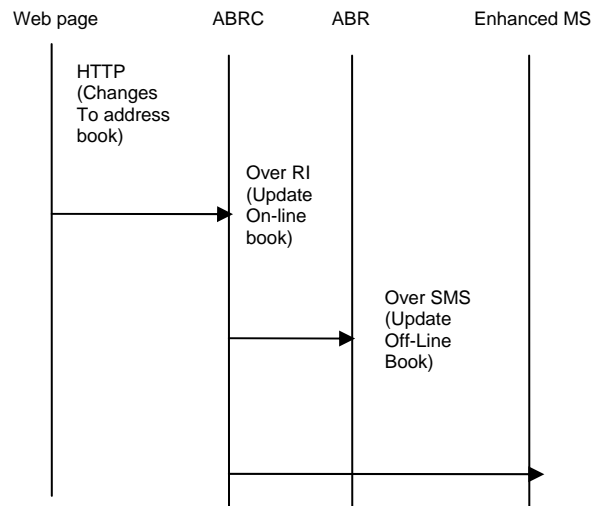
*First scenario: An end-user subscribes to the service (option 1) via SMS*

Figure 4 depicts the sequence of messages and events. The end-user sends an SMS to the ABRC to announce her/his intention to subscribe. The ABRC sends a message to the ABR to create a new on-line address book in the repository. We assume that the new on-line address book is successfully created. The ABRC then sends a message to the enhanced MS in order to initiate the transfer of the off-line address book to the newly created on-line address book. The entries of the off-line address book are then transferred by SMS to the on-line address book.



*Second scenario: A subscriber makes changes to the on-line address book via the Web page.*

The changes made via the convivial Web interface are sent to the ABRC. The ABRC updates the on-line address book. It then updates the off-line address book using the same data. Figure 5 depicts the exchanged messages.



### F. Technical challenges

We start with the challenges related to the modified functional entity (i.e enhanced MS), and then move to those related to the new nodes.

#### 1. Enhanced MS related challenges

Enhancing the MS means adding new logic to a SIM card. This is an uphill task for several reasons. SIM cards have limited memory capacities. Furthermore, programming them requires specialized skills.

SIM cards have Read Only Memory (ROM), programmable Electrically Erasable Read Only Memory (EEPROM) and Random Access Memory (RAM). The capacities are as follows: ROM (16 to 24 KB), EEPROM (8 to 32 KB) and RAM (256 to 512 KB).

There are several tool kits for programming SIM cards. One example is provided by SUN Microsystems [7]. The level of abstraction offered by the application programming interface (APIs) is rather low.

Furthermore, the basic programs that come with SIM cards are usually written by SIM card providers and there is no guarantee that third parties can easily integrate additional logic to these cards, especially when the logic is as complex as that required for the anywhere, anytime on-line address book.

#### 2. ABR- and ABRC-related challenges

The ABR can be implemented either as a centralized database or a distributed database. Distributed databases, however, will be more suitable in most cases. They offer

better reliability through duplication. Furthermore, they enable quicker access, especially when the cellular network covers a wide area and end-users can request access from anywhere in the coverage area. In addition, distributed databases enable scalability. Designing, deploying and managing distributed databases is no easy task. Several challenges need to be addressed.

The ABRC supports three protocol stacks: HTTP, SS7 and the stack that makes interactions with the repository possible. It also parses and generates SMS messages. The most challenging task here is to keep off-line and on-line address books synchronized, because end-users can make changes via both the MS and the Web page. Several synchronisation algorithms have been proposed over the years [8]. We briefly review here the most important and draw some conclusions as to their suitability for the problem at hand. These algorithms are: Fast Sync, Slow Sync, IntelliSync, SyncML, and CPISync.

FastSync is one of two modes of operations provided by Palm Hotsync. It can be used only when a handheld PDA is being synchronized with the computer used in the previous synchronization. In other words, the handheld device can synchronize with one and only one computer. The algorithm uses status flags to determine the changes that occurred since the last synchronization with the computer.

Slow Sync may be used whenever Fast Sync is not suitable, such as synchronization of a handheld device with different computers (e.g. office computer, home computer). The status flags may therefore not convey the real differences between the data on the handheld device and that on the computer. Actually, the handheld device backs up all of its records on the computer after each synchronisation. It uses these records as reference the next time it synchronizes with the same computer.

IntelliSync relies on a centralized server. Users have accounts and all the devices always synchronize with this centralized server. All synchronizations can therefore be characterized as FastSync. There is no need for peer-to-peer connection in order to synchronize multiple devices.

SyncML is an open industry initiative. To minimize communication time, each device maintains information modification flags for each of its records with respect to every other device on the network. Thus, modifying a record on a PDA would entail toggling not simply one set of status flags as in Fast Sync, but a set of status flags for every device on the network. The amount of memory needed can easily become prohibitive. Note that adding or removing a device from the network entails an update to every other device in the network.

CPISync (Polynomial Interpolation Synchronization) is based on an algebraic solution to the problem of reconciling two remote sets of information. This algorithm has been shown to be significantly more efficient than Slow Sync in the most common scenarios. Unlike the previous approaches, the CPISync algorithm is computation intensive.

None of these approaches is really suitable for our needs. The memory capacity and computation power they require may not be available on low- and medium-end cellular phones. Furthermore, SMS may not be the appropriate way to carry the synchronisation messages and data prescribed by these approaches.

## V-CONCLUSIONS

This paper has proposed an open architecture for providing anywhere, anytime on-line address books in settings where the classical means for backing up the off-line address books that come with cellular phones are not available or their cost is prohibitive. Cellular technology is the pillar of the architecture. The on-line address books are stored in repositories residing in the network and SMS is used as the prime interaction mechanism. We presented the basics of cellular networks (using GSM as the archetype) and also the basics of SMS. System design goals and end-user requirements were derived and used to critically review the state of the art. Our proposed architecture introduces two new functional entities to the GSM architecture: the address book repository controller and the address book repository. Illustrative scenarios were presented and technical challenges identified.

There are several avenues we will explore in future work. We will start by building proof-of-concept prototypes of selected sub-sets of the systems. These prototypes will help us to further refine the end-user requirements and the architecture. Performance will then be studied via real measurements and simulations in order to validate viability, and we will subsequently extend the architecture. A potential extension could be the use of the multimedia messaging system (MMS) instead of SMS. We will also explore new value-added services that may be built using the same infrastructure.

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# Adapting Current Technology for Information Communication in a Third World Country

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**Abstract** - In the present climate of information age, effective dissemination of information creates an environment that accelerates the learning process. The process of dissemination should be designed such that the information reaches the target group. On a national scale, the target group may be in urban or rural areas, or in both urban and rural areas. At the present, the choice of technology for this purpose is the Internet. This is because it combines the speed of transmitting information and the multi-tasking functionality of computing, hence different sources of information can be accessed quickly. Computers also provide access to a vast resource of educational materials. The Internet therefore provides an effective means of disseminating information and creates an environment that accelerates the learning process. The added advantage of having global connectivity will enable the users to access developmental information from other nations thereby improving the knowledge base of Ghanaians, and hence the country's developmental progress.

Dissemination of information may be a problem even in urban areas in a third world country such as Ghana where it is desirable that information essential for societal development should reach all people. It is therefore needful to find a means of communication that is effective as well as inexpensive. This paper discusses the use of Broadband Powerline Communication (BPL) for this purpose. It describes the initial stage of a cooperative project between Pennsylvania State University and Kwame Nkrumah

University of Science and Technology (KNUST).

## I. INTRODUCTION

The developmental process for any technology from the inception of the idea through the prototype phase to fully accepted and applicable state is a costly venture and the capital outlay can be very high. For this reason, there are not many companies that are able to undertake such process from the beginning. Many companies in developed and affluent nations will adopt the technology when it is established as a viable application. It is therefore even further out of reach for a developing nation to undertake such a process. Developing nations are therefore generally user nations that depend on technological developments from manufacturing nations, and at best can be service nations when their technicians, technologists and engineers are trained to operate and maintain the technology.

Currently, technological development in leading nations coupled with the idea of global village is driving a trend that is advancing development of under developed nations through transfer of technology. To date, the transfer has mostly been in the form of finished products such as equipment being sold to developing nations. The technological developments are initially inspired by technological needs in temperate regions. For this reason, the environmental conditions that are considered as part of the design criteria, and are therefore well suited for the applications of the technology, are those of the temperate regions.

It is very likely that not all of the pieces of equipment sold to developing nations are preconditioned to be operated in the equatorial region. In this region, excessive heat that may cause thermal drift [1] in some integrated chip components, and dust are problems during the summer months when the temperature can be around 100° F for several days, and humidity is a problem during the rainy seasons when heavy torrential rainfalls listed up to, and in certain areas over 83 inches are experienced. Also technologies such as radio, TV and cell phones are already being employed in most under developed nations, if not all. As such, the elements as well as electromagnetic interference have to be considered where these can have adverse effects as a result of location on the planetary surface.

A major factor in choosing an applicable technology for a developing nation is how expensive the technology will be, not only in setting it up, but also the operational and maintenance costs need to be considered. For this reason, if the technology can be overlaid or mapped onto an existing system, the cost of setting up an infrastructure to support the technology is eliminated, hence greatly reducing the overall cost. This influenced the selection of the system mentioned above. When operational, the BPL system will be subjected to all the atmospheric conditions referred to above, and will also be impacted by the electromagnetic emissions from the sources stated above.

## II. RATIONALE FOR SELECTION

The purpose of the project is to develop a functional Broadband PowerLine Communications System for Internet applications. The rationale for proposing the use of the power line [2,3] is that currently electrification is well established in Ghana and covers about 92 % of the country. Power lines therefore span the length and breadth of the country, covering both urban and rural areas as an existing infrastructure. To achieve the same coverage with cable, DSL or wireless will be extremely expensive financially, and to use satellite will be equally expensive. While Broadband Power Line Communication may be relatively new compared to other technologies, advances in this area have shown it is an effective technology that is ideal for a developing country in which the national grid is uniform and is controlled by one authority the

Volta River Authority (VRA), and power distribution is also under one company, the Electricity Company of Ghana (ECG). This eliminates the difficulty of having to negotiate with many companies over the rights to use their sections of the grid, and how responsibilities as well as proceeds from the commercialized system will be shared.

This therefore eliminates the initial capital outlay for providing the supporting infrastructure. The initial outlay of capital for the additional application will therefore be in the initial experimentation to complete the design, which will be a small percentage of what will be needed to create a new infrastructure.

Another factor is how easily and efficiently the people will adapt to using the technology. An existing power line infrastructure is already familiar to all the people and hence a development based on that will only be an extension of a system that the people are already used to and comfortable with in its application. The extra effort needed to become familiar with the new technology as the addition to the existing infrastructure is not too great.

The interest in becoming familiar with the Internet and the many new horizons that will open will in itself create enough excitement and make the whole project attractive to the people. This factor should act as a catalyst in the learning process. The learning process for the majority of the people will therefore be one that they will find engaging. Hence the concern over how the people will adapt to the new technology is minimized, if not eradicated all together.

The problem of digital divide is well documented [4, 5, 6] in the literature. The introduction of computers and the empowerment that will bring to the people in all aspects of their lives will raise the standard of living across the nation. As noted by the authors in [4], “digital divide” adversely affect societies because a good proportion of the population are not able to effectively participate in the development of the society, and bridging the digital divide will contribute towards socio-economic development. With this system under the control of a committee that controls the type of material allowed on it, should provide enough safeguards to eliminate harmful material being transmitted to the people.



### III. CONSIDERATIONS FOR SELECTED APPLICATION

The selected application combines three major technologies. These are

- (i) Antennas
- (ii) Electric power transmission
- (iii) Data transmission.

#### (i) Antennas

The structure under discussion is a power line that is being used as a medium of transmission for electrical signals. Along the line will travel two signals, electric power and data. In considering the structure as a whole, the problem can therefore be described as *wave propagation on a transmission line* [7]. The traveling wave has solutions

$$V(z) = V_o^+ e^{-\gamma z} + V_o^- e^{\gamma z} \quad (1)$$

$$I(z) = I_o^+ e^{-\gamma z} + I_o^- e^{\gamma z} \quad (2)$$

where  $V(z)$  and  $I(z)$  are the voltage and current at a distance  $z$  from the point of entry where the voltage and current are  $V_o$  and  $I_o$ ,  $e^{-\gamma z}$  represents wave propagation in the  $+z$  direction,  $e^{\gamma z}$  represents wave propagation in the  $-z$  direction, and  $\gamma$  is the complex propagation constant and is a function of frequency. This suggests that at the point of entry, the signal will travel in both  $+z$  and  $-z$  directions. Generally, transmission lines demonstrate loss as a result of finite conductivity and hence it will be necessary to assess attenuation along the transmission line. It will therefore be necessary to determine how far the signal can travel and not be seriously attenuated, and maintain its integrity.

It is to be expected that the transmission line radiate electromagnetic energy. It will also absorb electromagnetic energy that will manifest as noise. This will manifest as electromagnetic interference (EMI). EMI can have both man-made and cosmic sources. The line will therefore behave as an antenna. As such, it is important to evaluate the electromagnetic effect on the structure.

#### (ii) Electrical Power Transmission

As previously stated, Ghana is about 92 % electrified, the generation occurring at

Akosombo Dam. The transmission level is 220 volts at 50 Hertz. The frequency level of the power is thus sufficiently different from what will be required for the transmission of data. Even so it will be necessary to ensure that there is no interference in the data.

#### (iii) Data Transmission

This will be the transmission of information along the line, and it will be essential to ensure that its integrity is not seriously compromised. It will therefore be necessary to determine the levels of interference from other sources of electromagnetic waves such as radio and TV transmissions and the earth's magnetic field. These factors are important due to the fact that the line will act as an antenna and will therefore be able to absorb other electromagnetic emissions as noise as previously stated. Another source of noise is *additive white Gaussian noise* which affects each transmitted symbol independently [8]. The need is therefore to assess the atmospheric, environmental and system conditions that can impact the design to determine the extent to which each can degrade the data transmission. Also, the ambient temperature and the heating effect within the different components of the complete system will constitute the total heating effect in the system.

In dealing with data, it is desirable to discuss the transmission in terms of energy waveform, and the signal as energy signal. Whereas a ratio of signal power to noise power is a useful figure of merit for analog communication, for digital communication the figure of merit is bit energy to noise power. A useful metric of performance is therefore the bit-error probability versus bit energy to noise power ratio. Trade-offs for the different parameters such as intersymbol interference (ISI) which should be zero, and the appropriate choice of pulse-code modulation (PCM) waveform type that is used for baseband transmission to yield the performance metric can be effected to achieve the desired result [8].

### IV. EDUCATIONAL IMPLICATIONS

This project is planned to be a student project and students of KNUST and Penn State will be involved in the project. Considering the different activities involved, the project is divided initially into three phases. The first phase will involve determining the different sources of radiation at

the chosen site for the experimentation and characterizing the electromagnetic presence at the site. The second phase will involve analysis of the collected data and design of the system. The third phase will be connecting the system up as a pilot project and testing it. Currently, the project is at the stage where the first phase can be implemented. The following therefore discusses the different aspects of the first phase.

All the factors discussed above have serious implications in the design and manufacture of equipment intended for use in electromagnetic propagation applications. This suggests that these factors should be given consideration in the design specifications employed. It is therefore essential that the engineers, technologists and technicians involved in any aspect of the manufacture and testing of the equipment be aware of these factors. This can be achieved through dissemination of information, and a time honored approach to dissemination of information is education. Education, in this sense can occur on two fronts, these being on the manufacturing end and on the user's end. On the manufacturing end, the design engineers and the technicians will be aware of the differences in specifications needed for effective operation of the equipment in the equatorial region. The ideal scenario would therefore be one in which the manufacturers of the equipment will include all the pertinent factors in their design parameters. On the user's end, it is important for the user to understand the need for adhering to the specifications in operating the equipment. It is therefore a necessity that the engineers, technologists and technicians who will operate and maintain the equipment receive instructions that incorporate the physics and technological aspects of the factors mentioned above. These will include [1] but not be restricted to

- Temperature effects on equipment
- External and internal noise
- Stray capacitances and inductances
- High frequency effects as a result of stray capacitances and inductances
- Testing procedures for specific equipment
- Error detection and correction
- Appreciation of manufacturers' specification sheets

An aspect of the study that may be essential only during certain periods of the year is the resultant

effect of cloud cover in the atmosphere over the earth's surface on electromagnetic propagation. The extreme weather conditions will affect the heights of the ionospheric layers from the surface of the earth during different periods of the year. Also the temperatures during the day time compared to the night time in the summer months drop noticeably. Again, during the latter part of the year when the direction of the winds is from the Sahara Desert, the moisture content reduces and together with that come a change in temperature compared to the summer months. All of these will affect the heights of the ionospheric layers. The changes in the ionospheric layers over the region will result in changes in the ionospheric density. These changes may be considered to have a cyclic pattern throughout the year. This part of the instruction [9] will cover aspects such as ducting, reflections through the ionosphere and distant points at which radiations can be received, that could be from sources of radiation that are not within the expected region of experimentation. Some of the parameters that need investigation, and hence consideration for operation are

- Atmospheric impact on electromagnetic propagation
- Wave attenuation and absorption
- Optical properties of radio waves
- Terrestrial propagation of electromagnetic waves

When put together, the points raised above lead to a critical aspect of radio propagation and that is operation of the system in compliance with the set Standards. Standards govern the use of radio space by operators to ensure that all operators are in compliance with the regulations that guide their functions. The need for this is to ensure that all operators are accommodated, and also that each respects the others' business. In third world nations, such operational oversight is generally in their infancy. However in Ghana, the National Communications Authority (NCA) has oversight of the Standards and allocation of frequencies, and in general the use of the radio space. It is expected that as these nations gain recognition in the global community, all operators who use the radio space as a medium for transmission conform to both national and international rules of operation.

## V. HANDS-ON WORK EXPERIENCE

As stated above, work has started with the first phase of the project which has been funded by Engineering Information Foundation (EiF) based in New York, NY, USA. Among the equipment provided by the fund to support the laboratory experience in a new Telecommunications program started by KNUST, were an RF (Radio Frequency) Analyzer, a TriField Meter, a Broadband Meter and an Earth Magnetometer. Such pieces of equipment are particularly useful in characterizing the radio space. Currently, laboratory exercises are being designed to help the students not only gain experience in using such equipment, but as well, characterize the radio space around KNUST where the pilot project will be constructed. They will use these pieces of equipment to determine the electromagnetic field presence at the site, which will include the radio emissions from all services such as TV, radio and cell phones. They will determine the magnitudes of each emission, and determine the impact the emissions will have on the propagation of data along the power line used in the pilot project. As stated before, the power line will act as a traveling wave antenna, hence electromagnetic radiations that impact it will be absorbed by the antenna as EMI, which will manifest as noise. Any such noise will obviously adversely affect the integrity of the data transmitted.

## VI. CONCLUSION

The reason for selection of suitable technology for dissemination of information has been discussed, and the rationale for use of BPL in a developing country such as Ghana is presented. Three technologies that combine to provide the BPL application are stated and discussed. The project is being planned as a student project, and for that reason, the educational implications are presented. The project is planned as a three-part endeavor at the present, and funding has been provided in part by Engineering Information Foundation (EiF) towards the first phase.

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## APPLICATIONS OF EXTENSIBLE MARKUP LANGUAGE: A REVIEW

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### ABSTRACT

The extensible markup language (XML) is a markup language as well as a meta language among other characteristics. This paper discussed the concepts of XML such as its well-formedness, declaration, document structure and some key XML implementations, which include Wireless Markup Language and VoiceXML. This paper concluded that XML is a Meta Language that can be used to create many declarative programming languages, which are domain specific in nature and fit for problem solving in the academia and industries. It recommended that its concepts should be taught to computer science students at the basic level for them to be able to appreciate and embrace its significance.

Keywords: XML, meta language, VoiceXML, WML

## **1.0 INTRODUCTION**

Computer programs are virtual pieces of software that contains instructions for performing certain tasks on computer systems (Pankaj, 2006). Some languages are general purpose, for example Java, C++, and some are domain-specific in nature, for example, spreadsheet macros. .

From time to time system analyst and computer programmers are faced by problems that are highly challenging and require a specific and non conventional approaches, and besides, the available programming languages may not be very suitable for a particular problem in nature, hence is the need for creating new programming languages. Thus, the objectives of this paper include discussing the extensible markup language (XML) and its relating concepts, some key XML implementations and the concept of domain-specific languages as an approach for creating or developing more efficient new programming languages.

## **2.0 CONCEPTS OF XML**

The extensible markup language (XML) has numerous definitions, depending on the area it is being applied. Put strictly, it can be defined as a meta language that describes the concepts and rules for the creation of specific markup languages (Fabio, 2001). Markup is a term

applied to any set of codes or tags added to the contents of a document in order to indicate its meaning or presentation. A meta language is a language that allows you to define a document markup language and its structure.

You can use XML to create your own markup language that includes a set of rules and tags that describe information suited to your needs. You define this markup language in a document type definition (DTD) that functions as the standard way to describe your information. Using XML to share standardized information means that you do not have to worry about writing programs to address proprietary software or convert and translate different data formats.

XML documents are made up of storage units called entities, which contain either parsed or unparsed data (W3C, 2000). Parsed data is made up of characters, some of which form markup. XML documents are composed of declarations, elements, all of which are indicated in the document by explicit markup.

### **XML Documents Well-Formedness**

A document is well formed if it does not have any syntax errors such as unwrapping tags missing closing tags, and so on (James, 2001). The elements in the document are correctly nested, that is every element in the document must have its end tag inside the same element

where it has its start tag. According to the World Wide Web Consortium (W3C) specifically a textual object is a well-formed XML document if

- 1) Taken as a whole, it matches the production labeled document.
- 2) It meets all the well-formedness constraints given in this specification.
- 3) Each of the parsed entities which are referenced directly or indirectly within the document is well-formed.

### **Document Structure**

According to the W3C XML 1.0 specification. The Backus Naur Form (BNF) of an XML document is given as

Document:: = 

Prolog
--------

 + 

Element
---------

Misc
------

Matching the document production implies that an XML document is mainly composed of:

- An optional prolog, which includes the XML declaration and document type definition.
- A root element (also called document element, which contains all other markup and character data in the document.
- An optional (and not recommended) miscellaneous collection of comments and other non-element markup after the end of the root element.

## Comments

Comment is defined as by

$$\text{comment} ::= \text{'<!--'} \left( \left( \boxed{\text{Char}} \text{'-' } \right) \left( \text{'(' } \boxed{\text{Char}} \text{'-'} \right) \right)^* \text{'-->'}$$

That is, anything between <!-- and --> is considered a comments. And comments may contain any combination of characters except the string --.

## Instruction Processing in XML

Processing instructions (PIs) allow documents to contain instructions for applications. The production is given below.

$$P_I ::= \text{'<?'} \boxed{P_I \text{ Target}} \left( \boxed{\text{White space}} \boxed{\text{Char}} \right)$$
$$\text{'*'} \left( \boxed{\text{Char}} \text{'?' } \boxed{\text{Char}} \text{'*'} \right) \text{'>'}$$
$$P_I \text{ Target}; = \boxed{\text{Name}} \left( \text{'(' } \boxed{\text{Char}} \text{'(' } \boxed{\text{Char}} \text{'(' } \boxed{\text{Char}} \text{'(' } \boxed{\text{Char}} \text{'(' } \right)$$



PIs are not part of the document's character data, but must be passed through to the application. The PI begins with a target [PI target] used to identify the application to which the instruction is directed.

## **2.5 The XML Declaration**

The XML declaration indicates explicitly that the document is an XML instance. It is composed of the following three elements:

- A mandatory XML version information of the form *version="1.0"*.
- An optional encoding declaration, stating the name of the encoding used for the document. This declaration takes the form *encoding = encoding name*
- An optional standalone declaration stating that the document is a self-contained unit, with no markup declarations outside it.

## **3.0 Some Key XML Implementations**

Due to the declarative nature and ease of usage, XML has been implemented in the development of many other markup languages such as, wireless markup language (WML), VoiceXML.

### **3.1 Wireless Markup Language**

The wireless markup language (WML) is a markup language based on XML (Oloyede et al, 2006). WML is designed for specifying

content on wireless devices such as phones, pagers, and personal digital assistants (PDAs). WML is designed to support a range of devices, which have the following characteristic small display size.

### **3.2 Voice Extensible Markup Language**

The voice extensible markup language (VoiceXml) is an XML vocabulary used to create voice-based applications such as those found in phone banking systems and automated delivery service. VoiceXML applications feature synthesized speech, digitized and voice recognition and touch-tone input.

A VoiceXML application reflects a decision tree with input elements that may cause the interpreter to catch a voice or touch-tone response and may give back a taped or generated audio.

### **4.0 DOMAIN-SPECIFIC PROGRAMMING LANGUAGE**

A domain-specific programming language (DSL) is a programming language designed for, and intended to be useful for, a specific kind of task (Wikipedia, 2007). It is not intended to be able to solve problems outside of its domain. This is in contrast to a general-purpose programming language, such as C. Examples of DSLs include spreadsheet macros, YACC for creating parsers, Csound, a language used to create audio files, and create visual representation for directed graphs.

DSLs have also been called by various names, which include

- Little languages
- Macros
- Application languages
- Problem-oriented languages

The domain of a DSL can include

- Life insurance policy DSL developed internally
- Combat simulation DSL
- Salary calculation DSL
- Billing DSL

There has been much interest in domain-specific languages to improve the productivity and quality of software engineering. DSLs could possibly provide a robust set of tools for efficient software engineering. The software cost reduction (SCR) toolkit is an example of such tools. The toolkit is a suite of utilities including a specification editor to create a requirement specification, a dependency graph browser to display variable dependencies, a consistency checker and a theorem prover to check program properties against the specification, and an invariant generator that automatically constructs invariants based on the requirements (Constance, 1998).

DSLs should be used by programmers who have security in mind. Because, DSLs are expected to exhibit minimum redundancy, which

means it is less likely to introduce bugs by incompletely implementing changes in a program unit

## **5.0 SUMMARY**

The advent of XML is a major landmark in the twentieth century. It is relatively easy to learn and flexible in terms of usability. Being a meta language, it can be used to define other programming languages (markup). It has been done in the time past for the creation of languages such as WML and VoiceXML.

Domain specific programming languages are usually more flexible in their domain when compared to general-purpose languages. Hence, more languages are developed from time to time in order to satisfy some specified requirements.

## **6.0 RECOMMENDATION**

This paper recommends that XML should be taught at the basic levels of computer science studies in Nigeria universities and the world at large. By so doing, computer scientists will be equipped with the skill sets that are required for problem solving in this ever dynamic field of computing and Information Technology.

## 7.0 CONCLUSION

It is obvious that knowledge and orientation has to do with the approach an individual takes in solving problems. Equipping computer scientists with XML and its related skills will have a positive impact on the way software developers and programmers go about application development.

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# THE ROLE OF M-LEARNING IN THE DIGITAL ECONOMY: A CASE STUDY OF NIGERIA

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## ABSTRACT

There are few institutions in Nigeria, which are over crowded with students who are seeking one degree or the other. As a result of this, institutions of higher learning limit the number of students admitted as a result of National University Commission (NUC) Policy on Admission, leaving many students to face the rigour of reapplying for admission. This paper proposed Mobile Learning as a strategy for alleviating this problem in Nigerian context, and argued that quality education could be delivered in some fields of human endeavor by putting the appropriate mobile learning strategy in place.

Keywords: mobile learning, NUC, quality education.

## 1.0 INTRODUCTION

Mobile learning is the use of mobile technologies or devices, such as mobile phones and hand-held computers, to enhance the process of learning or skill acquisition[1]. With a background of more than four years of trailing, research and development in m-learning has helped thousands of learners from all walks

of life to development their skills or (in developing their skills), confidence and motivation to learn [2].

It originated from a three year Pan-European Research and Development Programme that aimed at helping young adults aged sixteen to twenty-four, who were considered most at risk of social exclusion in Europe. The group consisted largely of disaffected learners who had not succeeded in the education system. They were not involved in any education or training and were unemployed under employed, or even homeless.

What do many of these young people have in common? A mobile phone that is; inexpensive, portable and accessible to the majority of Europe Citizens [3]. Mobile learning allows instructional designers and instructors to utilize the strengths of mobile platforms to bring a variety of new applications to the learning environment [4].

## **2.0 DEVELOPMENT OF M-LEARNING**

Any strategy that employs both the internet and Mobile applications cannot but use with the Wireless Application Protocol (WAP), so also is M-learning. WAP was developed to deliver internet content in the wireless space while meeting the restrictions and shortenings of a new kind of device (e.g. phones, PDAs, etc) that differ from desktop computers in many fundamental ways because the have:

- ❖ more restricted memory
- ❖ more restricted computational power
- ❖ more restricted input devices
- ❖ more restricted output devices



Furthermore, these devices are connected using wireless networks that are not as reliable as traditional Internet connections [5]. Additional characteristics of today's wireless networks are:

- ❖ less bandwidth
- ❖ less connection stability
- ❖ less predictability

The diagram below shows what goes on behind the scenes of a client request in WAP.

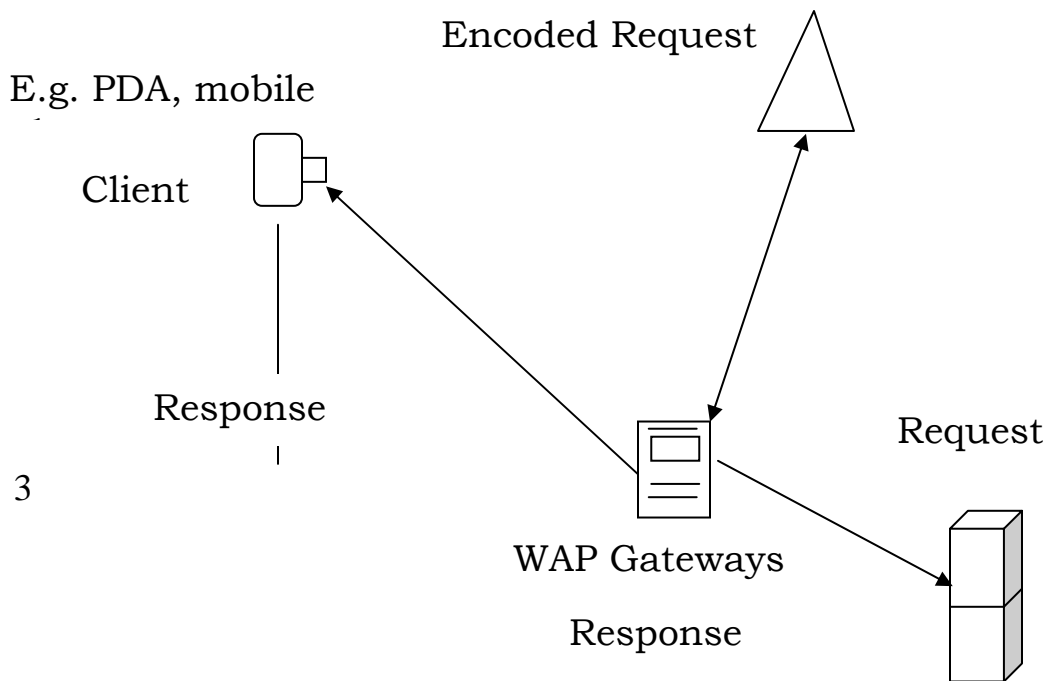


Fig 1. WAP Model (Source [5])

The important features of WAP model include:

- The existence of a gateway – In the WAP case, the client does not talk directly to the server; instead, it goes through the gateway, which forwards the request to the final destination server.

- Encoding and compression of the data- In the WAP case, the data are not passed directly to the client; instead, the gateway encodes the original server response and sends it to the client in a compressed format better suited to the restrictions mentioned previously.
- Type of content-The content powered by the server is not of the same type used for web applications, i.e. it is not HTML; instead, the server replies with content marked up on WML, the Wireless Mark Up Language [5].

The highest level of the WAP stack is the Wireless Application Environment (WAE). It defines the languages and data types necessary for the creation of Wireless Application over WAP.

WAE- is essentially composed of two technologies, which are:

- WML – The Wireless. Markup language, an XML (extensible markup language) application for the presentation of data on wireless devices.
- WMLScript- A scripting languages based on ECMAScript, similar to Javascript. WML is, first of all, an XML application therefore it shares the syntax and well-formedness of rules of every XML vocabulary.

In order to get a working WML development environment, you must:

- Install a WAP phone emulator
- Install a Web server
- Set up the WML MIME types

### **3.0 A MOBILE LEARNING SETUP**

An M-learning setup should consist of

- IT Administrators / Developers
- Academics and Professionals
- Unskilled works required for physical maintenance

The gadgets required for implementing m-learning include:

- (a) Mobile device: the interface between the learner and the tutor. e.g. PDA, handsets.
- (b) M-learning centre: for coordinating the programmes.
- (c) A well set-up WAP implementation

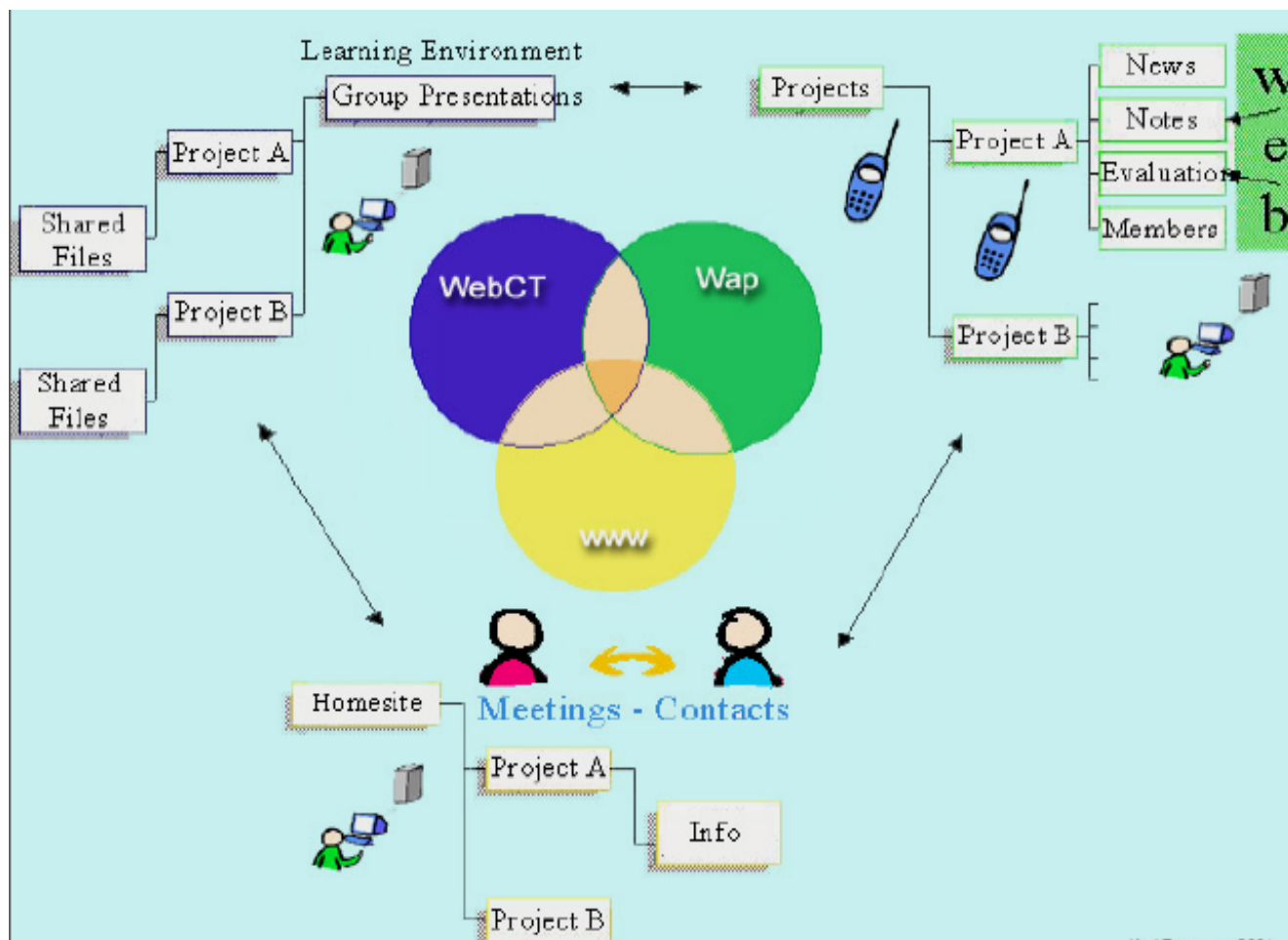


Figure 2 Architecture for the implementation of m-learning (Source: [8])

#### 4.0 THE ROLE OF M-LEARNING

The benefits of M-learning in a developing Nigerian economy include the following.

## **i. CREATION OF EMPLOYMENT OPPORTUNITIES**

As personnels would be needed, both skilled and unskilled, for the successful implementation of m-learning, ranging from information to technologists, who are responsible for creating and maintaining the needed wireless applications, educationists and well informed professionals, responsible for the supply and validation of educational contents, to office assistants, that takes care of the M-learning development centres.

## **ii. ATTRACTION OF FOREIGN INVESTORS**

It is obvious that the implementation of M-learning will increase demands on mobile devices. Hence, foreign investors would be attracted by the large market created, to build manufacturing plants for mobile devices in the country. This will also provide employment opportunities.

## **iii. NATIONAL ORIENTAION AND DEVELOPMENT**

The government can easily use the m-learning strategy as a tool for information dissemination to the citizenry by developing curriculums with national orientation as a goal.

## **iv. POVERTY ALLEVIATION**

The implementation of a strategy such as M-learning, will alleviate poverty to an extent, as it will provide employment opportunities, educate, and render information that if exploited could be pave way for business opportunities.

## **v. EASE OF LEARNING**

Since you do not need to travel distant miles before you receive quality information and training, as it is delivered to your hand at the appropriate time, the constraint of distance and time can be eliminated.

## **vi. TECHNOLOGICAL ADVANCEMENT**

Since too many large structures are not required for the implementation of m-learning, funds that could have been used for building the huge structures for a learning center can be diverted into developing technology strength of the nation. This will further enhance the success of m-learning in the country and could bring about technological advancement.

## **4.1. SUMMARY**

Scientists and the academic have been working for years to develop M-learning, by which learning can be made as convenient and accessible as possible, by making use of the Internet and mobile devices. This can go a long way in the development of a nation, and help reduce the issue of overcrowding and insufficient space of admission in Nigeria institutions of higher learning.

## **1.5 CONCLUSION**

Since some developed countries had used this concept and benefited from it in time past, the developing countries should not be an exception. It could be embraced as a strategy for developing the citizenry.

## **1.6 RECOMMENDATION**

It is recommended that the government and the appropriate stakeholders in Nigerian education system should look into this concept and see how it (M-learning) can be used to reduce overcrowding in our higher institutions.

Also, the government should enact laws and IT policies that will encourage m-learning, such as reducing the tax rates on mobile devices that will be used for m-learning to 0%.

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# ICT AND POVERTY ALLEVIATION IN NIGERIA: MOBILE PHONES AS TOOLS OF INTERVENTION

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## Abstract

The global growth and development of ICTs has led to their wide application both in developed and developing countries, and thus increased economic and social impact on the people. Mobile phones satisfy basic needs by generating the extra income so crucial for middle and low income households in Nigeria to make ends meet. This paper fundamentally addresses the use of mobile phones, as the most common ICT tool used for wealth creation. Its role in re-shaping the socio-economic well-being of individuals in Nigeria is also discussed.

**Keywords:** ICT, Mobile Phones, Call centers, Nigeria

## I. INTRODUCTION

ICT is changing most aspects of human life and it is breaking barriers and building new interconnections. ICT has become a chief determinant of the progress of nations, communities and individuals. Reference [1] observed that of the three main types of ICTs namely; Computers, mobile phones and the Internet used in Nigeria, mobile phones are the most popular. Ajayi, Salawu and Raji (1999) in [2] noted that access to telephones in Nigeria had been marginal by the end of twentieth century with the teledensity rate of 1:100 for a country of estimated 130 million persons. Today, over 10 million Nigerians have access, improving the teledensity to 13:100.

Reference [3] noted that telecommunication arrived in Nigeria over 100 years ago. At independence in 1960 the country had only about 18,724 lines for use by a population of roughly 40 million. By the beginning of 1999, there were roughly 500,000 lines available for a population of around 120 million Nigerians. The World Bank carried out a comparative study on Information and Communication Network between 1994 and 1997 in some African countries, and the study revealed that, Nigeria have four (4) phones per 1000 people. This underlines the great enthusiasm with which Nigerians embraced the GSM at its introduction.

## II. BACKGROUND OF STUDY

Prior to 2001, the number of connected phone lines in the country before the introduction of GSM services was a mere 450,000 for an estimated population of 120 million. Information obtained from the 2<sup>nd</sup> September 2007 issue of Cellular News traced the origin of GSM operations in Nigeria to 2001 with ECONET Wireless now (CELTEL), MTN and MTEL, as the three main operators [4]. In 2002 a fourth Digital Mobile License (DML) was issued to Globacom

(GloMobile). Reference [5] on the 31<sup>st</sup> January, 2006 reported that the Nigerian Communications Commission (NCC) recorded a total number of 18.6 million mobile subscribers in the country at the end of 2005. Ownership of phones now cuts across the various social classes, opening good opportunities for the e-health, e-education, e-security, e-commerce and e-banking in the country. The outstanding growth in the use of mobile phones has correspondingly created a significant number of new jobs in the economy.

Today the telecom sector is a key contributor to the nation's Gross Domestic Product (GDP). The Federal government has earned over US\$2.5 Billion from Spectrum licensing fees alone between 2001 and now. Import duties and taxes from the telecom industry have also contributed substantial revenue to the Federal Government. Individuals are not left out of the positive impacts of the GSM technology on their economy. The various ways in which mobile phones improved the economies of various individuals in Kenya and Nigeria were reported in [6], as follows:

- Business centers: Self employment opportunities for people who might otherwise be idle.
- "Umbrella" operators: It is estimated that 600,000 people are engaged in selling airtime in Nigeria today.
- Top-up cards: Increased revenues for shops, kiosk and other outlets, selling top-up cards, as well as income opportunities for people selling cards in the traffic.
- Repairs: Self-employment for young men with technical qualifications.
- Retailers: Sales of new and second hand-mobile phones.

The increased teledensity in Nigeria has led to job creation with the advent of the GSM "umbrella people" who, in many towns across Nigeria, resell GSM wireless services, most notably by selling phone calls. With an umbrella to mark their stand (see fig. 1), or a GSM phone booth (see fig. 2), a Subscriber's Identification Module (SIM) card and handset, they are ready for business. GSM resale has become a viable employment opportunity for hundreds of young Nigerians. It has even become quite lucrative. In an economy where the average monthly Gross National Income per capita stands at 24.17 USD, umbrella people can net up to 15.40 USD per day [7].

GSM has contributed to increased access in Nigeria while also providing employment opportunities to unemployed and low-income Nigerians. This paper fundamentally addresses the use of mobile phones as one of the most common ICT

tools used for wealth creation in Nigeria. Its role in reshaping the socio-economic well being of individuals in Nigeria is also discussed.

### III. METHODOLOGY

In carrying out this research, the research instrument used to gather data was the questionnaire. Individuals involved in the use of mobile phones to make wealth in Nigeria form research population.

The questionnaire was designed to elicit responses in the use of mobile phones in making money. The items were structured in such a way as to enable the researchers secure information about making money through the use of mobile phones.

The research instrument developed was administered to five (5) Information Technology (IT) staff and five (5) Economists for validation and the corrections were effected. A total number of two thousand, two hundred and fifty (2,250) copies of the questionnaires were administered to individuals (or small businesses) involved in various types of mobile phone businesses in five randomly selected states in Nigeria. This was to reduce the possibility of sample bias. The research instrument was closed ended.

The questionnaire solicited data relating to their earnings from GSM business. The respondents comprised an original sample of people providing various forms of GSM services ranging from sales/repairs of handsets, sales of recharge cards and selling of phone calls (air time). Out of the two thousand, two hundred and fifty (2,250) questionnaires administered, two thousand (2,000) were returned and used. The data obtained was analyzed using simple percentage and the results obtained are presented in tables (1) to (6).

We also interacted with a few of the respondents and their testimonies were also reported.



Figure 1. Umbrella Stand



Figure 2. GSM Phone Kiosk

### IV. DISCUSSIONS/FINDINGS

In table 1, it is observed that respondents within the age group of 26-30 have the highest percentage of 39.90, which is an indication that the subscribers within this age brackets use their mobile phones for business more.

The results from table 2 indicate that 1,300 males, which account for 65% of the respondents are involved in one mobile phones business or the other while 700 i.e.35% of them are female.

Table 3 below indicates that the degree holders representing 37.00% of the respondents use their mobile phones more than any of the other categories for one form of business or the other while 8.25% of the respondents are primary school holders.

From table 4 below, it is observed that 70.60% of the respondents are into full time business with mobile phone while 28.40% use their mobile phones for part time business.

Table 5 shows that the highest percentage (43.50%) of the respondents are in the business of phone calls combined with the sales of recharge cards. This is followed by those that are involved the business of phone calls only (34.40%). Only 15.30% are into sales of recharge cards and lines while the 5.25%, and 1.55% are respectively involved in the sales of recharge cards, hand set and lines and repairs and sales of accessories.

TABLE 1  
AGE

Age Group (yrs)	No. of Respondents	%
15-19	290	14.50
20-25	516	25.80
26-30	798	39.90
30 and above	396	19.80



TABLE 2  
SEX

Sex	No. of Respondents	%
Male	1300	65
Female	700	35

TABLE 3  
EDUCATIONAL QUALIFICATION

Qualification	Number of Respondents	%
Degree	740	37.00
Undergraduates	200	10.00
Secondary school	415	20.75
Primary school	165	8.25
None	480	24.00

TABLE 4  
EMPLOYMENT HISTORY

Nature of Employment	No. of Respondents	%
GSM as Full time Job	1412	70.60
GSM as Part Time Business	588	28.40

TABLE 5  
TYPE OF BUSINESS

Type of Business	No. of Respondents	%
Phone Calls Only	688	34.40
Phone Calls And Sales Of Recharge Cards	870	43.50
Sales Of Recharge Cards and Lines	306	15.30
Sales of recharge cards, Handsets and lines	105	5.25
Phone Repairs & sales of accessories	31	1.55

TABLE 6  
BUSINESS AND ESTIMATED REVENUE PER DAY

Business	Average Revenue Per Day (₦)	Average Expenditure per Day (₦)	Profit (₦)
Phone Calls	6,000	4,500	1,500
Sales Of Recharge Cards (wholesale)	500,000	467,800	32,200
Sales Of Recharge Cards (retail)	55,300	52,100	3,200
Repairs of phones & sales of accessories	12,700	11,500	1,200

Table 6 shows that if a business is dedicated to just phone calls and the phone is loaded with recharge cards worth four thousand five hundred Naira (N4, 500.00) per day, he/she will generate a revenue of six thousand Naira (N6, 000.00), with a profit of one thousand five hundred Naira (1,500.00) per day on the average for one mobile phone line. For sales of recharge cards (wholesale), investment of N467,800.00 will generate revenue of N500,000.00 with a profit of N32, 200.00 per day, while an investment of N52,100.00 on the sales of recharge cards (retail) will generate revenue of N55, 300.00 with a profit of N3, 200.00 per day. In addition, table 6 shows that for the repairs of phones and sales of accessories, an investment of N11,500.00 will generate revenue of N12, 700 with a profit of N1, 200.00 per day.

## V. TESTIMONIES

Businessman Julius, as he is popularly known by his customers, graduated and spent the first year searching for a paid job. Since no job was forth coming, his in-law got him an umbrella, two handsets, two lines and ₦10, 000.00 worth of recharge cards. Today, Julius is an employer of labour and a wholesaler of GSM cards and lines with a business empire worth over ₦1M all from an initial investment of about ₦50, 000.00.

Patricia (from Edo state), started a mobile phone business after secondary school when the parents could not sponsor her through tertiary education. She started with her own handset and line from her home. Her major customers were neighbours and friends. Today, she has sponsored her self up to her third year in a part-time programme in the University of Benin and owns a well furnished snacks shop with a sitting capacity of 20 customers in addition to calls and sales of GSM cards. She also distributes coca-cola products. All this was from an initial phone and line.

Diane, an undergraduate residing in the Federal Capital Territory, Abuja, generated her first income from phone business when she was in dire need of cash. She decided to sell calls with her phone. She made about ₦2, 000.00 profit the first day and decided to continue in the business for the rest of her holidays and thereafter. Today, Diane is a banker with a part-time GSM shop.

Uncle Gbubemi (Delta state), owns a patent medicine store. Due to high customer demand for recharge cards, decided to diversify into sales of recharge cards. Today, the shop rent is paid from the proceeds from the sales of recharge cards.

Victoria (Lagos) takes care of her sick and aged mother. Her younger sister in Benin initially had difficulties sending an upkeep allowance for their. With the inception of mobile phones in Nigeria, Victoria's younger sister could send the monthly up-keep allowance via SMS with a top up card numbers amounting to about ₦10, 000.00. Victoria usually sells the top up cards to a business centre for a fee. This saved the normally bank charges due to money transfer and the allowance could be sent at anytime and from anywhere.

## VI. PROBLEMS

The Nigerian mobile phone business world expressed dissatisfaction over the services of the GSM network providers, five years after commercial deployment. Subscribers described their services as poor and complained that it was difficult calling or connecting other phone users either in the same network or other network. This is in line with the findings recorded in [8] and [9]. They opined that their mobile phone business will do better if the GSM service provider improves the interconnectivity between their and other networks. Other problems faced according to the respondents are: huge cost implications, drastic drop in price of SIM packs, theft of phones and recharge cards and even money by so called “customers”.

## VII. CONCLUSION

The benefit of mobile phones dramatically improved living conditions for the jobless and the poor people in Nigeria. The main driving force for buying a mobile phone within the low-income and even the middle income people in Nigeria is increased income and efficiency for very small businesses. When earnings are limited, calls are made strictly in relation to earning money.

In addition to increased earnings for ordinary businesses, the network itself opens the possibility for new sources of income. Both people in the rural areas and in the city in Nigeria can actually make a living from mobile phone related businesses, though there are huge cost implications in terms of the sales of cards.

## VIII. RECOMMENDATIONS

The middle and the low income households in Nigeria provide great market potential for the telecom business community.

There is a great challenge for the network operators to improve on the efficiency of their network and to provide network coverage every where in Nigeria.

Making this happen would go a long way in alleviating poverty among the teeming masses in Nigeria.

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# On the Viability of Wireless Mesh Networks as a Next Generation Wireless Networking Alternative

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**Abstract-**Wireless Mesh Networks (WMNs) have been under active research for the past half a decade. WMNs find many applications including municipal networks, emergency response networking, residential broad band networking, and wireless wide area mesh networking. The main qualities that make this emerging networking form attractive include the inexpensiveness of WMNs, flexibility of deployment, easiness to reconfigure, and above all the high fault tolerance exhibited by the WMNs. However, all these benefits are potentially countered by several challenges faced by today's wireless mesh networks. We, from our theoretical and experimental research, derive the main issues that are faced by WMNs. We define the following three categories of challenges: architectural issues, protocol development issues, and regulatory, socio, economical, and spectral issues. We discuss a set of solutions that can meet some of these challenges and improve the performance of WMNs. In addition, we specifically discuss a number of spectral issues that are not known till date. Our experiments expose a number of the counter-intuitive observations for next generation wireless mesh networks.

**Keywords-** Wireless Mesh Networks, architectures, protocols, network capacity, next generation wireless networking.

## I. INTRODUCTION

Following the trend in wired networks in the early sixties and late seventies, today's wireless networks move from a centralized architecture to a fully distributed wireless networking paradigm. A big thrust in this direction is the emergence of wireless mesh networks. In the near future, one might see a radical shift of significant amount of voice traffic from the traditionally centralized systems such as cellular networks to the fully distributed packet-based wireless mesh networks. An early indication to this effect is the popularity of Voice over IP (VoIP) applications such as Skype on the Internet. Major cities such as San Francisco, CA and other smaller cities such as Mountain View, CA have started benefiting from large scale public wireless mesh network deployments. This tendency of using fully distributed, inexpensive, quickly reconfigurable, and license free networks, could revolutionize the wireless communication in the future. However, such proliferation of wireless mesh networks as a viable alternative communication infrastructure to today's cellular networks is faced with several challenges. These challenges mainly arise from the limitations imposed by today's wireless mesh network design. One of the important concerns is the limited capacity of today's wireless mesh networks. There are several factors that contribute to the low capacity of wireless mesh networks. First among them is the wireless mesh network architecture. Early approaches such as flat network architecture though simple, however, proved disastrously

undelivering on the network throughput and scalability. Of particular interest within the architectural design are the hybrid network architectures and their impact on the system capacity. Second biggest factor that affects the wireless mesh network capacity is the design of protocols which need to be carefully carried out in order to achieve high performance. The medium access control, routing, and transport protocols have significant impact on the performance of a wireless mesh network. The most popular MAC protocol, IEEE 802.11, is found to be inefficient and a number of variations of 802.11 are proposed to improve the efficiency of MAC protocols for wireless mesh networks. Third main challenge in making an efficient wireless mesh network is the spectrum and the physical layer related issues. Since most networks and service providers use license free bands, it becomes an important issue to design the network for co-existence with a number of other competing networks and technologies that share the same spectrum. In addition to the above technical problems, a host of economical issues such as billing, pricing, and infrastructure sharing are also critical in the successful deployment of such systems.

Organization of the rest of the paper is as follows: Section II briefs the factors affecting the viability of WMNs and presents a number of observations and solutions for making WMNs a viable alternative. Section III concludes the paper.

## II. FACTORS AFFECTING VIABILITY OF WMNs

The first classification that we make on the factors that contribute to the viability of WMNs is the following: (i) architectural issues, (ii) protocol design issues, and (iii) regulatory, socio, and economical issues. Each of these issues is described in detail below.

### A. NETWORK ARCHITECTURAL DESIGN

The primary issue that arises when a WMN is designed is the network capacity and network scalability. Capacity is typically defined as the achievable end-to-end throughput for every user in the network. This becomes very critical as the throughput depends on many factors: the number of hops in the end-to-end path, the number of nodes contenting for the channel, the physical layer data rate, and the architectural design. The end-to-end throughput drastically degrades as a function of hop length, a solution for this particular problem is discussed later in this section. The second issue is the scalability problem where the increase in user density can contribute to degradation of throughput. One potential solution for this is to use multi-radio, multi-channel wireless mesh networks which can increase the per channel contention. The third important factor that contributes to the end-to-end throughput is the physical

layer data rate where the use of higher data rate PHY layer can potentially increase the end-to-end throughput. However, our experiments, described in Section II-B, show that the mere replacement of the physical layer interfaces cannot deliver the expected benefits in a large WMN. Finally, the architectural design is the major design issue that can increase the performance of WMNs.

The WMN architectures can be classified into the following three architectural categories [1][2]: (i) Flat WMN architecture, (ii) Hybrid WMN architecture, and (iii) Hierarchical WMN architecture. The flat WMN architecture is the simplest one; however, it is not scalable. On the other hand, hybrid WMNs use a combination of technologies such as WiMAX, point-to-point, and cellular networks to design and deploy wireless mesh networks. However, the main disadvantage of hybrid wireless networks is the limited bandwidth provided by other network forms in comparison to the WMNs. Finally, the hierarchical WMNs use multiple tiers of wireless mesh networks in order to increase capacity. For example, the users can access the WMN over one interface and the backbone communication can be carried out over another interface. Such multi-channel, hierarchical networks can better support the scalability and capacity requirements of WMNs.

## B. NETWORK PROTOCOL DESIGN

In addition to the architectural issues, protocol design assumes significance in WMNs for supporting the network protocol design. The wireless medium adds to the complexity due to its (a) location dependent characteristics, (B) high channel error rate, and (c) interference from within and out of the network. In this section, we discuss some of the important points in the design of protocols spanning, PHY, MAC, and Network layer.

### 1) INFLUENCE OF PHY LAYER ON SYSTEM DESIGN

The existing design of WMNs is made in a radio-agnostic way. This provides a unique capability of replacing the WMN with higher capacity physical layer interfaces which can increase the capacity. Such high capacity physical layers are very important as the physical layer data rate is the primary factor that contributes to the end-to-end users' connection throughput. However, traditional knowledge that communication data rates in a WMN can be significantly increased by using a higher rate physical layer is found to be not true from our experiments. On a single hop network, upgrading the network interface can greatly improve the achievable data rates. However, in a multihop network, the increase in data traffic due to multihop relaying can degrade the end-to-end throughput drastically. We conducted an experiment where a spanning tree based wireless mesh network is setup on a linear string topology. Every node in the network (Node 1 to 9) is directed to communicate with a gateway node, Node 0, using TCP traffic. We ran FTP connections from a client node (Nodes 1-9 in the string topology) to the server node (Node 0) in the string topology. A traffic generation utility, iPerf [1], is used for generation of traffic as well as measuring the end-to-end throughput. The observed throughput is monitored as a function of hop length. Initially the experiment is conducted with IEEE 802.11b physical layer and later the 802.11b cards are replaced with IEEE 802.11a cards and the experiment is repeated. The observed throughput behavior is presented in Figure 1. From Figure 1, the IEEE 802.11b-based WMN

provided very low throughput of less than 1 Mbps even over a single hop. However, the degradation of throughput turns out to be relatively smaller and remained almost same for nodes that are away for more than four to five hops. The 802.11a physical layer provided much better end-to-end throughput when the hop length is smaller and both the systems provided a very low throughput for the nodes with higher hop length beyond seven hops. Therefore, this turns out to be an important factor in deciding network design. For example, if all the users in this network are operating at hop lengths of higher than seven hops, then changing over to a higher data rate physical layer (802.11a/g) is not of significant benefit. Our investigations further lead us to the important conclusion that the rapid throughput degradation is mainly contributed by the limited processing power of the WMN nodes which cannot handle the high traffic load generated by the 802.11a NICs. The limited processing power aggravated the traffic load problem due to multihop relaying.

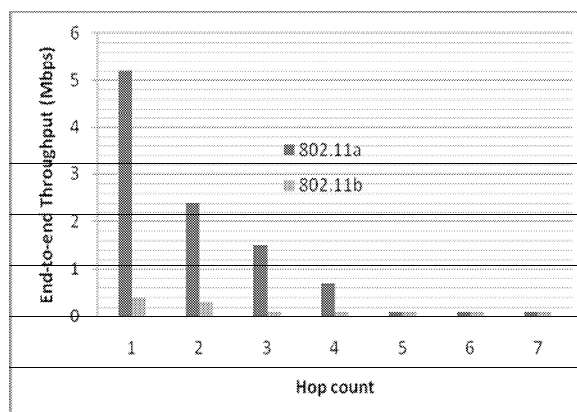


Figure 1. PHY layer Vs WMN performance.

### 2) MAC LAYER DESIGN ISSUES

In this section, we discuss two important issues pertaining to the MAC layer protocols for WMNs. The first issue is the throughput degradation, defined as end-to-end throughput, as a function of hop length. In order to study this issue, we simulated, using Glomosim [2], a 10 hop wireless mesh network with a string topology. Each node in the string topology is separated by a distance of 350 meters where the transmission power is set at 15dBm, equivalent to a transmission radius of 375meters when the two-ray propagation model is employed. We ran FTP connections from a client node (Nodes 1-9 in the string topology) to the server node (Node 0) in the string topology. The obtained throughput as a function of hop length is presented in Figure 2. The graph marked one in Figure 2 (a) shows the average contention window used by different MAC layer schemes. Figure 2 (b) shows the final throughput achieved at the end of 10 hop string network. The graph marked with numbers 1-4 in Figure 2 presents the throughput achieved by the IEEE 802.11 protocol. The graph numbered 1 in Figure 2 (a) shows the throughput degradation experienced by the IEEE 802.11 MAC protocol. We observed that this throughput degradation is mainly contributed by the binary exponential backoff algorithm which exhibits a negative slope for the average contention window as a function of hoplength. In order to study the impact of the negative slope of the average contention window, we further modified the binary exponential back-off function with an exponential back-off

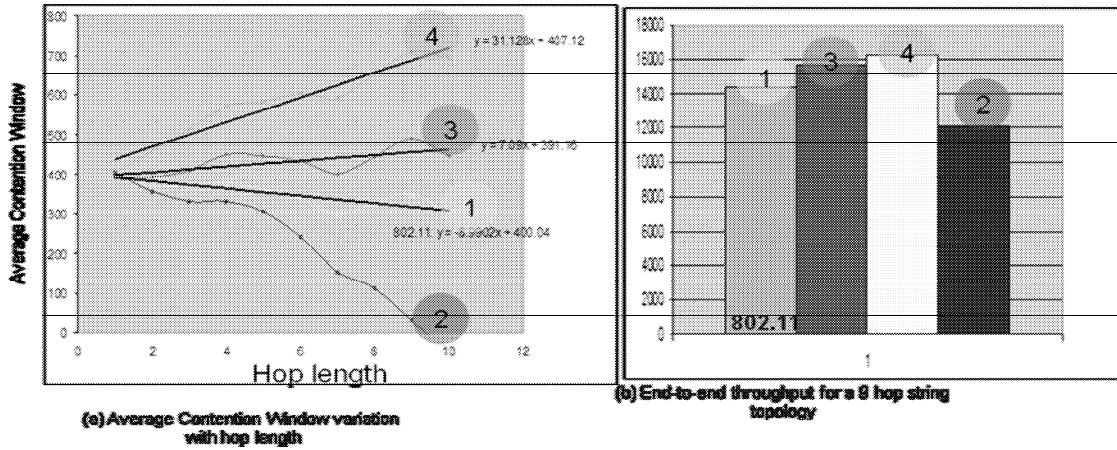


Figure 2. Throughput variation as a function of hop length

function with back-off factor less than 2, say 1.5. As a result of this change, we noticed an increase in the negative slope of the average congestion window as a function of hop length [see graph 2 in Figures 2 (a) and (b)]. We also noticed that the increase in negative slope of the average contention window resulted in further decrease in throughput. Therefore, reversing the slope of the average congestion window variation can potentially lead to increase in end-to-end throughput. We further modified the binary exponential backoff to an exponential backoff that uses a backoff factor greater than two. In Figure 2 (a), graph 3 shows a function where the backoff factor is four and with this change we noticed a positive increase in the average backoff window variation. As a result of this, we noticed increase in end-to-end throughput. Each of the points in the simulation was a result averaged from more than 10 independent runs. In order to ensure that the throughput increase is sustaining for other back-off factors greater than two, we further used a backoff factor of eight and the graph numbered 4 in Figure 2 (a) and (b) showed the consistency in throughput increase. The increase in the back-off factor leads to increased slope of the average contention window over multiple hops leading to increased end-to-end throughput. This potentially is one of the possible solutions for increasing the throughput performance of WMNs over long hop count paths.

#### MAC layer Adaptation for Wide Area WMNs.

Though the popular IEEE 802.11 DCF is designed primarily for Wireless LAN (WLAN) environments, today it is being widely used for wide area wireless mesh networking. The protocol parameters of IEEE 802.11 such as timeout values, interframe spaces, and slot durations, which are sufficient for a general WLAN environment need to be modified in order to efficiently operate in wide area wireless mesh networks. The current wide area wireless mesh network deployments use manual configuration of these parameters to the upper limit which essentially makes the networks operate at lower system efficiency. In this section, we present d802.11 (dynamic 802.11) which dynamically adapts the protocol parameters in order to operate at varying link distances. We present the link RTT memoization (LRM), to adapt the ACK\_TIMEOUT in d802.11 in order to provide better adaptation for varying link dimensions. Through extensive simulation experiments we observed significant performance improvement for the proposed strategies.

Some of the recent attempts to use IEEE 802.11 technology in the Wide Area Mesh Networking area are the Digital Gangetic Plain (DGP) [3], [4], [5], DjurslandS.Net project in Denmark [6], Aswini project [7], the Akshaya Project [8], the High Performance Wireless Research and Education Network [9], and the CalMesh [10] based wireless mesh network platform for emergency response. The DGP project utilizes more than half a dozen long haul wireless links operating on IEEE 802.11b and the link distances range from 1-37 Kilometers.

The important protocol parameters that affect the MAC protocol performance are ACK timeout ( $T_{ACK\_TIMEOUT}$ ), CTS timeout ( $T_{CTS\_TIMEOUT}$ ), slot duration ( $T_{SLOT}$ ), interframe spaces (IFSs). The ACK and CTS timeout values according to the IEEE 802.11 standard [9] are given by  $T_{ACK\_TIMEOUT} = T_{SIFS} + T_{SLOT} + T_{ACK}$ . For a DSSS physical layer, the  $T_{SIFS}$  and  $T_{SLOT}$  are specified as 10uS and 20uS, respectively. The  $T_{ACK}$  is the transmission time or transmission duration of an ACK packet which can be divided into two parts, the Physical Layer Convergence Protocol (PLCP) part and MAC. The PLCP part is further divided into PLCP preamble and PLCP header. The PLCP preamble is also called synchronization preamble. The duration of synchronization preamble is 144 bits and the duration of PLCP header is about 48 bits. Therefore, in total, the PLCP part consumes duration of about 192uS. This PLCP overhead is not significant when the packet length is very large whereas it may become significant when short control frames are transmitted. For example, the MAC part includes the ACK control frame and it has duration of 14 Bytes which at 1Mbps rate, take about 112uS. Therefore, the total  $T_{ACK\_TIMEOUT} = 10+20+192+112= 192+142uS$ .

According the IEEE 802.11 [12] specifications, if a *PHY-RXSTART.indication* does not occur within  $T_{ACK\_TIMEOUT}$  interval, then that DATA or RTS transmission is considered unsuccessful and back-off and retransmission process begin immediately after this  $T_{ACK\_TIMEOUT}$  period. The PHY sublayer indicates the local MAC entity with a *PHY-RXSTART.indication* only when the PHY Layer successfully received a valid Start Frame Delimiter (SFD) and PLCP header. Therefore, the major part of the ACK/CTS timeout is consumed by the PLCP preamble and header. This can be observed from the following example.

Figure 3 shows an example situation of the transmission of a DATA and ACK packet for an 802.11 link for distance 21,000 meters. In this example, sender node (Node A) transmits, at 1 Mbps, a DATA packet of size 1024 Bytes

length to a receiver (Node B). The transmission is initiated at time  $T_0$  and the whole packet transmission is finished at  $T_0+8384\mu\text{s}$ . The signal arrives at Node B at time  $T_0 + 70\mu\text{s}$  and at this time, Node B's MAC layer receives an indication of the channel state change from IDLE to BUSY state. In this state, Node B's PHY attempts to synchronize with the signal and upon receiving a valid SFD and PLCP header, the

PHY layer indicates the arrival of a packet to the MAC layer by sending the *PHY-RXSTART:Indication*. At Node B, this takes about  $192\mu\text{s}$  and at time  $T_0 + 262\mu\text{s}$  the Node B's MAC layer is informed of an arriving DATA packet. At time  $T_0 + 8384\mu\text{s}$ , Node A finishes transmission of DATA packet, changes the sender MAC state to WAIT FOR ACK, and starts a timer with timeout value TACK TIMEOUT ( $T_0+334\mu\text{s}=8718\mu\text{s}$ ). Node B finishes receiving the data packet at time  $T_0 + 8454\mu\text{s}$  and after an SIFS duration of  $10\mu\text{s}$ , it begins transmission of an ACK packet at time  $T_0+8464\mu\text{s}$ . As a result of the transmission of ACK packet, at Node A, the first indication of channel state change from IDLE to BUSY occurs at time  $T_0 + 8534\mu\text{s}$ . Though an indication of state change happens at time  $T_0 + 8464\mu\text{s}$  which is within the ACK timeout value ( $T_0 + 8718\mu\text{s}$ ), the physical layer implementations according to the IEEE standard [11] do wait until successful completion of the synchronization phase before alerting the MAC layer. Therefore, the PHY layer waits until it receives a valid SFD and PLCP header which takes time until  $T_0+8726\mu\text{s}$  to send a *PHY-RXSTART:Indication* to the MAC layer. Therefore, the MAC layer experiences timeout at  $T_0+8718\mu\text{s}$  before the ACK packet is received at the MAC layer. This results in the retransmission of packets at the sender and this cycle of timeout continues until the packet's maximum retransmission limit is reached. Once the retransmission limit (max retransmission limit is 7) is reached, the packet is dropped by Node A. Manual resetting of the ACK/CTS timeout at a very high value works in small networks with a few links, however, in a network with many nodes, deployment is a laborious task and therefore, manual configuration is less preferred. Even in smaller networks where manual configuration of timeout values are used, configuring the timeout with high value would result in inefficiency of operation. For example, in the event of a real packet loss, the sender would be forced to wait for an unnecessarily long time to begin the retransmission process.

Our solution to the MAC protocol parameter adaptation is dynamic 802.11 (d802.11) which has capability to adapt to widely varying link dimensions [14]. We present d802.11 as an extension of 802.11 that can dynamically manage the ACK/CTS timers in order to efficiently operate across a variety of link distances.

In d802.11, we use Link RTT Memoization (LRM) approach in order to optimize the ACK/CTS timeout management. According to this strategy, the link RTT is remembered for successful transmissions (transmission of RTS or DATA is considered successful if CTS or ACK arrives, respectively) and use the value for subsequent transmissions. In the event of a timeout then there can be the following two situations: (i) a delayed ACK is received successfully after the timeout and (ii) no delayed ACK is received. In the first case, the sender will keep track of the round trip time (RTT) when the delayed ACK is received and this round trip time (RTT) is stored in a linkRTTTable which is indexed by the receiver's address. In the event that the delayed ACK/CTS is not received, then the sender has no information to validate the reason behind the missing

ACK/CTS. That is, the missing CTS/ACK can be either due to the packet loss resulting from interference at the sender or due to the receiver's inability to send the ACK/CTS. However, in a planned wide area wireless mesh networks, the interference can be negligible as each node employs highly directional antennas. Nevertheless, the sender might have initiated another transmission when the delayed ACK/CTS that arrives after timeout making the reception of

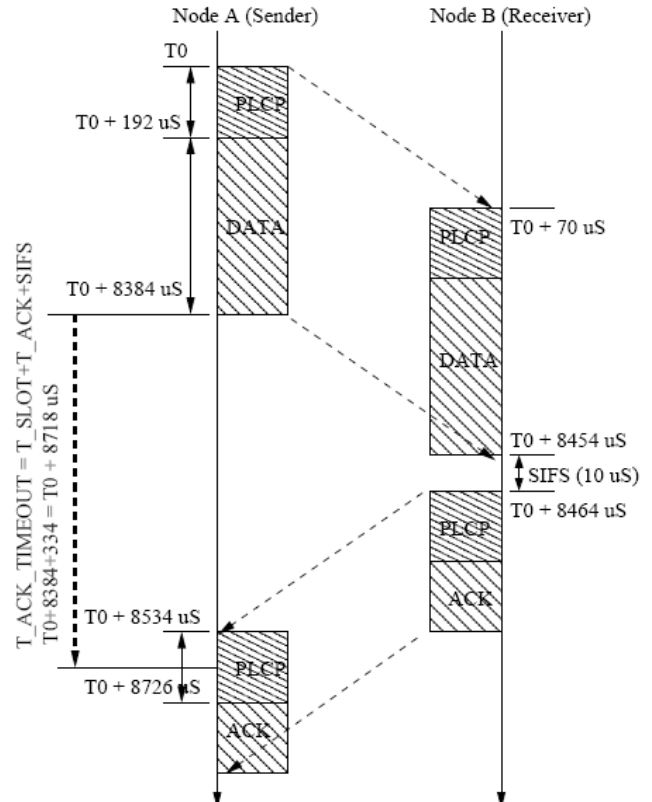


Figure 3. An example timeout scenario.

the delayed packet less successful. In either case, if there is a timeout, this scheme adapts the timeout value based on the ADDITIVE TIMER BACKOFF (ATB) mechanism [12]. When the sender node receives a delayed ACK/CTS, the RTT is measured and stored. While storing, we add a small guard time in order to ensure that small perturbations in the RTT that might occur in subsequent transmissions does not require additional backoff in ACK/CTS timer values. In order to achieve this, we add  $T_g$  to the measured RTT value. In order to study the performance of such adaptive timer management schemes, we used Glomosim [2] simulator to create a single long distance link. However, in Glomosim, the timeout happens at a much earlier time than in real networks. For example, the timeout happens at 3000 meters in Glomosim whereas the timeout in real wide area WMNs would occur well beyond 10000 meters. This is because, the synchronization mechanism implemented in Glomosim is in an overly simplified manner and therefore, the time consumed by the PLCP part is not accurate. However, since the simulation is evaluating a comparative scenario, absolute values are not significant and therefore, we proceeded with simulation.

From simulation experiments, we obtained the results shown in Figures 4-6. Figure 4 shows the ACK/CTS timeout value. This result shows the ACK/CTS timeout of IEEE 802.11

and our d802.11 protocol. The IEEE 802.11 protocol maintains a constant value for the timeout whereas the d802.11 scheme adapts the timeout as a function of distance and which follows very closely with the RTT. Figure 5 shows the retransmission count as a function of distance where we noticed that the retransmissions for the IEEE 802.11 protocol increases to the maximum retransmission limit (in most implementations, this value is set as seven) when the link distance grows beyond 3000 meters. This is primarily because the RTT of the link exceeds the  $T_{ACK\_TIMEOUT}$  which is set as a constant in 802.11. Figure 6 shows the throughput variation as a function of link distance in 802.11 and d802.11.

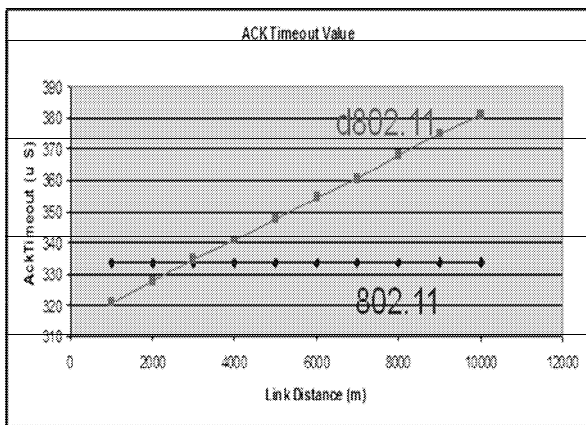


Figure 4. ACK/CTS timeout performance.

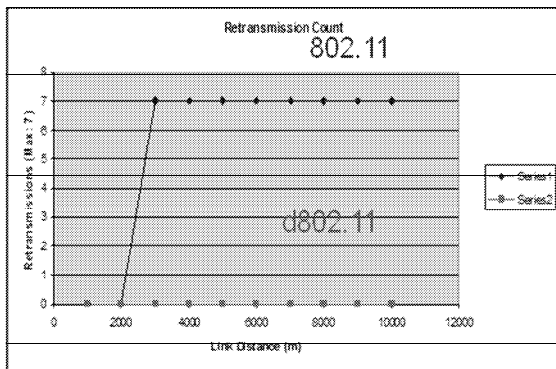


Figure 5. ACK/CTS retransmission count performance.

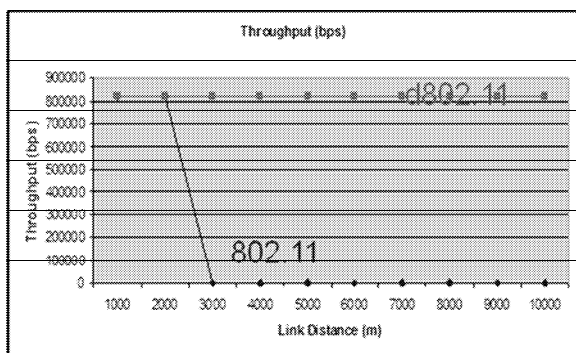


Figure 6. Throughput performance.

The throughput performance in Figure 6 shows that the link throughput achieved by 802.11 drops down to zero thereby making the link completely broken when the link distance goes beyond 3000 meters. On the other hand, d802.11 maintains the link even after the link distance goes beyond this point. However, throughput shows a minor linear degradation as a function of link distance. Therefore, the link remains operational when using d802.11 for a wider range of link distances compared to 802.11. This is particularly useful when WMNs are used for rural communication networks where the link distances are in the range of several tens of kilometers.

### C. REGULATORY, ECONOMIC, AND SOCIAL FACTORS

The proliferation of WMNs would greatly depend on the regulatory, economic and social factors. We briefly discuss each of these here.

#### 1) SPECTRUM REGULATIONS AND THEIR IMPACT

Spectrum regulations on the 2.4 GHz License free ISM band is one of the primary factors behind the proliferation of WMNs as an alternative communication infrastructure. However, free spectrum also contributes to several issues as it provides a very low upfront investment for companies to enter into the WMN market. Commercial survival of any network form requires profitable return on investment and therefore, the low entry cost to this market can potentially lead to excess proliferation of service providers thereby leading to a serious problem affecting the profitability of WMNs. In addition, the presence of multiple service providers can potentially lead to high packet loss which will eventually create an unreliable service. Therefore, new revenue generation models based on content-based or advertisement driven services are necessary to aid the healthy proliferation of WMNs.

#### 2) SOCIAL ISSUES ARISING OUT OF WMN PROLIFERATION

Capacity and fairness issues among competing nodes are considered to be a technical problem that is solved by the MAC layer protocol. Unfortunately, competing people interact with the WMN at the presentation. Nevertheless, WMN can open the gateway for diversity of content on information networks, facilitating communities a platform for sharing cultural issues and enabling people of different cultures to understand each other. Mesh networking technology can maximize the benefits of educational, informational and cultural content by expanding access to information. For this vision to become true, relevant concerns raised in connection with the new technologies have to be taken into account such as privacy issues, fear of discrimination, and blocking of assembly and expression rights through the possibilities of location tracking techniques.

Another important social issue that arises from WMN proliferation is the issue of unsafe content reaching potential victim population. For example, in several communities, children were given access only to safe cable, TV, or other media content. However, the proliferation of Internet through WMNs can potentially limit the parents' ability to provide safe content to children. New solutions are required to enable such parental control to Internet content access when WMNs become omni present.

### 3) INTERFERENCE ISSUES AND WMNS

We classify and discuss the important categories of interference faced by WMNs in this section.

*In band interferences:* The IEEE 802.11 spectrum in the 2.4GHz range is divided into 14 channels (only 1-11 channels are allowed to operate in USA). Each of these channels are separated at 5 MHz with a channel bandwidth of 11MHz. Since the channel bandwidth is more than the separation between center frequencies each of the channels will overlap with two neighbor channels on either side. Therefore, only three channels (1, 6, and 11) are assumed to be orthogonal in the first 11 channels defined in the 2.4GHz spectrum. However, this orthogonality is not really visible in practice found that there exists significant interference across all the 11 channels in the 802.11b spectrum [16-17]. This is especially a factor that depends on the 802.11b NIC manufacturer [16-17]. For example, expensive NICs from manufactures such as CISCO provide orthogonality between channels 1 and 11 when the interfaces are separated by several inches apart.

*In band external system interferences:* From our experiments in CalMesh platform [9], we observed significant interference even when we use different technologies (e.g., 802.11a and 802.11b/g) within a single WMN device. This potential drawback can bring down the performance of using multi-radio multi-channel WMNs. In order to improve the performance when using multiple technology-based network interfaces, we had to engineer the WMN device such that the antennas and NICs are separated by at least one-half wavelength distance.

*Interference between systems that share license free bands:* One of the most challenging of all interferences in 802.11 spectrums is the interference from external systems that share the license free spectrum. A detailed discussion this is given in [15]. We also found from our experiments that some of the less used channels such as channel 3 and 7 are exposed to unknown interferences which were later found to be due to Bluetooth sources. Another source of this interference is the Microwave ovens that use 2.4GHz spectrum. Therefore, commercial deployments of WMNS must consider such potential sources of interference. Figure 7 shows the 42 WLAN access points that were detected at a popular coffee shop in downtown San Diego, California. The in-band interference caused greater than 90% WMN packet loss at this location.

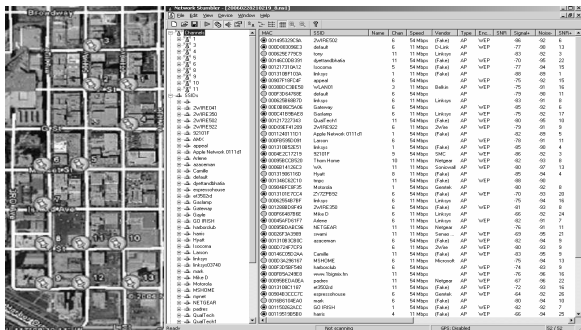


Figure 7. Example of sources that can interfere with WMNs.

*Interference between licensed and unlicensed bands:* Cellular systems in the 800MHz cellular, 1.9GHz PCS and the 2.1GHz UMTS band can interfere with 802.11 systems

in the 2.4GHz bands. This is one of the most unknown types of interferences in WMNs. This is primarily due to the poor performing filters and limited shielding that are used in most commercial 802.11 cards. Testing conducted in downtown San Diego in March 2006 showed that pedestrians using cellular phones within 3m of WLAN transceivers cause packet loss. Figure 8 shows the cellular band spectrum measured in Gas Lamp Quarter during a Mardi Gras celebration. The automatic gain control and adaptive equalizer in the WMN card would respond to the nearby cellular phone, and miss several subsequent packets from the much further away WLAN client.

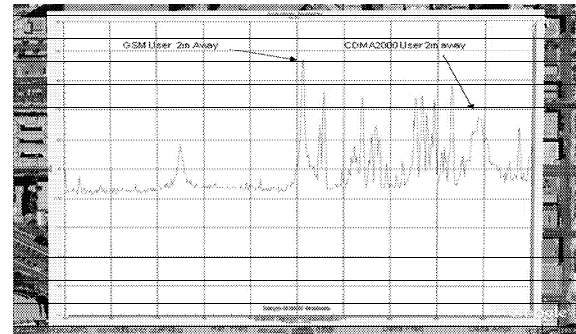


Figure 8. Interference between licensed and unlicensed bands

Other wireless systems operating from 2.2GHz to 2.3GHz also caused interference with the 2.4GHz WMN. The primary sources of interference were TV news vans with temporary point to point microwave links. During the 15 minute broadcasts the WMN located path of the microwave links experience severe packet loss. Figure 9 shows the spectrum of the news vans compared to the WLAN WMN spectrum. A packet loss of 15% to 30% was experienced by the WMN during the news broadcast. In this case the news vans were greater than 10m to 30m from the WMN and WLAN clients.

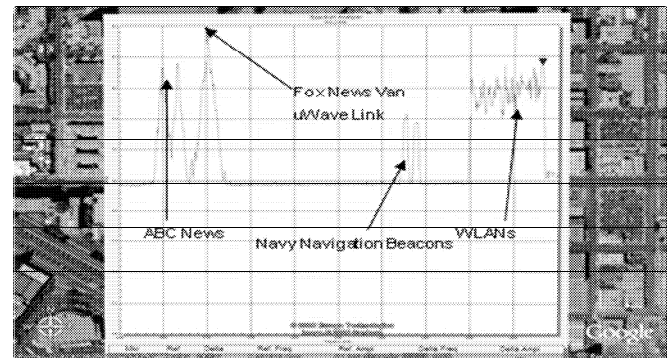


Figure 9. An example of interference between licensed and unlicensed bands

The electromagnetic interference observed emanated from relatively nearby sources. WMNs mounted 3m to 10m above the people and truck traffic greatly reduced the level on interference. WMNs mounted higher than 30m resulted in a larger coverage area, but reduced capacity. This was caused by using omni-directional antennas that broadcast too much of their energy into regions without WLAN clients. (e.g. the sky)



### III. CONCLUSION

Wireless Mesh Networks (WMNs) are emerging as an alternative communication infrastructure for the next generation wireless communications. WMNs are also suitable for rural communications, residential broadband communications, and emergency communications networks. However, there exist many challenges in achieving the end goal for this purpose. We look at several issues that are classified in to architectural, protocol, and regulatory, social, economic issues in order to discuss the challenges in detail and also to discuss some of our recent experimental results in alleviating those problems. We discuss these issues in detail and present our experimental observations and solutions that can improve the performance of these networks

### ACKNOWLEDGMENT

The work reported in this paper is supported by NSF projects RESCUE, Responsphere, and CogNet (award numbers: 0331690, 0403433, and 0650048, respectively) at the University of California San Diego division of California Institute of Telecommunications and Information Technology (CalIT2). The author for correspondence is Dr. B. S. Manoj, email: bsmanoj@ucsd.edu.

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# VSAT Satellite Communications Systems & Their Local Loop Applications

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**Abstract**—Since erstwhile USSR launched the world's first artificial satellite SPUTNIK I on 4th October 1957, the technology has advanced from satellites that lasted only 13 days (US SCORE) to modern ones which last 10 years and over. One remarkable feature of a satellite network is its everywhere availability; a non-terrestrial wireless system with the widest footprint. Only three geostationary satellites can cover almost the entire earth. They are the cheapest means of communications in sparsely populated regions, remote locations, or regions without landline communications infrastructure. Hence, the VSAT technology is becoming popular for high-speed, always-on Internet access in the developing world to bridge the digital divide. A satellite system comprises a ground-based station and a space segment. The Very Small Aperture Terminal (VSAT) is a satellite earth station which is fixed and uses small directional dish antennas with typical aperture diameters in the range 0.6-3.8 m. This article is not a research paper but provides a simplified review of VSAT systems at lower undergraduate level. It resulted from the notes taken when the author reviewed VSAT networks for voice and Internet services for private use. Hence, the information provided may be valuable to VSAT installation personnel or people seeking a handy introduction to VSAT-based satellite Internet.

## I. INTRODUCTION

A COMMUNICATIONS satellite [1] is an artificial object that hangs in space and revolves around an orbit at a given altitude above the earth's surface. Such an object functions as a microwave repeater and comprises several functional blocks such as transmitter, receiver, regenerators or amplifiers, filters, multiplexer/demultiplexer, antenna and waveguides [2]. Satellite systems have a multitude of applications, including communications, TV broadcasting, Internet access, global positioning system, weather forecasting, geographic information systems, and distance learning. A satellite network comprises a ground-based station and a space segment. The space segment, however, comprises one or more satellites orbiting at a given altitude. Satellite systems are the cheapest means of communications in sparsely populated regions or remote locations. These application areas are popular as the cost of satellite communication services does not depend much on distance. Another remarkable feature of satellite systems is their oblivion of geographical and political boundaries. Satellites on the same orbit must be apart by a minimum distance to avoid damaging interference, and ITU recommends 2 degrees, which means that a maximum of 180 satellites can be hosted on a given orbit.

A satellite in space is powered by onboard battery or/and solar energy system. As the latter energy system may not function well during eclipse, some satellites have both types of energy supply. What about satellite launching and disposal? A satellite can be directly launched onto a low-altitude orbit below 200 km in altitude. The launching of a higher-altitude orbit satellite proceeds in stages whereby the satellite is first brought to a *transfer orbit* and then moved to the intended orbit. Two main methods are used to launch a satellite: *unmanned expendable rocket* and *manned reusable space shuttle* called Space Transportable System (STS) controlled by astronauts. What happens to a satellite when its operational lifetime expires? It is simply released to the outer space to increase the population of junk satellites. This is arguably not the best way to handle junks except for cost reasons. If this is threatening then what about people thinking of dumping nuclear waste in outer space?

We now pause here to familiarize ourselves with some of the satellite terminologies used in this article. A transceiver (i.e. transmit/receive radio) used on a satellite is referred to as a *transponder* and the number of transponders on a satellite determines its capacity. Each transponder typically has a 40 MHz bandwidth and a communications satellite can have 10-40 transponders on various frequency bands. A satellite system transfers two types of load: payload and bus. The *bus* is the lifeblood of the system-it comprises the control and signaling used to manage the system-while the *payload* is the actual user information transferred between two points. The coverage area of a satellite antenna is referred to as *footprint*, and the higher the altitude of the orbit the larger the footprint. This is the reason why only three GEO satellites can illuminate almost the entire earth. The earth station antenna's site should be within the footprint of the satellite of interest. The direction at which an antenna achieves its maximum gain is called *boresight*. Two angles are very important in the proper alignment of the antenna with the satellite, the *angle of elevation* and the *azimuth*. The elevation angle and the azimuth are respectively the vertical and horizontal angles that a VSAT dish must be set to point at the satellite of interest. These angles are together referred to as *antenna look angles*. The look angles depend on the longitude of both the orbiting satellite and the VSAT antenna site as well as the latitude of the VSAT antenna site. The position of a satellite on the earth is identified by the longitude of the point on the earth that is vertically and directly under the satellite. This point is referred to as *subsatellite point*

(SSP), and the SSP for a VSAT satellite falls on latitude zero or the equator. This is the reason why locations in VSAT systems are specified in degrees longitude, either west or east.

Satellite systems are categorized into low-earth orbit (LEO), medium-earth orbit (MEO) and geostationary-earth orbit (GEO) according to the altitude of their orbits in that order. The respective orbital altitudes above the earth's surface are 1200-3000 km for LEOs, 3000-35,786 km for MEOs and ca. 36,000 km for GEOs. The GEO orbit is circular and the GEO satellite moves in the same direction as the earth's rotation. A GEO satellite is uniquely identified by its longitude as it hangs directly above the equator and remains approximately stationary to an earth station, as the satellite orbits the earth once every 24 hours. The stationarity of the satellite w.r.t. the earth station is enhanced by using an antenna with a large beamwidth. In this case no satellite tracking is required by the earth station antenna as used in Very Small Aperture Terminal (VSAT) systems. The high GEO orbit's altitude requires high-power transmitters and large dish antennas with high gains. VSAT is a GEO satellite system providing a point-to-point or point-to-multipoint service. Traditional VSATs normally handle low-rate bursty traffic such as for paging alert, inventory control and EFTPOS (Electronically Funds' Transfer at Point of Sale) used at remote retail shop without telephone lines for credit card authorization. Owing to the small amount of traffic generated from a single VSAT network, multiple VSAT networks may share a single transponder on a satellite to reduce costs. For this reason several multiple access protocols have been proposed to allow multiple VSAT stations to share a single satellite transponder on the uplink. These include code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), demand-assignment multiple-access (DAMA), distributed queueing random access protocol (DQRAP), announced retransmission random access protocol (ARRA), generalized retransmission announcement protocol (GRAP) [?], [3], [4]

Introduced around 1983, VSAT is a satellite earth station which is fixed and uses small directional dish antennas with typical aperture diameters in the range 0.6-3.8 m. The small size of the antenna reduces the cost of the antenna itself, civil works, mounting and installation. VSATs are usually private networks providing data, voice and TV (video) services in either a receive-only or bi-directional modes. A good tutorial about VSAT installation can be found at the Galileo VSAT Training website [5]. VSAT systems usually operate in the *C-band* (3.72-8 GHz) denoted as 6/4, *Ku-band* (11.7-18 GHz) denoted as 14/12 or the *Ka-band* (20-40 GHz) of the frequency spectrum. The trend is more towards the usage of higher frequency bands which allow smaller aperture antennas. Hence, investigations are underway for 20/30/44GHz horn antennas for mobile VSAT applications [6]. The C-band systems are common in Africa, Asia and Latin America, while the Ku-band VSAT is popular in North America and Europe. Applications in the Ka-band are just evolving. Owing to signal fading due to heavy rains, Ku-band and Ka-band systems with small wavelengths are not the best for regions in tropical climatic zones [7], [8]. Another important frequency band in VSAT is

the *L-band* which spans the frequency range 0.39-1.55GHz. In the designation  $x/y$ , where usually  $x > y$ ,  $x$  is the uplink (i.e. VSAT to satellite) frequency while  $y$  is the downlink (i.e. satellite to VSAT) frequency. A tangible reason for using a higher frequency on the uplink is that the satellite weight must be minimized and hence smaller dish antennas should be mounted on it, requiring higher receive frequency on the uplink. As a wireless system, VSAT systems transfer signals as electromagnetic waves and the direction of the electrical field component of the wave is called polarization. The capacity of a VSAT system can be boosted by transmitting multiple signals with different polarizations (usually vertical and horizontal) simultaneously. Leading vendors of VSAT systems include Codan, ViaSat, Intelsat, Comtech, iDirect, C-Com and SeaTel.

The rest of this contribution is structured as follows. Section II reviews the key components of a VSAT system. Section III deals with VSAT topologies and some operational principles. VSAT application scenarios are the theme for Section IV. We then move to issues related to the cost of commissioning and running VSAT networks in Section V. The review can never be complete without mentioning key VSAT system parameters and how to set up a VSAT network. Hence, this is reviewed in Section VI. The article then concludes in Section ???. This review is biased towards the earth station of the VSAT system.

## II. VSAT COMPONENTS

A VSAT system comprises a hub, a transponder on a satellite hanging in space and a number of remote VSAT stations. A remote VSAT station comprises the Indoor Unit (IDU), the Outdoor Unit (ODU) and the cable connecting them, referred to as interfacility link (IFL), as illustrated in Fig. 1. The IFL is a pair of low-loss coax cables, one to receive and the other to send signals. Besides signal transfer, the IFL is used to supply low-voltage (24 VDC) power to the outdoor electronics in the ODU. The IDU, typically of the size of a DVD/CD player or desktop computer, operates like a MODEM and it is the end-user interface to the space communications service. It comprises modulators at the transmitting side, demodulators at the receiving side, two pairs of Recommended Standard 232 (RS 232) serial interfaces, and one Ethernet port for connection to data networks such as LAN or Internet/CyberCafe. The IDU determines the multiple access scheme used in the VSAT system.

The ODU, illustrated in Fig. 2, comprises the antenna (including the parabolic reflector, feedhorn and mount), and the radio frequency transceiver (RFT). The RFT is mounted on the antenna frame and connected to the feedhorn. The feedhorn is made up of an array of passive microwave components. It directs transmit signals towards the reflector and collects receive signals from it. Depending on the set of equipment used, there are two basic types of VSAT ODUs of which the RFT is a part:

- 1) dish (incl. feedhorn and reflector), IFL, OMT, LNB and L-band BUC (L-band modem and BUC).
- 2) dish (incl. feedhorn and reflector), IFL, OMT, and 70 MHz transceiver (70 MHz modem, up/downconverter, solid state power amplifier (SSPA) and power supply).

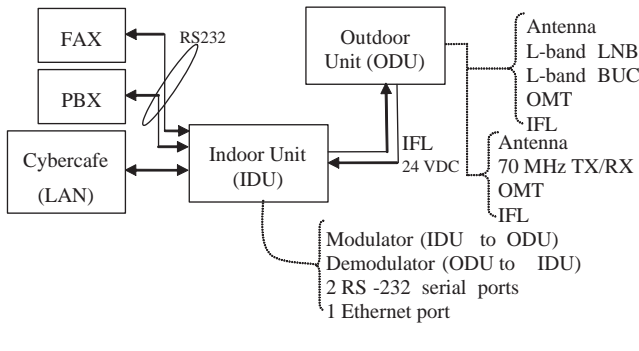


Fig. 1. VSAT ground-based network parts and interfaces.

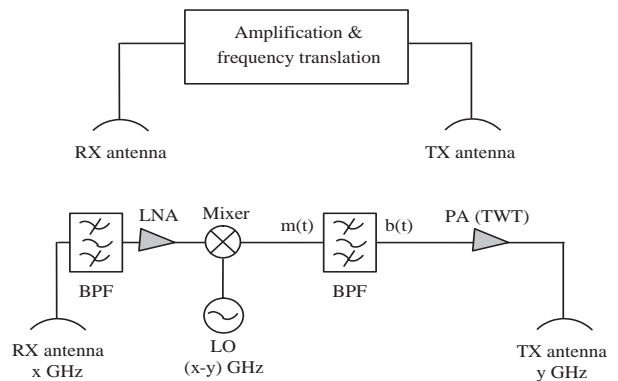


Fig. 3. Single-stage conversion transponder on a satellite hanging in space.

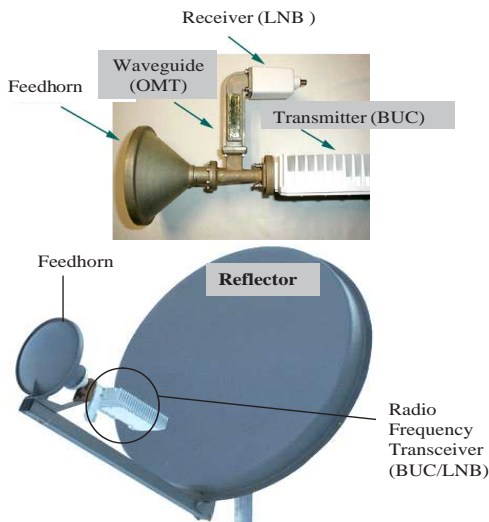


Fig. 2. The outdoor unit of a Ku-band VSAT system with 1.2 m dish of transmit gain 43.3 dBi and receive gain 41.8 dBi [5].

As illustrated in Fig. 2, the Orthomode Transducer (OMT) is a waveguide that interconnects the Low Noise Block (LNB), the Block Up-Converter (BUC) and the antenna feedhorn. A waveguide is a hollow conductive tube used in microwave communication systems. Rather than using parallel metallic transmission lines, systems operated at high frequencies (e.g. above 1 GHz) or high powers (voltages) use waveguides. This is attributed to signal attenuation due to skin effect and radiation losses at high frequencies. Also, high powers or voltages can destroy the dielectric material separating the two conductors in the parallel line. The VSAT system uses one type of polarization to transmit signals to the satellite over the BUC and the opposite polarization to receive signals from the satellite through the LNB. Hence, the OMT has two polarizations which are opposite to each other. It exploits the differing frequencies and polarizations used for the transmit and received signals to separate the two signals. The other parts of the VSAT system are briefly reviewed below. The word “block” is used in LNB and BUC as these devices translate a block of frequencies to another block of frequencies.

### A. Traditional Satellite Transponder

A traditional satellite transponder has the bent-pipe structure shown in Fig. 3. The bent-pipe transponder is so called because in functionality it comprises only linear amplification and frequency translation without any onboard signal processing. The amplification is achieved via a Low Noise Amplifier (LNA) at the receiver (RX) and the power amplifier (PA) at the transmitter (TX) which is usually a traveling wave tube (TWT) or SSPA. The frequency translation is accomplished using a local oscillator (LO), a mixer or frequency multiplier and a bandpass filter (BPF). If the satellite transponder receives signals at the frequency of  $x$  GHz from earth stations and transmits signals to earth stations at  $y$  GHz, then the LO should generate a carrier frequency of  $x - y$  GHz to achieve the required modulation/demodulation. The simplicity of the bent-pipe transponder has been promoted by the need to keep the space segment simple as the space environment is malignant for the satellite to allow much sophisticated signal processing. Notwithstanding the need for simplicity at the space segment, intelligent satellites use transponders with onboard signal processing. The onboard processing includes functional blocks such as de-/modulators, de-/coders routing engine and beam switching. The intelligent transponder can be used to network satellites in space.

To see how the circuit in Fig. 3 accomplishes frequency translation let us consider the following. In communications system analysis sinusoidal signals are commonly used. This is partly due to analytical simplicity and the fact that most signals can be represented as sums of sinusoids with varying amplitudes and frequencies over Fourier theory. Hence, we use single-tone sinusoidal signals in the examples in this article. Assume that the signal from the LNA to the mixer is  $A(t) \cos(2\pi xt + \varphi_a)$  and the reference signal from the LO is  $\alpha \cos[2\pi(x - y)t + \varphi_c]$ . This yields the output of the mixer as

$$m(t) = A(t)\alpha \cos(2\pi xt + \varphi_a) \cos[2\pi(x - y)t + \varphi_c] = \frac{A(t)\alpha}{2} \{ \cos[2\pi(2x - y)t + \varphi_a + \varphi_c] + \cos[2\pi yt + \varphi_a - \varphi_c] \}.$$

As the circuit in Fig. 3 is doing upconversion, the BPF will be tuned to reject the low-frequency term in  $m(t)$  and produce the output signal



$$b(t) = \frac{A(t)\alpha}{2} \cos[2\pi yt + \varphi_a - \varphi_c]. \quad (1)$$

The scaling  $\alpha/2$  in (1) can be offset by the proper gain of the PA, while a phase-locked loop can be used to achieve  $\varphi_a - \varphi_c \approx 0$  to retrieve the useful information from  $A(t)$  assuming an amplitude-modulated transceiver.

### B. VSAT Antenna

An antenna is a transducer (or even a sensor) that converts an electrical signal to/from electromagnetic waves. Satellite antennas have three basic types: (a) TeleVision Receive-Only (TVRO) dish, (b) VSAT dish, and (c) direct broadcast satellite (DBS) dish, with their sizes in decreasing order. VSAT network installations use earth station transceivers with directional dish antennas having aperture diameters in the range 0.6-3.8m. For example, the BradSat VSAT system uses dishes with diameter 0.96-2.4m. The 2.4m dish is equivalent to  $32-48\lambda$  in the C band and  $96-142\lambda$  in the Ku band. Hence, as a rule of thumb, the aperture diameters of dish antennas used in VSAT systems measure up to about 100 wavelengths. Mobile satellite systems such as Globalstar and Iridium use earth stations with even smaller omnidirectional dishes (0.6 m in diameter) due to the usage of lower-altitude orbit. Such systems are dubbed ultra small aperture terminals (USAT). Mobile VSAT solutions have auto-pointing, vehicle-mounted antennas which automatically search for a selected satellite and locks onto it. The antennas used in VSAT networks can switch between vertical and horizontal polarizations. VSATs use two main types of antennas: front-fed type with the feed in the front of the antenna, and back-fed type where the feed is mounted behind the antenna. Note that, irrespective of its type, the VSAT antenna must be installed outdoors to reduce absorption of the low-wavelength signals by walls, roof or window materials.

### C. 70 MHz Transceiver & L-Band BUC

Both 70 MHz transceivers and L-band BUCs are used for the same purpose: they accept the low-frequency signal from the VSAT modem, upconvert it to higher-frequency C-band, Ku-band or Ka-band and transmit it upstream to the satellite. This is frequency upconversion—a form of frequency translation. The frequency translation is needed to reduce signal attenuation over the IFL as cable cable's attenuation increases with frequency as well as its length. While the transceiver operates on a 70 MHz signal (see Fig. 4), the L-band BUC operates on input signals with frequencies in the range 0.39-1.55 GHz. Both the BUC and the transceivers are usually mounted on the VSAT antenna and as close as possible to the feeder of the VSAT dish to reduce the higher losses at high frequencies. The BUC is sometimes referred to as the TXB (Transmission Block). BUCs are rated by their output power. The output power of a low-power Ka-band BUC can be as little as 2W, while that of a high-power C-band BUC can be as high as 200W.

In the L-band BUC set, the power supply, frequency selections and radio output settings are inside the L-band modem

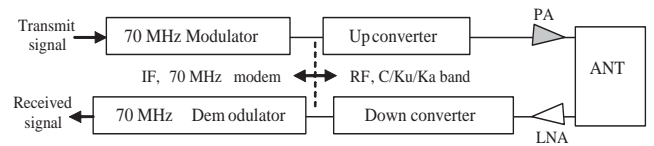


Fig. 4. A classical 70 MHz VSAT transceiver, ANT is the VSAT antenna.

which is part of the IDU and hence kept indoors. Hence, the BUC includes only L-band to radio frequency (RF) up-converter, an SSPA, and a universal AC power supply (47-63 Hz, 100-240 VAC). The 70 MHz transceiver which is kept outdoors with the dish contains the power supply. The L-band BUC radio transmitter is a more modern technology than the 70 MHz transceiver. The costs of these two sets of equipment are compared in Table II. It is obvious from the table that the L-band radios which convert the RF signal from the satellite to a higher intermediate frequency has a lower cost than the 70 MHz transceiver.

### D. Signal Conditioners

Signal conditioners are widely used in radio electronics. Signal conditioners used in VSATs are mainly amplifiers and frequency translators. These functional blocks are briefly reviewed below.

1) *Amplifiers:* Several types of amplifiers find applications in VSAT systems, including TWT amplifiers (TWTA), SSPA and LNA. Invented during World War II, a TWT is an electronic device used to produce high-power RF signals. Prior to the advancement in semiconductor electronics, TWTAs were common in microwave systems that handled high-power signals. The choice between tube-based and solid-state-based amplifiers (e.g. SSPA) may not be straightforward. However, owing to their light weight and reliability, SSPA amplifiers are gradually replacing TWTA in satellite communications systems, except systems with output powers exceeding 50 watts. Also, TWTAs are more prone to non-linearity problems (such as intermodulation distortion) than SSPA. An LNA is a specialized analog amplifier that adds very little noise to the very weak signals arriving from the satellite and captured by the antenna coupled to it for level boosting. It is usually positioned at the very front-end of radio receivers as the noise added to the signal at this stage causes a higher penalty than the noise terms from the amplifiers afar from the antenna. Hence, the LNA sets the noise figure of the total receiving system.

2) *Frequency Translators:* A frequency translator comprises LO, mixer and BPF. Two types of frequency translators are used in VSAT systems: downconverter and upconverter. An *upconverter* passes the sum frequency term in the mixer output signal while suppressing the difference frequency term using a BPF. A *downconverter* does the opposite to upconverter, it blocks the sum frequency term while passing the difference frequency term.

The LO is usually a frequency-tunable device used to generate the reference signal used to change the frequency

of a signal of interest by passing the two signals through the mixer. The signal of interest and the IF are fixed, but the LO can be tuned to select the appropriate signal. For example, if the signal of interest is a tone at frequency  $f_{sig}$  and the frequency that we want to translate it to is the intermediate frequency (IF)  $f_{IF}$ , then the LO's frequency will be set to  $f_{LO} = f_{sig} - f_{IF}$ . In this case the unwanted image frequency generated by the mixer is  $2f_{sig} - f_{IF}$ , which is blocked by an appropriately tuned BPF.

The operation of a *mixer* has already been explained in Sect. II-A. In general, a mixer is a nonlinear device which combines two signals at its input to produce signals having frequencies which are the sums and differences of the frequencies in the input signals. As any nonlinear circuit can operate as a mixer, a mixer can be realized using Class C amplifiers or semiconductor diodes.

The *BPF* is used to select the frequency band of interest from the output of the mixer and reject/suppress the unwanted frequencies. BPFs are commonly used to block image frequencies in radio communications systems. A BPF can be realized by combining a low-pass and a high-pass filters or by a simple resistor-capacitor-inductor (RLC) circuit.

E. L-Band LNB

The L-band Low Noise Block (LNB) is the front-end receiver of a VSAT station; it receives RF signals from the satellite, downconverts them to L-band frequencies, and send them via the IFL to the IDU. As part of the ODU, it is powered by 24 VDC from the IDU through the IFL cable. It comprises LNA, voltage-controlled crystal LO, BPFs and the first stage IF amplifier. The LNB is usually affixed either in or on the VSAT dish immediately behind the antenna feed. Its purpose is to utilize the superheterodyne effect, amplify and convert a wide block of frequencies between L-band and satellite frequencies. This helps compensate for the signal loss associated with typical coaxial cable at relatively high frequencies. The architecture for the LNB is just like the bent-pipe transponder illustrated in Fig. 3 except that the left antenna is replaced by the OMT waveguide, the PA is replaced by an L-band amplifier, and the right antenna is replaced by the IFL connected to the IDU.

III. VSAT ARCHITECTURES & OPERATION PRINCIPLES

VSAT networks can basically be categorized into five groups: (a) broadcast networks, (b) multipoint networks, (c) single channel per carrier (SCPC) or point-to-point network, (d) fully-meshed network and (e) hybrid voice and data network. The basic features of these five network types are compared in Table I. All these network types are built from the two main VSAT network topologies of star and mesh. A hybrid VSAT network in which a part of the network operates on a mesh topology while other parts operate in a star topology also exists. The hub uses a more powerful servers and transceivers with dish diameters of 6-11m. In the star topology the hub monitors, controls and communicates with multiple VSAT sites that it controls. In the mesh topology the VSATs communicate directly and hence the hub station

TABLE I  
VSAT NETWORKS

Network type	Basic features
Broadcast	One-way links (24 Mbps hub to multiple receive-only VSATs)
Multipoint	Data-oriented with voice support, 2-way communications, hub-VSAT communication over TDMA
SCPC	2-way P2P links between VSAT pairs, multiprotocol, 9.6kbps to 8.4 Mbps, asymmetrical/symmetrical links, ISP-to-ISP interconnection
Mesh	Voice-oriented, reduces delay by direct VSAT-to-VSAT communication, powerful VSAT than multipoint, one VSAT works at master for network control and billing, good to interconnect dissimilar devices
Hybrid voice/data	Direct VSAT-to-VSAT communication, LAN/WAN service, PBX, 2-way broadcast

performs only control and monitoring functions. Unlike in the past, some modern VSAT platforms such as SkyEdge support multiple applications and different networking topologies: star, multistar, mesh or hybrid.

1) *Star Architecture & Satellite Internet*: As illustrated in Fig. 5, the star architecture used for a multipoint network is the simplest topology to use to describe Internet access over satellite. Here a centralized hub housed at the network operation center (NOC) of a satellite service provider serves multiple VSAT terminals located in remote places. The VSAT stations can be distributed operations of a company which are linked together to its head office private network via the hub. On the other hand, the VSAT stations can be independent homes, LANs or cybercafes that are linked to the Internet via the NOC/hub of the satellite service provider. The hub uses a more powerful servers, a large antenna and high-rate transmitters. The weaknesses in this star architecture includes a single point of failure and the lack of direct VSAT-to-VSAT communications as all information exchange has to pass through the hub. However, this architecture allows the usage of small and hence low-cost dishes at the VSAT stations. Data rates from the hub to the terminals can be anything between 256 and 512 kb/s, while each VSAT terminal transmits at 12-19.2 kb/s. These rates are relatively small in the perspective of broadband communications, especially over wired links.

2) *Mesh Architecture*: The mesh topology allows two-hop communications between any pair of VSAT terminals. It is more or less a star architecture in which the hub is not involved in VSAT-to-VSAT communication, but only for supervisory and network management. This reduces signal transmission delay as each pair of VSATs can communicate directly over the satellite. This is the reason why this architecture looks attractive for delay-sensitive traffic such as voice.

IV. VSAT APPLICATIONS

VSAT systems have achieved penetration in several application environments, including:

- locations such as rural and remote areas where there is little or no terrestrial communications infrastructure.
- extension of the coverage of a terrestrial cellular network.

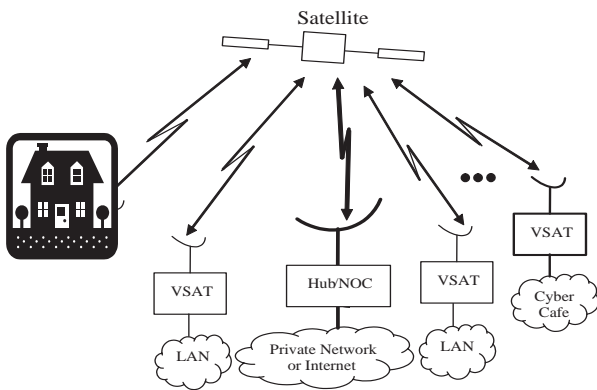


Fig. 5. A VSAT system with a star architecture for multipoint networks.

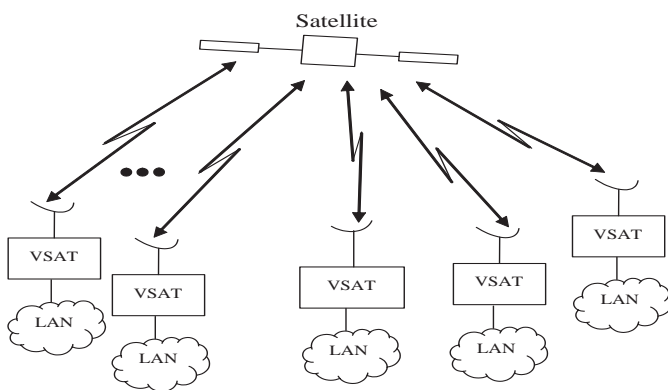


Fig. 6. A mesh VSAT architecture.

- interconnection of disparate Local Area Networks most probably with a common ownership.
- sparsely populated regions where multiplexed communications links are not cost effective.
- regions with capacity-limited telecom infrastructure where capacity expansion is not cost effective.
- a cost-effective replacement for traditional dial-up networks using modem or leased line.

In all the above application environments the population density should fall within approximately 10 users/km<sup>2</sup> and 100 users/km<sup>2</sup> ([9], p. 346) to make the VSAT system cost effective. Some VSAT service providers allow variable user-defined air time. VSATs have evolved from very low-rate paging service to innovative services, including:

- Large file transfers over e.g. Virtual Private Networks.
- Internet Access: cybercafes, homes, offices, government departments, and remote access to host web servers.
- Bank ATM transactions or EFTPOS.
- Video conferencing and digital audio/video transmissions.
- Multimedia applications.
- Voice (including Voice-over-IP or VoIP) and fax communications and interactive distance learning.

In fact, VSAT can be used to provide virtually every telecommunications service, except very delay-sensitive applications due to the long signal transmission path.

TABLE II  
COST OF VSAT SOLUTIONS

Equipment Set	Total Cost	Comment
Anacom 20W transceiver with LNC (\$16,650) & Datum PSM4900 modem (\$3,500)	\$20,150	20 W, 70 MHz transceiver
Anacom 20W BUC (\$8,770), PLL LNB \$450 & Datum PSM-4900L modem \$3,930	\$13,150	20W L-Band BUC
Anacom 5W transceiver with LNC (\$9,663) & Datum PSM4900 modem (\$3,500)	\$13,163	5W 70 MHz transceiver
5W BUC (\$1,770), PLL LNB (\$450) & Datum PSM-4900L modem (\$3,930)	\$6,150	5 Watt L-Band BUC

### A. Paging Systems

A traditional application of VSAT is the extension of the coverage area of a cellular network to provide simple one-way paging service. In this system a low-cost, low-power and small-sized paging handset beeps to alert its user to call a central office for a message. Typical frequency bands used are 152/158 MHz and 454.025-454.650 MHz to transmit at data rates of 512 b/s, 1.2 kb/s or 2.4 kb/s over 25 kHz channels using FSK (frequency shift keying) modulation with  $\pm 4$  kHz deviation. A typical communications protocol used for the most basic paging system originated from the Post Office Code Standardization Advisory Group (POCSAG).

### V. COST OF VSAT COMPONENTS

The popularity of VSATs is promoted by its sinking costs and the fact that a VSAT client does not need to purchase a hub. Currently, a 2W Ku-Band BUC alone costs ca. US\$300. As at September 2007 the total costs for a complete C-band VSAT package including equipment, installation (US\$395) and operational support starts from US\$10,000 plus an ongoing monthly fee of US\$1,700 for 128/256kbps dedicated link in West Africa. Such a system can support up to 200 computers and a 4-port VoIP equipment at an uplink speed of up to 244 kbps. The ongoing fee covers transponder capacity and support. A system supporting 300 PCs and an 8-port VoIP equipment at 384 kbps uplink speed can be acquired at US\$12,000. These prices include 1.8m IntelSat VSAT antenna, 5W C-Band ODU, C-Band feed, indoor terminal, connectors, cables and BUC. Another VSAT provider installs a broadband package at an upfront fee of US\$7,500 and a monthly ongoing fee of US\$300. Table II compares the prices of some VSAT solutions [10]. In this table the LNC (Low Noise Converter) is a combination of a LNA and a frequency downconverter built into one antenna-mounted package. A Phase-Locked Loop (PLL) is an electronic circuit which ensures that a signal of interest is locked on a particular frequency. It comprises a phase detector, low pass filter and an oscillator. It usually controls the phase of the oscillator that is used to generate the reference carrier needed to demodulate/modulate a received signal in communications system.

### VI. SYSTEM PARAMETERS & INSTALLATION GUIDE

This section discusses pertinent issues on VSAT acquisition.

VII. VSAT INSTALLATION GUIDE

Following the adage “a workman is never better than the tools available to him,” we provide the list of basic tools needed for VSAT installation. For example, Galileo VSAT training recommends the following tools: CD-ROM containing the software and instructions needed for installation, Satellite Finder, GPS receiver for locating the latitude and longitude needed to determine the antenna site’s look angles, digital multimeter for troubleshooting cables, handheld magnetic compass, pointing parameters’ finder (e.g. Satmaster QuickAim Pointing), inclinometer angle meter, crossover Ethernet cable, snap & seal crimper, coax cable wire cutter, inline receive side coax cable amplifiers, snap & seal coax connectors with nuts, coax shielding grounding blocks, rubber tape, dielectric grease for coating O-Rings but not for coax connectors, and wrenches (including a 7/16 and 1/2 inch box end wrenches) [5].

Figure 7 gives a self-explanatory steps for installing a VSAT system. In the final stage a test signal is used to adjust the transmit power to appropriate signal level. It should be noted that the VSAT dish should be installed so as to allow an unobstructed view of the satellite for the system to operate well. In particular, the antenna boresight should point directly to the satellite hanging in space for an optimum communications quality. The alignment of the dish’s boresight with the appropriate satellite requires the appropriate setting of the antenna look angles, and the polarization. This is usually completed with the help of the NOC at the hub of the satellite service provider. Luckily, VSAT earth station is relatively stationary with respect to the satellite. Hence, the look angles may be adjusted only once at system commissioning. Another issue is the interference level which requires the IDU to be positioned away from electromagnetic field emitting devices such as microwave oven, motors and cordless phones. If the required length of the IFL is less than 30 m then RG6 cable can be used, otherwise a more expensive low-loss RG11 cable must be used to reduce signal attenuation over the IFL.

Other precautionary measures during VSAT installation include grounding of the BUC and antenna to protect personnel and equipment against induced electrical surges like lightning, avoiding exposure to the high transmit powers at the BUC and antenna which can hurt body tissues or even cause blindness. There are two ways of installing VSAT ODU: roof-penetrating mount and non-penetrating mount. The former mounts the antenna on the roof top of the house in which the VSAT IDU is located. A structural analysis must be done on the building upon which the VSAT antenna is to be mounted as the weight can be damaging to the structure. Non-penetrating mount installs the antenna on a structure positioned anywhere except the rooftop where line-of-sight with the satellite is possible.

A. VSAT Round-Trip Delay

Another relevant parameter in satellite communications is the time taken by a signal to move from one earth station to another earth station and return. This is referred to as round-trip delay, and it is one of the penalties in GEO satellite systems for using a high-altitude orbit. The distance covered

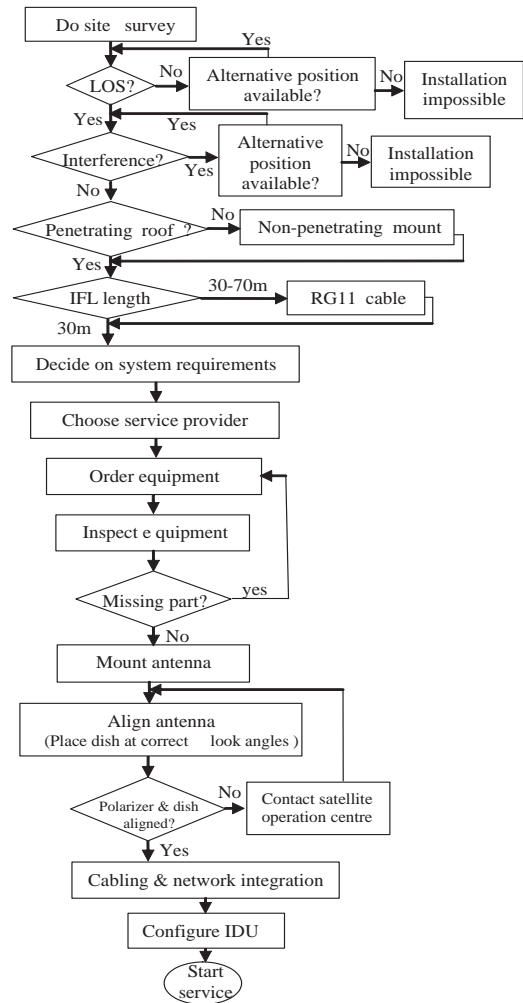


Fig. 7. A procedure for VSAT equipment acquisition and installation.

by a signal between a (GEO) satellite and a VSAT antenna site is given by ([11], p. 73)

$$d = \sqrt{R^2 + r_{geo}^2 - 2Rr_{geo} \cos b} \quad (2)$$

where  $r_{geo} \approx 42,164$  km is the radius of the geostationary earth orbit,  $R = 6371$  km is the average earth radius and  $b = \arccos(\cos(\phi_E - \phi_{ss}) \cos \lambda_E)$  is obtained from the Napier’s rule ([11], p. 71). Here,  $\lambda_E$  and  $\phi_E$  are respectively the latitude and longitude of the earth station, while  $\phi_{ss}$  is the longitude of the SSP. From (2) and the given values we obtain the range

$$35,793 \text{ km} = d_{min} \leq d \leq d_{max} = 48,535 \text{ km} \quad (3)$$

This yields the round-trip delay ( $\tau_{rt}$ ) range of

$$477.24 \text{ ms} = \frac{4d_{min}}{c} \leq \tau_{rt} \leq \frac{4d_{max}}{c} = 647.13 \text{ ms} \quad (4)$$

where  $c \approx 3 \cdot 10^8$  m/s is the speed of light in vacuum. Hence, the high altitude causes a penalty in signal transfer delay, making it not very suited for delay-sensitive applications.



## VIII. CONCLUSION

We have presented a simplified review of VSAT systems in this contribution. VSAT is very important for developing countries without any extensive wireline telecommunications, media and entertainment infrastructure. With respect to ongoing monthly/yearly service fees VSAT and ADSL are very similar for a comparable service offering, except that the initial installation costs for VSAT is exceptionally high in West Africa. This is partly due to the large C-band antennas commonly used. Hence, it is hoped that the information provided may be valuable to VSAT installation personnel or people seeking a handy introduction to VSAT-based satellite Internet. Future extensions to this work will add information on figure-of-merit (i.e. G/T) for VSAT links.

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## **CONFERENCE DIVISION:**

Education, Training & eLearning

## A PARADIGM SHIFT IN ENGINEERING EDUCATION: Implications for Assessment, Instruction and Curriculum

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### ABSTRACT

*The primary goal of engineering faculties is to facilitate students' maturation into skilled real-world problem solvers able to make reasoned decisions in challenging situations. This real-world problem solving requires a number of skills including technical competence, critical thinking, team work and lifelong learning. The traditional behaviourist educational paradigm, often, does not enable engineering faculties meet these educational outcomes. The traditional model is content/instruction-based and encourages content delivery and memorization of facts while the learner remains largely "unknown". System dynamics have propelled a shift to learner-centred educational paradigm for learning enhancement, fostering sustainable thinking, promoting experiential learning and cognitive growth. In this paper, we detail this paradigm shift and address its implications for assessment, teaching and curriculum. This requires a closer look at the constructs of student development. We also highlight the implications of the shift for engineering laboratory education and propose the virtual laboratory as a workable alternative in resource constrained environments. The paper is aimed at motivating and stimulating Engineering Educators to harness their potential to improve the quality of engineering education through creative teaching and make assessment more diagnostic in nature. We also hope to elicit some level of positive response from faculties towards more effective engineering curriculum.*

**Keywords:** paradigm shift, educational outcomes, diagnostic assessment, creative instruction, effective curriculum

### INTRODUCTION

The main goal of engineering faculties is to facilitate students' maturation into skilled real-world problem solvers able to make reasoned decisions in challenging situations. The pressure of rising population and societal dynamics necessitates that engineers will be called upon to design and implement sustainable systems and technologies with multidisciplinary implications [1]. The engineers will need to possess such skills as technical know-how, critical thinking, creativity, life-long learning and team work among others, which underpin an engineer's performance effectiveness in a wide array of settings or contexts. These skills (educational outcomes) are an integral part of what is expected from universities and therefore the responsibility of every engineering faculty to ensure that they are met through appropriate curriculum, instructional strategies and assessment.

However, these outcomes are often not adequately met with the traditional behaviourist educational paradigm, the "Instruction Paradigm" [2], that encourages content delivery and memorization of facts. Behaviourist learning theory enforces authoritarian manipulation of people and sees learning seen as acquisition of new observable behaviour within the framework of universal laws [3] [4]. The overt behaviour acquisition is a series of learning events, rather than a process, with focus on a set of achievable and verifiable outcomes. There is no consideration for mental activities by the learner and creativity and independent learning are not priorities. Passivity and rote learning are fostered. This educational paradigm is content/instruction-based with the instructor assuming the position of an all knowing authority and trainer and holds the key to learning success [4]. Knowledge is separated into many mostly unconnected parallel parts and the teacher knows which parts are most important [5] [2]. Motivation is by carrot and stick method and an engineer is "produced" when a student is assessed to have received the specified amount of

instruction [2]. "I just don't feel that that is a way to increase students' learning fully. They may learn a lot, but they may also forget a lot very quickly" [6]. Table 1 depicts the behaviourist educational procedure and the instructional events within this framework.

Table 1: Behavioural educational procedure.

Behaviourist Educational Procedure	Behaviourist Instructional Events
<ul style="list-style-type: none"> <li>• List specific objectives and learning outcomes.</li> <li>• Assessment must be based solely on these outcomes.</li> <li>• Break the course down into units.</li> <li>• Sequence these units according to the desired learning.</li> <li>• Present the rules for learning the units and their topics.</li> <li>• Ensure that learners respond and learn as planned by mastering the topics.</li> <li>• Provide opportunities for feedback.</li> <li>• Reinforce correct behaviour with immediate rewards.</li> </ul>	<ul style="list-style-type: none"> <li>• Call for and gain the learners' attention</li> <li>• State the objectives so they know what is expected</li> <li>• Remind learners of what has been learnt before</li> <li>• Highlight key features so they perceive what is important</li> <li>• Create a learning pattern</li> <li>• Promote learning events</li> <li>• Give opportunity for feedback</li> <li>• Evaluate assimilation progress and satisfaction</li> <li>• Signal future learning</li> </ul>

*Source: adapted from [3]*

This behaviourist model is highly limited when there is need for deep learning, with learner identification, to foster creativity, initiative and originality and impact critical thinking and problem solving and other life skills.

Engineering education criteria are usually stipulated by recognized accreditors for engineering programs. Among the most respected accreditation organizations in the U.S., ABET (Accreditation Board for Engineering and Technology) provides leadership and quality assurance in engineering education [7]. QAA (Quality Assurance Agency) does the same in the UK and has set Subject Benchmark Statements (SBSs) for engineering teaching and learning [8]. So also have other bodies in other countries. The criteria and SBSs highlight the skills, qualities and attributes of an engineer (a graduated engineering student), and the criteria for engineering education curriculum content. They are usually a

reference for academic review and evaluation of standards and outcomes for engineering education. Engineering students are expected to acquire and demonstrate these skills and qualities. The main expected engineering educational outcomes stipulated by ABET and collaborated by both QAA's SBS and others include the abilities to:

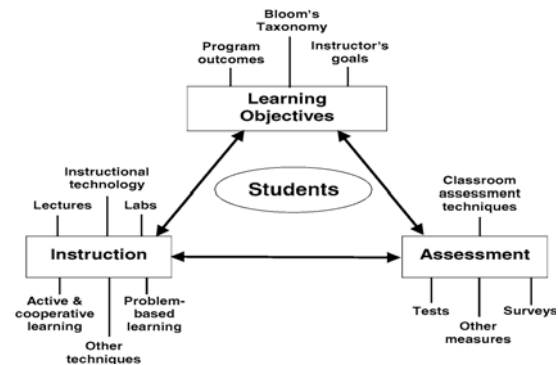
- Apply knowledge of math, science and engineering.
- Design and conduct experiments, analyze and interpret data.
- Design a system, component or process to meet desired needs.
- Function on multi-disciplinary teams.
- Identify, formulate and solve engineering problems.
- Understand professional and ethical responsibility.
- Communicate effectively.
- Understand the societal impact of engineering solutions, use the techniques, skills and modern tools necessary for engineering practice and engage in life-long learning.

Source: [7]

Obviously, the behaviourist model is unsuitable for these current general requirements of engineering education despite building effective aspects of practice such as repetition, presenting strong and varied stimuli, planning, sequencing of learning events and objectives specification [3]. Studies indicate that only 20 to 30% of life skills and competencies are acquired in schools, an indication of the accelerating ineffectiveness of the traditional ways of teaching [5].

The need for “an educational framework that takes into account not only the need for knowledge mediation packed in arbitrary subjects but also the need to (know and) develop the whole personality of the learner” [4] was a driving force for a paradigm shift to the “Learning Paradigm” [2], a student-centred (learner-centred) educational model. The learning paradigm, based on the cognitivist/constructivist learning perspectives, is for learning enhancement, fostering critical and sustainable thinking, promoting experiential learning and cognitive growth. The emphasis is no longer on teaching but on learning. Instructors are now required to not only change their use of the lecture time but lecture must be used in conjunction with other methods and techniques in order to facilitate learning [9].

Cognition employs the concept of mental processing and focuses on the way that learners gain, view and organize knowledge [10][3]. It emphasises development of intellectual skills which are the basic tools for design, analysis, discussion, evaluation, synthesis and problem solving generally. Constructivism, on the other hand, poses that people construct their own meaning from information by building on previous knowledge and experiences. Learners find individual meaning in situations based on different experiences and constructs of the world and reality which asserts learning autonomy [3]. The instructor is no longer in charge of student learning, rather, the student is in charge of his/her learning with the teacher as a facilitator and mediator. The emphasis is not on accumulation of facts but on making meaning and understanding. This change in emphasis from teaching to learning has deep implications for teaching and assessment which suggests an intimate association (Figure 1) [11]. Changes or improvement in one may lead to reformation in all or any of the others.



Sources: [11]

Figure 1: Elements of an engineering course

This paper is focused on addressing the implications of this paradigm shift. Its main aim is to help the engineering instructor, tasked with the production of globally competitive engineers, gain useful insights. The paper is also beneficial to the engineering student, the focal point of the discourse, whose familiarity with the term was found to be so poor that despite a University's student-centred policy, 60% of the students had not heard of the term [12]. In the final analysis, it is the instructors and students, working together to make the difference between excellence and mediocrity, that are the most directly able to actually improve learning [13]. The introductory section describes the instructional paradigm and highlighted the paradigm shift to learning. Subsequent sections address the implications of the paradigm shift for assessment, instruction, the curriculum and the engineering laboratory education.

### FROM TEACHING TO LEARNING

Universities' existed to provide instruction (the end or purpose), within the instruction paradigm, and corresponding structures put in place to provide for the activity of teaching. Profoundly there is now a clear shift in purpose: to produce learning with every student [2]. Learning is holistic with knowledge as an interaction of inter-related parts.

There is a huge amount of interwoven literature on teaching and learning with researchers using the various learning concepts interchangeably with varied definitions of learning. Honderich's [14] description of learning as “the acquisition of a form of knowledge, ability or skill, through concept formation, involving mental process and the use of experience and practice”, aptly captures the fundamental objectives of student-centred learning and clearly highlights the deficiencies of the content/teacher-based model of engineering education.

### Student-Centred Learning (SCL)

The Student-centred learning paradigm seeks to improve the quality of learning through a redefinition of the learning environment, the roles of the instructor, the roles of the learner and the relationship among them” [1]. The emphasis is on participatory learning and understanding and increased responsibility and accountability on the part of the student [15]. It advocates for reduction in the amount of lecture hours and an increase in problem-based activities and student independence and self-

reliance with decreased reliance on instructors to provide answers to problems and questions. Students take responsibility for their own learning and the instructor takes the role of a facilitator, guide or mentor in the learning process. This is a significant departure from lecture-based learning which signifies a paradigm shift [1] [16]. Problem-Based Learning is a major student-centred teaching and learning tool which incorporates collaborative, active and experiential learning and has relevance in situated learning where learning is not only real-world based but a function of the activity, context and culture in which it occurs [17]. SCL has been shown to be an effective approach to learning [15].

However, it is not entirely without criticism. It has been cautioned against allowing individual learning concepts to overshadow the learning needs of the entire class as a single body [18]. Also, Students expect and may prefer instructor-centred learning due to their dualistic nature and secondary school experiences and therefore may not fully appreciate SCL. Studies show that students hold very positive views of student-centred learning as a feature of high quality education [19] [20]. Instructors, on their own part, may see it as a breach of instructional tradition with the general feeling that nothing beats the traditional teacher controlled classroom [6]. This is why adoption of SCL calls for a paradigm change in instructors' professional profile and change in conceptions. An instructor's conception affects both her activities as an instructor and the learning outcomes of the students. It has also been argued that SCL is mainly a Western approach and may not necessarily effectively transfer to countries in transition where there are limited resources, different learning cultures and large classes [21]. This argument has been addressed by situated-learning in which knowledge is presented in an authentic context, i.e., settings and applications that would normally involve that knowledge and learners become involved in a "community of practice" that embodies certain beliefs and culture [17].

### **Problem-Based Learning (PBL)**

PBL is about giving students repeated practice in formulating solutions to genuine real-life technologically and socially relevant problems, which is one of the best ways to inculcate the culture of lifelong learning [11]. Learning results from working towards the understanding and resolution of a problem, where the problem is encountered first and students are forced to identify what they need to learn to solve the problem [22]. Finding a solution to the problem requires students to think, reason, research, evaluate and engage in peer tutoring and self- and peer-assessment.

PBL originated from efforts to find an alternative to the traditional approaches of preparing medical students for future professional practice which was necessitated by the fact medical professionals, like engineers, are often faced with new types of complex ill-defined problems requiring analytical and reasoning skills [23] [1]. The main elements of PBL are the essential ingredients of student-centred learning [1]:

- Problems should be ill-defined and allow for free inquiry by students.
- Problems must be multidisciplinary.
- Student collaboration should be encouraged in both group- and self-directed work.
- Students must constantly re-analyze problems as individuals and as a group.
- Students must reflect on what they have learned from the problem.
- Students must take part in self and peer assessment.
- Problems must have value in the real world.
- Student assessments must evaluate problem solving (and other) skills.
- PBL must be rooted in the curriculum, not episodic.

Source: [1]

PBL has achieved widespread adoption and is so important that universities now facilitate PBL staff development initiatives [22] [1] [24]. Methods, approaches and initiatives for selected universities that have incorporated PBL into most or all of their undergraduate programs have been detailed [1]. A typical example is the application at the Colorado School of Mines where most undergraduates complete a projects course, specifically designed to harness the benefits of PBL, in six out of their eight semesters [25]. The students work in teams on open-ended problems given to them by an industrial or government agency client while instructors mentor them through the experience. The project is reported to have yielded very satisfying results in meeting stipulated engineering education criteria. PBL application methods to address engineering education criteria have been articulated [11]. For the interested reader, there is a PBL web site at [26].

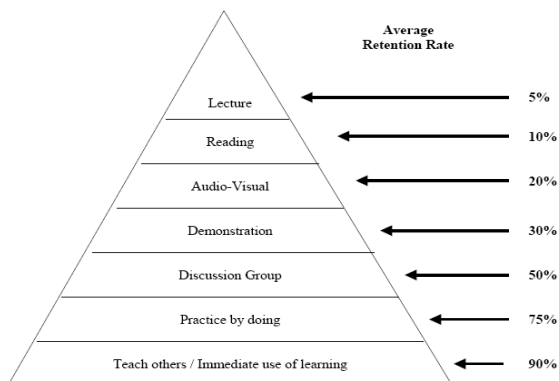
### **Collaborative Learning (CL)**

This concept is usually confused with cooperative learning because of the overlap or inter-concept usage. Panitz [27] has not only made a clear distinction between these concepts but has also given a clear and concise definition of CL. "*Collaboration is a philosophy of (group) interaction ...not just a classroom technique. ... it suggests a way of dealing with people which respects and highlights individual group members' abilities and contributions. There is a sharing of authority and acceptance of responsibility among group members for the group's actions...*" This is said to be distinct from cooperative learning, a classroom technique, in which students work in teams, with defined roles for each student, to accomplish a specific task at hand [28], while each student is assessed individually [29]. Cooperative learning is usually not an integral part of the curriculum, unlike collaborative learning. "Learning is enhanced when it is a (collaborative) effort... Sharing one's ideas and responding to others' improves thinking and deepens understanding" [30]. A basic criterion is that a collaborative situation should be quite interactive to a certain degree which is defined by the extent to which the interactions influence the peers' cognitive processes [31]. Measurements of the effects of collaboration indicate conceptual change, increased self-regulation, promotes learning outcomes and academic achievement and student retention [31] [1] [30]. The power of group work has also been demonstrated [32].

### **Active and Deep Learning (ADL)**

- Students must take responsibility for their own learning.

Passive and Surface Learning (PSL) is enforced by the traditional lecture-based instruction. “Products of PSL may not effectively apply knowledge from learning unless the area of application is related to what has been lectured. The hallmark of a PSL product is lack of confidence and despondence in the face of problems, for failing to make learning an active endeavour” [9]. This is a manifest of inherent problems of lectures: students’ attention is inversely proportional to the lecture time; lectures promote surface learning of factual information. Learning is an active process [3]. Active learning instructional approaches ensure students are involved in more than listening and are involved in “doing things and thinking (reflecting ) about what they are doing” [28]. Active Learning activities enable tutors have a new role as facilitators, giving more responsibility to students and as shown in Figure 2, affords student a 75% retention rate.



**Figure 2: Learning Pyramid** Sources: [22]

The instructional strategies that promote active learning in engineering include simulations, student presentations, library/research assignments, problem solving, peer teaching, problem-solving exercises, writing tasks and homework. Details of these and so many other strategies are given in [33][34][35][36][37]. The number of possible active learning tasks is limitless [33]. The activities to be used depend on the instructor and the objectives of the particular class. Some of these activities involve team work, trial and error or actual visits to industry [28] [38]. Instructors can utilize the opportunity of active learning to integrate writing activities, a key lifelong skill and reflection tool, into their teaching, in order to extend their thinking and meaning exploration [39]. The idea is not to teach how to write but to promote writing as a tool for thinking, an essential ingredient of engineering practice [39].

Active learning has been included on a list of recommendations for teaching methods that work [38] [40] [41]. It also has been proven to have positive effects of knowledge and skill acquisition [32]. Several techniques to make active learning as effective as possible have been suggested [33].

### IMPLICATIONS FOR ASSESSMENT

Assessment in education “describes any processes that appraise an individual's knowledge, understanding, abilities or skills” [8] and equates to testing in order to judge if learning has taken place [41]. Assessment is said to drive learning [42][8]. Traditionally, assessment may

be formative or summative and uses triangulation to ensure validity and reliability [43]. There are diverse assessment practices and tools. The use of written examination is a strong traditional practice and the giving of mark is over emphasised while the giving of advice, mentoring and the learning function is de-emphasised [12]. Student-centred learning necessitates that assessment is more diagnostic in nature to enable the collection of data or evidence that provide educators with information they need to motivate and enhance learning. There is a shift from assessment for accountability to assessment for improvement [13]. Instructors need to know what the students know and identify learning gaps. Classroom Assessment Techniques (CATs) [44][45][46], classroom research [13], dynamic assessment [47] and assessment of cognitive development [48], among others, provide such diagnostic data. Classroom assessment and classroom research are often used interchangeably but there are important differences between them. Classroom assessment addresses the status quo: what did students learn from the day’s activities, what did they fail to understand or what did they have further questions about? Classroom research, on the other hand, attempts to answer questions having to do with understandings and attempts to provide insight into how students learn and is used to study learning [13].

### Classroom Assessment Techniques (CATs)

CATs are teaching tools as well as assessment devices that aid the instructor to take a snapshot of the status quo and collect student feedback about their learning which helps answer the following questions [44] [13]:

- What are students actually learning in the lecture/lab?
- How are the students progressing toward the learning objectives?
- Where are they having difficulties in learning?
- Have they missed any important point?
- What did they fail to understand?

Source: adapted [44]

The instructor is able to identify learning gaps. The most famous CAT is the Minute Paper which “requires students to stop and think about what they have learned, to synthesize and articulate an important piece of learning, to express themselves in writing, and to think actively about what they did not understand. It engages students in evaluating their own learning” [44][13]. It is simple and easy to administer and provides immediate feedback to both teachers and students about the “learning that is taking place— or not taking place — in any given classroom while it is still fresh in everyone’s mind” [44]. The feedback of the Minute Paper is very informative. Feedback is probably the single most important ingredient in improvement [13] [49]. The Minute Paper is used in more than 400 classes at Harvard [44]. A Harvard Professor, Fred Mosteller, found it so useful he invented a version of the Minute Paper that he calls the Muddiest Point — an invitation to send a message to the instructor [50]. CATs afford students opportunity for self-assessment and teachers, opportunity for the development of scholarship of teaching [44] [51].

Other CATs tools include Background Knowledge Probe (BKP), Focused Listing (FL), Directed Paraphrase (DP),

Memory Matrix (MM), Process Self-Analysis (PSA) and Diagnostic Learning Log (DLL) [44]. The BKP is used in probing student's prior knowledge or experience of the subject which provides information on variation in background of the class especially in a situation where a prerequisite subject is crucial. These assessment tools take a few minutes of lecture time either at the beginning or at the end. Some are more effective when done outside the class session but are all an integral part of the learning process. The frequency and type of CAT depends on the class, the subject, the learning objectives and what is to be diagnosed [49]. The Cross and Angelo Handbooks [45] [46] are a good reference for implementing CATs.

### ***Student Development and Assessment of Intellectual Growth***

Studies indicate that students' cognitive processes develop over time from simple black/white thinking to a more complex evaluation of alternatives as they learn [51]. Quoting Felder [52], "...students enter college in what is referred to as a state of "ignorant certainty," believing that knowledge is certain, beliefs are either right or wrong only and the authorities (e.g., their professors and instructors) have all the answers and their job is to memorize those answers and repeat them on tests... As they gain experience, most (students) gradually progress toward a state of ... "intelligent confusion," in which they recognize that all knowledge is contextual, take responsibility for making their own judgments on the basis of evidence rather than relying on the word of authorities, and become relatively sophisticated at gathering and interpreting evidence from a wide range of sources. ...This progression has been referred to as intellectual (cognitive or epistemological) development".

The most accepted and applied cognitive models are those by Piaget [53] and Perry [54]. Piaget focused on child cognitive development while Perry focused on university students' cognitive development. Perry's scheme currently provides the framework for assessing cognitive development of learning. The scheme models nine developmental positions which are indicative of students' cognitive thinking and reasoning levels. Developmental assessment of probes the intellectual growth of students and provides information on the effectiveness of a subject, project or lab in promoting the intellectual growth of students. The Perry scheme has been used extensively in assessing the intellectual development of students and its application in engineering is described in a number of studies [25] [51] [52]. A student's cognitive position is measured through an open-ended interview process and/or the use of psychometric instruments full details of which are available from The Centre for the Study of Intellectual Development and The Perry Network [55]. The intellectual growth of students can be stimulated by challenges to their beliefs characterized by their current developmental levels [56].

### **IMPLICATIONS FOR INSTRUCTION**

The paradigm shift has extensive implications for instruction (teaching) and calls for a paradigm change of

the instructors' professional profile and commensurate conception of teaching. Teaching is a skill that has to be cultivated as good grounding in the basics of one's own discipline alone does not make a good teacher. Teaching needs to be scholarly and like learning, should be collaborative, active and creative and needs to be organized around learning in order to be more learner-centred which requires "knowing" the learner [57]. Students are said to differ in their learning styles; approaches to learning and orientations to studying; and intellectual development [52]. There is a diversity of learning styles based on learner preferences, influenced by habits, past learning and individual strengths and weaknesses [58] [4]. Different learner characteristics necessitate diversification of instructional strategies in order to achieve a high correlation between teaching and learning. Table 2 depicts restructured Felder-Silverman's [58] widely cited dimensions of learning and teaching styles.

Table 2: Dimensions of learning and teaching styles

<i>Preferred Learning Styles</i>		<i>Corresponding Teaching Styles</i>	
<i>Learning Style</i>	<i>Stimulation Method</i>	<i>Teaching Style</i>	<i>Emphasis</i>
Sensory/ Intuitive	Perception	Concrete/ Abstract	Content
Visual/ Auditory	Input	Visual/Verbal	Presentation
Inductive/ Deductive	Organization	Inductive/ Deductive	Organization
Active/ Reflective	Processing	Active/Passive	Student Participation
Sequential/ Global	understanding	Sequential/Global	Perspective

Source: [58]

The teaching styles require different types of instructional technologies ranging from simple presentation systems to multimedia technologies and e-learning systems.

### ***Instructional Technologies***

E-learning systems and web-based and multimedia technologies offer many possibilities for innovation in teaching and have the potential to overcome the shortcomings of the traditional classroom. Instead of talking about things and allowing students use their imaginations, teachers use interactive animations to enhance learning. They comprise significant levels of simulation and animation that enable the teacher adopt motivating and stimulating teaching styles to cater for the diverse learning styles in order to positively meet the stipulated criteria and outcomes. They can enhance active student participation using live demos and provide mechanisms for presentation using pictures, block diagrams and simulated schematics to appeal to visual learners. The GUIs allow users to interactively change the behaviour (reconfigure) of the system to appeal to the active learner. The inductive learner has facilities to dynamically set parameter values and watch the varying results. The ability to provide an overview of large scale systems with links to detailed demonstration of underlying properties should appeal to the global and sequential learner. The sensory learner is accommodated through demonstrations and concrete examples of underlying concepts. Hence, multimedia technologies and e-learning systems provide powerful means of supplementing existing classroom instruction to address



all types of learners and provide teaching styles to match any learning style.

Popular e-learning systems include SOAP, WebCT, BlackBoard and Learning Management System (LMS). There are also intelligent Tutoring Systems (ITS) that enable adaptive teaching and a number of software systems that are applicable in engineering education such as: MathCAD, MATLAB, and TK!Solver [59] [60] [61] [62] [63]. Symbolic algebra programs such as MAPLE, MACSYMA, MATHEMATICA, DERIVE and THEORIST may be used to teach calculus and may also be useful in engineering analysis and design [64][65][66][67]. Computer Aided Design (CAD) programs such as ADAMS, ASPEN, NASTRAN, SPICE and pSPICE, are also tools for teaching engineering [68] [69]. These programs are extremely powerful, specialized, and realistic. They can be used to work complicated problems in greater depth with reduced number of errors. However, they may be expensive to licence. A freely available e-learning system is Moodle, an Open Source software, under the GNU public licence [70]. These software systems have proven to have beneficial effects on learning [71] [72]. The extent of the use of e-learning environments in universities all over the world is difficult to determine but reports indicate that there are very significant advances in its use.

### ***Collaborative and Creative Teaching***

The educational system constitutes of interrelated or interactive parts that are handled by different educators. If every educator thinks only about his own subject or purpose, the system suffers and turns out to be a competition of parts [73]. Instructors are very good at their own disciplines, they know a lot about it but they need to understand that it's one part out of the whole system and therefore need to collaborate to integrate their thinking and efforts while being creative. Collaborative teaching "is an ongoing process whereby educators with different areas of expertise voluntarily work together to create solutions to problems that are impeding students success, as well as to carefully monitor and refine those solutions" [74]. A number of Instructors take responsibility for planning, teaching, and monitoring the success of learners in a class. It is a process and not a specific service delivery model [74]. Three approaches for implementing collaborative teaching have been proposed: team teaching, supportive learning activities, and complementary instruction. Complementary instruction requires that one instructor takes primary responsibility for teaching content material and the other(s) for teaching functional how-to skills so students can successfully understand and acquire skills from the content material.

Also, instructors are required to teach more creativity despite the fact that they feel they have no time to teach anything but the fundamentals and stipulated content. They can teach the stipulated content and yet be creative. They can get students to think in creative ways using mind mapping and encourage them to think by honouring and acknowledging the importance of their thinking. The "incubation model" [73] is a good creative teaching tool. It is a three-stage model: content related observation

activities; classroom fundamentals and content teaching; accommodation for the continuation of that learning, something that will connect them to additional learning or experiences in that field, or that will inspire them to pursue answers to curiosities that develop. Creative teaching can be applied anywhere and in any subject area.

### ***Scholarship of Teaching***

This is one of the emergent issues of student-centred learning which calls for a broader definition of scholarship to include the scholarship of teaching [75] [76]. "The current definition of scholarship is seen to be narrow and excludes areas of academic activity and productivity that are vital to the fulfilment of educational mission. According to this narrow definition, scholarship is demonstrated only by research and dissemination of new knowledge. For this reason, teachers are often not promoted if they do not engage in research" [77]. Teachers then give priority to research over teaching because teaching is not rewarded. Boyer's work [76] is intended to correct this overemphasis on research and publication as the route to promotion and tenure. This rethink of the instructor reward system is in synchrony with student-centred learning and was on the priority list of about 88 percent of research universities and 56 percent of the liberal arts colleges in America and was also a special program of the American Association of Higher Education [44].

However, the questions is how to evidence, represent, evaluate, examine, publicly display, archive and reference the practice of teaching in order to conclude that a particular teaching has coursed student learning to take place. How can learning be represented as an evidence of a particular effective teaching? It has to be made transparent, for public scrutiny, how learning has been made possible [78]. This question is at the core of over a decade of discussions because criteria for evaluating scholarship in teaching needs to be defined before teaching can be assessed [77]. Evidence has to be presented to show that defined teaching standards have been met and that other related activities, such as advising, mentoring, developing curriculum and instructional materials, and educational administration have also been done in a scholarly manner [77]. The quest is to find a means of documenting and referencing teaching that is comparable to the archival functions of research [79]. Fincher et al [77] have proposed the kind of evidence that can be collected by educators to demonstrate if Glassick et al.'s [80] scholarly criteria for instructors' roles have been met (Table 3).

Meanwhile, teaching portfolio has become well established as the dominant form of archiving teaching and has been adopted in over 2,000 higher institutions in the US [81]. The Call for changes in instructor reward system has also been stimulated in many other countries including Australia. The adoption in Irish universities was driven by seminar series and support of university administration and linkage with US universities, with emphasis on the "development of a statement of personal, individual teaching philosophy" [81]. This requires self-reflection and reflective writing by teachers.



One implication of scholarship of teaching is that teachers will need to know more about how their students learn. This may require instructors to get professional qualifications in teaching and learning. Majority of engineering teachers have never had a formal course in education and the lack of necessity for it is often rationalized [11]. This is the focus of development in the UK, with regard to scholarship of teaching, as against teaching portfolio in the US. “It is now compulsory, in most UK institutions, for new academic staff to obtain at least a postgraduate certificate in teaching and learning” [81].

Table 3: Kinds of evidence for the scholarship of teaching.

Criterion	Questions about an Instructor
Clear goals To what extent does the instructor . . .	<ul style="list-style-type: none"> <li>articulate clear, realistic, achievable goals/objectives that relate to the course/clerkship expectations and level of the learners?</li> <li>appropriately sequence goals and objectives, and state them in the context of basic knowledge and/or important/current questions in the field?</li> </ul>
Adequate preparation To what extent does the instructor . . .	<ul style="list-style-type: none"> <li>use accurate, current resources to develop the content of lectures?</li> <li>select, synthesize, and interpret material matched to the level of the learners?</li> <li>demonstrate command of basic concepts and current thinking?</li> </ul>
Appropriate methods To what extent does the instructor . . .	<ul style="list-style-type: none"> <li>use methods that reveal the logic, organization, and relevance of the material?</li> <li>match the quantity of material to audience level and allotted time?</li> <li>use images, metaphors, analogies and examples that connect the subject matter to the students' experience and knowledge?</li> <li>demonstrate responsiveness to learners' reactions during the presentation?</li> </ul>
Significant results To what extent . . .	<ul style="list-style-type: none"> <li>do learners' narrative comments and ratings indicate that the lecturer achieved the goals and objectives of the presentation?</li> <li>does learners' performance on comprehensive, cumulative examinations, demonstrate achievement of objectives?</li> <li>does the lecturer model teaching techniques that are adopted/ adapted by other faculty members?</li> </ul>
Effective presentation To what extent does the instructor . . .	<ul style="list-style-type: none"> <li>communicate to learners evidence of systematic application of one's intellect?</li> <li>demonstrate enthusiasm and interest in the topic?</li> <li>deliver the message with clarity and organization?</li> <li>provide handout material matched to the goals and objectives of the presentation?</li> <li>capitalize on the spontaneous occurrence of “teachable moments” during the presentation?</li> <li>present difficult topics in ways that help students learn?</li> </ul>
Reflective critique To what extent does the instructor . . .	<ul style="list-style-type: none"> <li>enhance his or her teaching skills through reading, discussion with colleagues, or participation in workshops?</li> <li>seek and respond to feedback regarding his or her teaching?</li> </ul>

Source: [80]

## IMPLICATIONS FOR CURRICULUM

Fostering development among characteristically diverse students faced with an unprecedented choice of values, rapid changes in technology and a dynamic society with demand for new competencies presents a challenge to engineering faculties. Transforming an educational system to embrace student-centred learning in order to impart sustainable skills and thought equates to a redesign or reform of the curriculum. Redesign signifies a complete integration of the concept into the curriculum at all levels, as against “bolt-on” or “build-in”, which affords an opportunity to redress problems entrenched in

a content-centred, teaching-based engineering curricular [1].

A learner-centred curriculum is intended to give students an increased sense of autonomy [12]. The overall aim is to provide a multi-dimensional curriculum that will help in developing multi-skilled individuals that can relate to the demands of their field within a dynamic social and economical environment [82]. Practice-based experiences should be integrated into every academic year of the curriculum and students recognized for their ability to work in teams to find optimal solutions to engineering design problems [83]. The specific goals of such a curricular will be to [84] [1]:

- deemphasise the linear sequencing of courses and gradual spacing over a number of years and transform the educational experience of students.
- adapt the iterative revisiting of concepts in a “spiral” model.
- incorporate thread of process and product design concepts over the entire curriculum.
- introduce appropriate instructional methodological changes and assessment processes that effectively measure the progress towards educational goals. Traditional methods are not effective in measuring the new competencies, skills and intellectual development that SCL promotes.
- address the most important challenges facing engineering education: attracting and retaining a diverse student body and providing an educational experience that builds confidence and enthusiasm in the student towards learning engineering principles and applications.

The thrust of the new curriculum will be a PBL-based structure centred on “design-build-test” experiences with focus on the experiences of the students as they progress from matriculation to graduation [84]. A major goal of such a curriculum is the preparation of students for the transition from student to practitioner. There should be clearly stated educational objectives and programme outcomes to address the educational objectives. The *program core*—“a set of courses in the program curriculum designated to address the knowledge, skills, and attitudes specified in the outcomes” [11] should be identified and *outcome-related course learning objectives* defined for each core. “A course learning objective is a statement of an observable student action that serves as evidence of knowledge, skills, and/or attitudes acquired in a course.” [11] Examples of generally acceptable learning objectives are listed in [11]. Also, outcome indicators and performance targets have to be defined.

Reforming a curriculum is not without its challenges. Student-centred roles take a time to develop and implement effectively. The increased workload for instructors and possible economic constraints of the institutions needs to be considered [83]. Also, misconceptions about the student-centred paradigm may seriously affect the curriculum reform project because of the challenge of understanding the new paradigm [83]. This understanding is necessary to guide curriculum

reform. The faculty is the backbone of the reform approach. It is its duty to provide learner-centred environments (a major prerequisite), disseminate tools and methodology of the curricular and pedagogical changes to instructors and reward teaching. The student-centred curriculum reform approaches of a number of universities have been highlighted [1].

### **IMPLICATIONS FOR LABORATORY (LAB)**

The value of lab experiences is widely acknowledged and physical experiments are indispensable for developing engineering skills. Basically, there are three types of labs: real lab (traditional lab), remote lab and virtual lab. All these lab types are computer mediated, the major differences being the degree of mediation and the psychology of presence [85]. The real lab involves the physical presence of the user in the lab where all lab instruments are physically set up. The remote labs are characterized by mediated reality and are mainly for experimental monitoring and control. Throughout literature, the definition of Virtual Laboratory (VL) is inconsistent and confusing. Virtually every online teaching and learning environment is referred to as VL. However, in this context, we take VL to be software versions of the real lab where each experimental setup is implemented in software such that a personal computer can be used to take the place of an entire workbench full of measurement and test instruments. Each experiment from signal generation to experimental setup is implemented in software using a combination of object oriented and graphical programming languages.

In a traditional engineering laboratory course, the students work through a series prescribed experiments, following instructions on equipment operation, experimentation, data collection and analysis. They then write and submit reports. This is behaviourist and not student-centred. Open ended experimental and specific objective problems that require students to take responsibility for everything from design to data analysis and interpretation/conclusions will make the lab more student-centred with better learning results. This is assuming that students are already experienced in fundamental lab use and activities from early years. [11]

However, it is not always possible to give students complete and genuine lab experience in situations constrained by very limited resources in the provision of laboratory hardware and infrastructure and/or where there is need for lab education, for large classes, with one laboratory stand. The research on virtual lab is focused, generally, on this great challenge: the need to give students laboratory experience that is as genuine as possible in resource constrained environments, despite the lack of physical contact with actual lab hardware and at the same time allow the teacher to use existing equipment and teaching materials. This has been demonstrated to be feasible and beneficial. A VL, based on Matlab and Simulink, for teaching power system dynamics and control at the undergraduate level was deployed for use in a number of countries in transition [86]. Favourable experiences of the use of the lab have been reported, an indication of VL as a workable alternative in resource constrained environments. There

are numerous other VLs including [87] [88] [89] [90] that can fulfil such a purpose. VL creation is and should be driven by need. Every implementation depends on the application, the designer and the tools used. No two implementations are exactly alike. However, the basic requirement is that every implementation should be functionally satisfying.

### **CONCLUSION**

Universities have been and are still experiencing change. The paradigm shift in engineering education from lecturing to learning enhancement implies an embrace of student learning autonomy. This demands well-planned educational experiences that help all students to develop as independent thinkers and life-long learners with full cognitive maturity. A huge body of work on student learning has been developed from which we now better understand how teaching styles influence learning. We have much to add to that body of work based on which diagnostic assessment and cognitive research have given insights into the phenomenon of learning and students' intellectual development.

The level of our understanding of student learning as instructors can only be substantiated by willingness to adopt instructional practices that enhance learning. Problem-based learning (PBL) is an instructional method where real-life problems with technical and social implications are introduced at the beginning of the instruction cycle and used to provide the context and motivation for the learning. It is always active and usually collaborative. Instructors are strongly encouraged to embed more activities in their classes. The evidence and support for active learning is extensive and should stimulate faculty to think about teaching and learning in non-traditional ways.

Research efforts on enhancing student learning has seen emergence of the concept of scholarship of teaching. In reaction to this, universities are including criteria for assessing and rewarding teaching, as a scholarly endeavour, in their requirements for academic promotion. Lecturing staff are being asked to evidence and demonstrate how their teaching is scholarly. Teaching is scholarly when a teacher's work can be made public, peer-reviewed, archived and exhibit all other qualities of scholarship. This means instructors will need to change their understanding of the term and give equal priority to both student learning and research.

The international trend in student-centred curriculum reform is the writing of learning outcomes and objectives that focus on what the student will be able to do rather than content being covered by the instructor. Student-centred education, if properly implemented, yields superior outcomes compared to the traditional approach to higher education, including: increased motivation to learn, greater retention of knowledge, deeper understanding, and more positive attitudes.

However, for a proper implementation to be feasible, the basic requirements include:

- a paradigm change of the educators professional profile
- not only a pragmatic handling of decreasing resources but change in politics and organizational improvement to ensure that all stakeholders are convinced of the need for the necessary paradigm change.
- Change in personal attitude and contribution to active and collaborative intervention.

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# ECOTOURISM DEVELOPMENT & MANAGEMENT: THE ROLE OF EDUCATION

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## ABSTRACT

Countries in Africa are faced with bleak economic and grave human conditions. Protracted civil wars, political instability, and falling prices for agricultural and mineral exports have combined to wreak havoc on the economies in the region. However, a country like Kenya in particular is still not a significant player in the world tourism industry. Ecotourism, which takes into account the value of natural resources and the interests of local communities, is a segment of the tourism industry that is growing rapidly. Since ecotourism is destined to become a substantial part of the travel industry, it is important to create an understanding of what ecotourism is, what its goals in education are and how they can be achieved. Knowledge about the possibilities ecotourism offers and the functioning of ecotourism can contribute to making tourism more ecologically and socially sustainable. This paper will look at the role that education plays in the ecotourism sector in Kenya. It calls for a coordinated, sustained and organized approach to education tourism to realize its social and economic potential.

**Keywords: Africa, Ecotourism, Education, Kenya, Sustainability**

## INTRODUCTION

The principle to which ecotourism should adhere is that of education. Wight [1994, p.40] asserts that ecotourism "should involve education among all parties – local communities, government, non-governmental organizations, industry and tourists (before, during and after the trip)". Guides should therefore have been taught conservation issues and the tourists should be told about local

conservation efforts and why they are deemed important. Tourists should be made aware of the damaging potential of their stay and should be properly informed on "ecotourism etiquette" and how to behave to reduce any negative impacts they might have [Cater, 1994, p.81]. Sub-Saharan African countries can increase their tourism earnings by tapping into this growing market phenomenon of Education Tourism. The combination of a crippling debt burden, political instability, civil wars and falling export prices is that living standards are lower today in sub-Saharan Africa than they were at the time of independence in most countries (Ankomah & Crompton, 1990). Attempts are being and continued to be made by leaders in the sub-region to alleviate these conditions. Promotion of mass tourism is one of several strategies that have been tried (Ankomah & Crompton, 1990). However, sub-Saharan Africa is still not a significant player in the world tourism industry. The sub-region accounted for less than one percent of the world's total tourism receipts in 1997 (WTO, 1999). What is Education Tourism? The term education tourism or education tourism refers to any "program in which participants travel to a location as a group with the primary purpose of engaging in a learning experience directly related to the location" (Rodger, 1998, p.28). It is comprised of several sub-types including ecotourism, heritage tourism, rural/farm tourism, and student exchanges between educational institutions. The notion of traveling for educational purposes is not new (Gibson, 1998; Holdnak & Holland, 1996; Kalinowski & Weiler, 1992) and its popularity in the tourism market is only expected to increase (Gibson, 1998; Holdnak & Holland, 1996). Many times over, Kenya has been listed among leading ecotourism destinations for visitors seeking a close encounter with nature. The untouched wilderness, abundant wildlife and diverse landscape combine to offer the visitor serene holidays and scenic drives. And all these come with a blend of Kenya's unrivalled hospitality through its friendly people. This combination of pristine environment and pristine people has been the foundation for the growth of ecotourism.

Today ecotourism is accepted as the alternative product that Kenya's tourism industry must embrace as part of its diversification efforts.

### ***Resource Base for Education Tourism***

Kenya is endowed with abundant tourism resources that could serve as the basis for education tourism. These resources may be categorized into the following dimensions: cultural/historical, ecotourism/nature based tourism/rural tourism, and study abroad programs. Examples of themes that may be used for education tourism include : studying dolphins in South Africa and wildebeest in the Mara, Kenya to discover their ecological limits; monitoring bird migration to restore declining populations and manage habitat change; tracking the habitats of rare endemic carnivores; measuring the impact of public health education and clinical testing of intestinal parasites of remote villages ; surveying traditional herbalists to preserve indigenous knowledge; finding the connection between global warming and termites by investigating Kenya's insect engineers. Other cultural and historical themes to be studied can include: arts and crafts, architecture, language, archaeological sites, music, dance, slave trade, etc.

### ***Potential Problems and Possible Solutions***

Potential problems in Kenya associated with the education tourism strategy include:

1. Limited financial resources to procure equipment, parts and other technology hardware;
2. Lack of skilled personnel to facilitate the tourism instruction delivery via the Information Superhighway; and
3. The sub-region's negative image in the tourist generating markets.

Countries and regional blocs can address the problem of limited financial resource by taking advantage of the World Bank's proposed loan and grants for Internet projects. In addition, governments will have to liberalize their over-regulated markets to foster competition and attract potential external Internet providers. Skilled personnel may be trained through technical aid from the World Bank and other international agencies. Marine Earth Expeditions works closely with researchers committed to conservation and education. Through Scientific Tourism, visitors are integrated in real-life research expeditions, taking part in various activities in data collecting, data processing, analysis, community workshops etc., depending on the program and priorities. The unique experience helps provide in-depth and close-up learning experiences otherwise impossible to obtain through regular tourism and ecotourism. Visitors are provided with specialized and tailored lectures, and may continue contributions in various manners even after completing the program. The nature and amount of "work" will be adjusted to the specific interests and capabilities of each group or individual, whereas those highly motivated will find fertile ground and for exploring their interests. Scientific Ecotours also provide mutual

benefits by helping to finance research initiatives while enriching the programs for our visitors. Revenue sharing from these programs means that a significant portion is reinvested back to the projects, thus promoting the production of new knowledge and strengthening local conservation and educational efforts. These efforts are extremely important contributions for countries in Africa, such as Kenya where regrettably science and knowledge production are rarely considered as priorities by policy makers and most private sectors, unless it can be used to their own benefit and within the shortest time. Unfortunately conflicts of interests place additional obstacles to the already difficult tasks involved in anything related science and education.

### ***Purpose of scientific ecotours:***

- 1- To promote scientific research and provide complimentary funding for science and conservation projects, and in return, to provide updated knowledge to visitors through direct participation in these projects.
- 2- To provide the opportunity for anyone to learn and experience the fundamentals in field science and conservation.
- 3- To provide alternative holidays to visitors with special interests.
- 4- To promote awareness and understanding in specific conservation issues and sustainable economic activities.
- 5- To "open the doors" to natural science and close the gap between the science and non science worlds.

### **WHY THE NEED FOR EDUCATION?**

Education is a crucial ingredient in strategies for integrating biodiversity conservation. One of the most obvious deficiencies at present is the level of education and communication skills of ecotourism operators in Kenya. The range of expertise varies enormously. Misinformation on biodiversity, ecology and management is common in the industry. This often has a detrimental effect on the tourism trade since many of the tourists traveling on ecotours are well-educated and may be alienated by deficient information and commentary. A less obvious problem is the relatively poor understanding of biodiversity conservation and ecotourism by land managers and field staff from government agencies. Programs of professional training and updating are needed, for travel agents, tourism operators and field staff (including natural area managers), to counter this problem. Some of the key areas that need to be addressed include:

- the meaning of biodiversity and biodiversity conservation;
- the relationships between tourism and natural areas;
- ecology, wildlife studies and land management;
- ecological sustainability;

- impacts of tourism and ways of preventing or minimizing them;
- true ecological values of places and their relationship to other places;
- best practices for tourism development and operations;
- interpretation of natural history;
- basic scientific concepts such as the meaning of 'scientific theory', ecological succession and species;
- ecosystem theory and practice.

These areas are best handled in training workshops conducted by national parks and other land management authorities. They can be supplemented by a wide range of accessible and easily understood literature, films, videos, and computerized information systems. Costs for such courses should be kept within reasonable limits. In some countries, models already exist for such training courses. Such courses could be mounted in association with accreditation processes for tourism operators. It is recommended that educational programs covering the basics of environmental science and ecology be a component of training and accreditation procedures for travel agents, tour operators and field staff.

#### ***Education and training***

While the tourism industry has tremendous potential to create jobs, the Government recognizes that appropriate skills and experience are necessary to facilitate employment growth as well as international competitiveness. With the projected staffing needs of the tourism industry and the current lack of physical and financial capacity to deliver education and training, the industry will increasingly be faced by a critical shortage of skills. Tourism education and training is one of the fundamental pillars of the development of a new responsible tourism in Kenya. The main principles governing the approach to education and training are as follows:

- promote the involvement of the private sector and private sector institutions in the provision of education and training;
- encourage the tourism/ecotourism private sector to increase its commitment to training;
- encourage capacity building among the previously neglected groups and address the specific needs of small, micro and medium-sized businesses (SMMEs) and emerging entrepreneurs;
- make training more accessible to the previously neglected groups of society;
- promote tourism awareness at all levels of society;
- develop and invest in an education system that will lead to self-sufficiency and reduce reliance on imported skills;

- encourage the local media and NGOs to become partners in the tourism education and awareness process in Africa;
- ensure that training is accessible to the previously neglected groups in society in terms of the appropriateness, affordability, location, duration, costs, packaging (not with unnecessary additions as to render them too costly) and language of instruction; and
- execute of training as a joint responsibility of the national and provincial governments.

#### **ISSUES IN TOURISM TRAINING AND EDUCATION**

The provision of tourism training and education has grown rapidly because of the increasing recognition of tourism's importance as a social and economic activity. However, as a relatively immature area of study, the field is characterized by disagreement over many fundamental principles (Leiper, 1987, Cooper, 2000). There is widespread disagreement as to what constitutes a tourism curriculum or the body of knowledge (Cooper, 2000; Howell & Uysal, 1987; Jafari, 1990; Leiper, 1981). There is also controversy over the distinction between vocationally-based 'training' and tourism 'education' (Gunn, 1998; Jenkins, 1997). One view of this is that tourism training and education provision tends to be *ad hoc* and preoccupied by short-term, functional outcomes rather than by long-term sustainable development objectives (Collins *et al.*, 1994; WTO/Surrey, 1996). This tendency is clearly a risk when one attempts to tailor education and training programmes to the needs of a particular industry sub-sector such as tour operations and consequently should be avoided. Curriculum development is complex and should be central to the development of training and education provision in different settings (Laird & Stevenson, 1993). Tourism educators concerned with curriculum planning can benefit from looking outward, drawing upon ideas which derive from the main stream education literature (Cooper, 2000). Contemporary definitions of curriculum are exemplified by Scheffler's programmatic approach, based on a model which links the various elements of a curriculum in a holistic way (WTO/Surrey, 1996, Tanner & Tanner, 1980, Cooper, 2000). In this context the curriculum is seen as 'the totality of the learning experience as guided and directed by the school' (Tanner & Tanner, 1980: 7). Such definitions view courses as forming part of the broader context of the curriculum, rather than considering the curriculum as a course of study in itself.

#### ***Tourism as education***

The 'eco' prefix appears to have driven an explosion of tourism marketing initiatives, while at the same time feeding proliferating critical discussion in the academic literature. However, debate about ecotourism has focused mainly on its direct environmental and economic implications, rather than on the educational claims which routinely appear in ecotourism rhetoric.

The standard pro-ecotourism argument is economic rather than educational; ecotourism is claimed to deliver economic incentives (or imperatives) for (local) nature conservation. Boo's (1990) frequently-cited study makes this claim, lightly qualified, while quarantining consideration of sustainability issues to National Parks and other protected areas (the negative impacts of air travel, for example, are not considered. Education is not always explicitly included in ecotourism definitions (Brookes, 2000). But tourism and education are overlapping categories; "tourism" itself may be taken to mean "education" in some contexts. At the same time, tourism has connotations which position it as education's opposite. Tourism is associated with the end of schooling (travel as something done after finishing university) or holiday breaks. In a further twist, travel in the tradition of the Grand Tour can be said to present the reality which formal education can only represent – tourism thus is education, while formal education is mere schooling. The extent to which such folk perceptions infiltrate tourism discourse is something to be determined, as is the extent to which they can be taken at face value. But the point remains that identifying the role of education in tourism discourse is complicated by the possibility that tourism may have educational connotations which remain un-stated, and more importantly, that 'education' and 'tourism' are neither clearly bounded nor neatly overlapping, but are engaged in a shifting and sometimes contradictory dialectic. The capacity of "education" to denote something quite narrow, such as passing on information, while connoting something more profound, provides camouflage for contradictions between ecotourism practice and sustainability, and also provides a means whereby contradictions can be resolved in favor of particular interests, often meaning business as usual. (C. M. Hall, Springett, & Springett, 1993; Kalinowski & Weiler, 1992).

### **EDUCATION AND SUSTAINABLE DEVELOPMENT**

To take seriously the possibility that nature based tourism could make an important contribution to education for sustainability requires a critique of aphoristic notions of education in tourism discourse, and attention to important omissions. What follows is intended as a step in that direction.

#### ***Social, cultural, and political dimensions of educational aims and goal settings.***

Individualism dominates the construction of education in ecotourism. The tourist is a consumer of knowledge, vulnerable to persuasion but ultimately free to pick and choose. Tourism lacks a conception of education as a public good, and of the educated democratic citizenry central to much education discourse (for example Marginson, 1993); it is therefore difficult to find purchase for discussions about the social, economic, or political implications of how tourism experiences (and knowledge derived from tourism) are distributed. Yet sustainable development is inherently political (Hajer, 1995); who decides what understandings and realities will dominate in ecotourism offerings, and by

what process? The point here is not so much that these questions are not answered in practice – ecotourism happens, so something has been decided – but that education discourse in ecotourism lacks a place for the depth of reflexivity demanded by these considerations, and is therefore inherently conservative. Ryan (1998, p. 192) comments: "tourists do learn through the modes of play offered by contemporary tourism. They learn the signs of modern tourism. "While tourism discourse is attentive to social, cultural, and political dimensions of tourism, the role of tourism in educating populations (of tourists) with a view to (possibly) radical social, cultural, or political transformation receives superficial acknowledgment at best. There are important differences here between local tourism, intra-national tourism, and international tourism. The latter may be a particularly hard case; exactly what environmental educational problems (and according to whose definitions) would require international travel by particular groups?

### **CONCLUSION**

Ecotourism discourse is sustained in part by its association with a constellation of flexible terms and concepts which allow the ecotourism storyline to be reconfigured to suit many purposes and beliefs, and which disguise deep contradictions. The role of education plays a distinctive part in this, hinting at a sense of the public good and processes of agreed social and cultural transformation, while denoting a far more limited project of passing on information and relatively mundane behaviour modification. Perhaps the collective experiences of place (or nature) of ecotourists have a profound contribution to make to the meanings and senses of reality which ultimately shape environmental politics.

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# Open and Distance Learning – the Key to Increasing Access to Higher Education for Women in Ghana

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**Abstract—** Gender advocates and development partners have targeted education as a tool for empowering women. There are several biological and socio-cultural factors that limit women's access to formal education. Compared to their male counterparts educational level of women in Ghana is relatively low. The Government of Ghana is providing several interventions for increasing women's enrolment in higher education. Open and distance learning, a system of education that overcomes almost all barriers to education has emerged as a tool for widening access to higher education for women. This paper explores the potentials of open and distance learning in widening access to tertiary education for women in Ghana.

**Index Terms—** open and distance learning, women, higher education, ICT.

## I. INTRODUCTION

Gender disaggregated data on education has revealed that compared to their male counterparts, women have attained low level of formal education. This has been as a result of women's role in society – child bearing, child upbringing, community commitments and societal perceptions about the status of women. As part of the interventions to widen access to higher education, the Government of Ghana has the strategy to promote open and distance learning. Though special emphasis has not been placed in the Government's policy to use open and distance learning (ODL) to facilitate women's education at the higher level, the uniqueness of ODL could be explored for this purpose [1]. Open and distance learning could simply be explained as any educational programme that is both *open* and offered at a *distance*. It is an educational system that has no barriers whatsoever. In principle ODL is absolutely open with no barriers or limitations in terms of entry qualification, mode of delivery or assessment. This paper discusses the potential of ODL in creating the opportunity for women to pursue higher education.

## II. STATE OF PROVISION OF HIGHER EDUCATION IN GHANA AND THE NEED FOR ODL FOR WOMEN

In Ghana, higher education is the education offered after secondary level at a university, polytechnic, specialized institutions, open university and any other institutions to provide training that lead to the award of diploma and degree qualifications. Tertiary institutions provide the platform for training people in all spheres of human endeavour such as the humanities, sciences and technology, which are the driving forces of development.

With the establishment of University of Ghana (UG) in 1948, Kwame Nkrumah University of Science and Technology (UST) 1952, University of Cape Coast (UCC) 1962, University of Education, Winneba (UEW) 1992 and the University for Development Studies (UDS) in Tamale 1992; private universities since 1998 in addition to the existence of Polytechnics in all the ten regions of the country Ghana still suffers limited access to higher education.

The expansion of tertiary institutions though contributed to significant increase in the enrolment in tertiary education, the participation rate of the age-group 18-21 years in tertiary institutions in the country is as low as 2.5% compared to 30-40% for the corresponding age group in some developed countries [1]. Available statistics indicate that from 1996-2001, only about 32% on the average, of qualified applicants for admission into the universities, and about 54% of same for admission into the polytechnics, were actually admitted. The figures have not changed much over the period. For the 2005/2006 academic year, 55% of qualified applicants were admitted into all the public universities and 78% into the polytechnics. For the same period, statistics indicate that the male-female enrolment for both the universities and polytechnics has increased slightly meanwhile the gap is still very wide. In 2005/2006 academic year the male to female enrolment ratio was 65:35 for the universities and 70:30 for the polytechnics. This is far below the national norm of 50% males to 50% females [2].

The underlying factors that have been identified as accounting for the situation of limited access to tertiary education include the following:

- Existing tertiary institutions are unable to meet the high demand for tertiary education, which has arisen out of the rapid growth in population and the expansion in pre-tertiary education, following the introduction of the educational reforms in 1987.
- Mismatch between existing academic facilities and physical infrastructure on the one hand, and the increasing number of students admitted into tertiary institutions on the other.
- Limited opportunities and avenues for working people and those who, for one reason or the other, have had to terminate their education for a period to re-enter or acquire higher education through other modes.
- Public tertiary institutions being originally developed as residential institutions because of their national character and the model adopted.
- The existing structures and facilities in tertiary institutions providing limited and in some cases, no access for people with disabilities and special needs.

The following deficiencies also exist in the structure of tertiary education in Ghana which calls for alternative modes of delivery:

- Limited opportunities for academic and professional progression, especially for those who enter the technical/vocational streams
- Limited opportunities for those who end their education at senior secondary school level and decide to re-enter the formal system at a later point in time
- Inadequate opportunities for life-long learning

These are challenges that ODL could simply overcome. As a result the Government of Ghana has recommended the promotion of ODL and the establishment of open universities as one of the key measures for widening access in its current educational reform. Ghana has a history in ODL. According to [3] the provision of ODL in Ghana predates the attainment of the country's political independence in 1957. Records show that some members of the educated and political elite during the pre-independence era used what was then called Correspondence Courses to further their education and training. Notable examples were J. B. Danquah and Kwame Nkrumah. They did this because there was hardly any higher education institution in the country at the time. It is also noted that as far back as March 1964, there was recognition that ODL and correspondence delivery was needed to serve the needs of Ghanaians, the society in which they live and the country as a whole. University committees and senior administrators have also recognised this potential [4]. But the utilisation has been very minimal. To date only two public Universities, UCC and UEW have made remarkable impact in promoting ODL at the tertiary level. The University of Education Winneba which began its ODL programme in 1998 has approximately 7000 and University of Cape Coast which began in 2001 has 17,000

students. This is why one needs to continuously bring to fore the potential of ODL in promoting higher education especially among women for their empowerment.

### III. OPEN AND DISTANCE LEARNING AND WOMEN

In a study on distance education and women, [5] explains that distance learning has been helpful in providing access to education to people who could otherwise not be able to access an educational programme. This could be rural folks, women, workers or people who are located far from the educational institutions. The societal perception of women and their productive and reproductive roles affect their participation in formal education. Society perceives women as homemakers and child minders hence any activity that takes them away from such *normal* schedules are frowned upon. As a result women find it difficult to embark on further studies, especially at their adult stage when they have begun building families. Numerous studies have proved this point [6; 7; 8; 9].

ODL is seen as having a potentially important contribution to make in overcoming barriers to women's participation in education in the developed and developing world. As a mode of study, ODL which is thought to provide flexible time management possibilities while preventing classroom attendance is particularly suited for women because of their role as housewives and mothers. Women have constraints of time, space, resources and socio-economic disabilities. ODL can help them with its outreach to their homes. It enables them to learn at their own pace and take up vocations and skills for economic and individual development. It gives them a second chance to step into the main systems of education, including higher education, enabling them at the same time to earn and learn as well as to fulfill family responsibilities.

Writing from a Canadian perspective, [9] remarks that women are enjoying ODL amid their hectic lifestyles. ODL allows them to learn at any time or any place, while juggling multiple roles given that women are more likely than men to interrupt their education and careers for parenthood and temporary confinement to the home. In a study undertaken in Athabasca University (AU) by [10], the author observes that approximately 67% of AU's students are women, the majority of whom may have had some post-secondary college education but may not have had the opportunity to complete their university studies. Several other studies have given statistical evidence to confirm women's high participation in ODL programmes. Most of the women who access ODL have been described to be in their adult stage, married, have dependants and are workers. In a study by [11] it was found that the ODL format attracted more married participants than the on-campus format: 30.4% versus 12.6%, respectively. Some of the women wanted to take their courses at home because they could not find or afford adequate childcare. Two-thirds of the women were married or divorced and half had at least one dependent. From the Newswatch [12] a study in the U.S. Department of Education showed that 7.6% of students took ODL courses in the 1999-2000 academic year. The study confirmed that of those taking ODL courses, women outnumbered men by 8.5% to 6.5%, single parents to others by 9.8% to 7.4% and married to unmarried by 10.9% to 6.7%. The study also revealed that

older women with families and jobs were more drawn to undergraduate ODL programs during the 1999-2000 academic year than were members of other groups.

In spite of these observations researchers like [9; 7; 13; 6] have sounded the caution that one should not be misled by the estimated high participation of women in ODL. In content the situation is different. Women are underrepresented in science, technology, technical and mathematics oriented courses. Compared to their male counterparts, this places them at a disadvantage. A way of going about this situation is ensuring gender awareness and promoting gender consciousness in all levels of ODL programming.

An assessment of learning styles of women in relation to ODL will also be useful in exploring ways of making ODL more women friendly. Women and men have different learning styles which affect their participation in ODL. Research has confirmed feminist theories of differential learning styles in men and women [5]. The socio-economic characteristics of women influences their learning styles to a very large extent. The influence is so strong to the extent that some scholars attribute the under-representation of women in some courses to their different learning styles. Adults have complex lives with multiple demands on their time and energy. They appreciate flexibility and individualization in their learning experiences. Institutional set ups have the potential of helping or hindering the chances of women to combine distance course with their family responsibilities and thereby contribute to more equal opportunities. It is assumed that distance learners are *autonomous* and *independent* learners who more or less study on their own and work their way through the course materials provided by the institution. The situation differs for female students. Female distance students have shown more interest in support and connectedness with other students and in dealings between students and academic staff. Unlike their male colleagues, they are oriented towards creating opportunities for meeting and working with other students. The study of [5] has found that women make different demands on the institution than do male students, and they value and utilize the services in a different way. Women also place a higher value on the local support services as a result they have a higher rate of attendance in study centres, even though they have to overcome more obstacles in order to be able to participate. This female oriented approach to learning at a distance need to be taken into account by an ODL system which actively wants to provide equal opportunities for men and women.

#### IV. A CASE IN GHANA

ODL has been extensively used for human resource development for the past two to three decades in Ghana. In the beginnings of the delivery of ODL in the country, workers, a large number of students in training colleges, and practicing teachers obtained tuition at a distance to earn salary increments and to improve their academic qualifications. Hundreds of Ghanaians were able to acquire both academic and professional qualifications in Ordinary (O) and Advanced (A) Level Certificate Examinations, in law, accountancy, management, and secretarial skills from British distance learning institutions such as Wolsey Hall, Rapid Results College, Mayflower

College, and the US-based International Correspondence School. Following these initial international programmes, for the past decade local tertiary institutions have intensified efforts at providing ODL at the tertiary level for both men and women.

In a study of 400 distance learners from University of Cape Coast, University of Education, and the foreign programmes run by University of Ghana the distance learners expressed their observations about the programmes and how it impacts on women. The instrument for data collection was structured to find out the socio-economic characteristics of the learners, reasons for pursuing further studies, what informed their decision to choose to study at a distance, their perceptions about the programmes, challenges that women face on the programme and recommendations for making the programmes women friendly.

From the results of the study, it was found that typical of ODL programmes, 63% representing 252 were females while 37% representing 148 were males. Majority of the learners were found to be middle aged adults. Only 1% of the respondents had their age up to 20 years. The remaining 99% were above 20 years. The results revealed that ODL creates opportunity for teachers to upgrade themselves. Majority of the respondents (87%) were found to be teachers with the remaining 13% being social and health workers, and self employed. Most of the respondents (70%) were found to be married and 30% were single, separated divorced or widowed. This profile of the respondents is remarkable of distance learners. These are adults who have occupational, family and societal responsibilities and therefore need flexible learning arrangements to enhance their career. Hence they found the ODL format to be suitable. The mode of delivery of the ODL programme was predominantly print, supplemented with regular face-to-face interactions, telephone contacts, emails and one-on-one contact with tutors as and when needed.

There were no indications of intensive use of ICT systems to enhance interaction among students and tutors. Interactive e-learning platforms, tele-conferencing, and other packages for e-learning were not used. There were no course websites that courses could be uploaded and downloaded online. Students mainly relied on the printed materials and the scheduled face-to-face tutorials. Final examinations were written at accredited examination centres which were usually located in the host ODL institution.

Students may find it more convenient to have computer-mediated interaction and write examinations online than finding time off their work or leaving their family responsibilities to make long trips to undertake such academic exercises. It has been noted that more and more learners are requiring flexibility in program structure to accommodate their other responsibilities, such as full-time jobs or family needs. With these constraints, students shop for courses that best accommodate their schedules and learning styles, and then transfer their credit to such universities to earn their degrees [14].

Part of the study was to find out students' (both males and females) perception of how ODL courses impact on women. In responding to the issue of how ODL is beneficial to women, respondents indicated that it gives opportunity for the women to improve their academic standards while at work (56%),

empowers them for their societal roles (15%), and provides them the opportunity to undertake their societal and family responsibilities while studying (29%).

Thinking about how ODL impacts on women, it was necessary to find out the convenience of the regular face-to-face meetings for women in terms of timing, duration of meetings, travel time and distance to meetings. The study revealed that though 69% found the regular face-to-face meetings to be convenient for women, 31% did not find it to be convenient. This was followed up with a question on problems that women face in participating in the ODL programmes.

The results showed that women face the following challenges:

- Inability to manage limited time
- Difficulty in meeting deadlines for submission of assignments
- Low participation in class discussions due to male domination in discussions
- Difficulty in combining house management with the studies
- Nursing mothers having problems of managing their babies
- Pregnancy related problems
- Suspicion of husbands
- Insecurity in making frequent travels to learning centres for face-to-face
- Pressure from career obligations

Just as expressed in literature, women who study at a distance are faced not only with career related challenges but that of reproduction and home management roles as well. Besides that, husbands who may not trust their wives pose a threat to the woman's engagement in meetings with their study partners and colleagues. While men could travel with ease to learning centres and return home at any time of the day, women have the challenge of insecurity in night travels due to experiences of highway robbery which is at times associated with rape. These are issues that strictly affect women but not men.

## V. RECOMMENDATIONS AND CONCLUSION

The results from the survey give signals for some recommendations. These include the need to harness the potential of adult learning methodologies, soliciting and utilizing communal and spousal support and the use of information and communication technologies.

### A. *Harnessing the Potential of Adult Learning Methodologies*

The study by [15] and [5] have shown that the different learning styles for men and women determines the teaching learning approaches to be adopted. Being adult learners who appreciate participatory approaches to learning and come to the teaching learning situation with some level of experience, adult teaching-learning approaches should be utilized in the process.

### B. *Communal and Spousal Support*

In Ghana and for that matter Africa, communal living and support from relatives is the norm. Since the use of household equipments like clothe and dish washing machines, micro

waves, mowers, vacuum cleaners etc to support house work is limited, women could seek support from relatives to help them manage their homes while they study.

The support of husbands and other male colleagues can also not be under estimated. To be able to make it at a distance, women need the support of their male partners both in the management of work and home and even their studies. Sensitizing men could be a starting point of soliciting their support for women on ODL programmes.

### C. *The Potential of ICTs*

ODL has evolved into a viable and innovative delivery system for higher education. It is playing a key role in university outreach and training.

The use of ICTs for ODL has special usefulness for women due to uniqueness of their multiple roles and its impact on their learning styles. Scholars have done studies on the interface between ICTs, ODL and women. While some argue that due to the learning styles of women and their multiple tasks, ICTs could be a supportive facility for their studies at a distance, others are of the view that the inherent technological challenges of women will not help the use of ICTs for ODL for women. These diverse views are evident in the studies of [16] and [17]. Irrespective of the divergent views, a well planned and effective training programme in ICT to promote industrialized education will be of tremendous support for women on ODL programmes.

Women's education to a higher level cannot be overlooked so long as empowerment continues to be on the drawing board of the development agenda. ODL has been seen as a sure way of making higher education highly accessible to women. To accomplish this, there is the need to adopt adult educational methodologies which meet women's learning styles; utilise information and communication technologies; and harness communal and spousal support so that women can explore the full potential of ODL to pursue further studies for their empowerment.

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# The One Laptop Per Child (OLPC) Project and Its Applicability to Ghana

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**Abstract-**The One Laptop Per Child (OLPC) project is an initiative that seeks to expand the use of computer technology, especially for school children, from the richer and industrial areas of the world, to the poorer and more rural areas. Not only does the OLPC project seek to narrow the “digital divide”, the project also seeks to improve educational opportunities for under-privileged children overall, by providing resources for these kids to be proactive and engaged in their own learning, through use of an internet-connected laptop. In this paper, we describe the OLPC project, its mission and goals, the XO laptop itself, and address the applicability of the OLPC project and the XO technology to Ghana, West Africa.

**Keywords-** OLPC, One Laptop Per Child, \$100 Laptop, XO Laptop, Digital Divide, ICT, Computers, Laptops, Education, Constructionist Theory, Ghana, ICT4AD, West Africa, Sub-Saharan Africa

## INTRODUCTION

The One Laptop Per Child (OLPC) project, launched out of MIT's Media Lab in 2005, is a non-profit organization that seeks to provide laptops to children in poorer and more remote areas of the globe. The vision of OLPC is to allow children who might otherwise not have access to quality educational opportunities to use the laptops to access knowledge and provide them the opportunity to engage their own capacity for learning, regardless of their physical location or financial limitations.

Headed by Nicholas Negroponte, OLPC now has numerous corporate partners including AMD, Brightstar, Chi Mei, Citigroup, eBay, Google, Marvell, News Corporation, Nortel Networks, Quanta Computer, Nortel, and SES-Astra, and non-profit partners include the Inter-American Development Bank and The United Nations Development Programme (UNDP) [1]. Corporate sponsors provided an initial research budget of 20 million U. S. dollars and provide on-going research support, while non-profit partners support the project by providing help with deployment and funding opportunities in targeted under-developed countries [2,3]. Intel, which at first labeled the OLPC laptop a “gadget” and later launched their own low-cost laptop, the Classmate PC, has now signed on as the most recent corporate partner [4].

Through funding from its corporate partners and more than two years of research and development, significant effort has gone into the design of a system and methodology that would meet Negroponte's vision of a low-cost laptop suitable for the developing world. The OLPC laptop has been specially designed for rugged, low or no electricity conditions, and has a screen that is readable in direct sunlight. It hosts a stripped

down version of Linux, has a modest processor speed, no hard drive, and utilizes a mesh interconnectivity network, which will automatically connect to other laptops in the mesh, and to the internet via a server if it is available. Software development has been mostly limited to operating system and essential applications, with the assumption that educational and other application software would be developed by interested individuals and third parties in parallel to launch and would grow in proportion to demand. Currently, the OLPC laptop is being sold only to governments, for distribution by the countries themselves, with assistance from non-profit partners. Now in prototype and initial launch stages, the OLPC laptop and project is being rolled out into several countries, where its effectiveness toward these goals can begin to be evaluated [4, 5].

Information about the OLPC Project is exclusively on-line (www.laptop.org) and largely in the form of a wiki maintained by OLPC (www.wiki.laptop.org). Because of the dynamic nature of on-line content, getting completely accurate and up-to-date information about the project can be difficult. This paper does not represent any original research surrounding the OLPC project, but instead is the authors' attempt to gather and synthesize accurate information relevant to the possible expansion of the OLPC project to Ghana, West Africa. As such, this paper is a summary and compilation of facts that the authors, a visiting lecturer/researcher and a student at a Ghanaian University, believed relevant to OLPC in Ghana, and opinions of those facts. When contradictory details were discovered in on-line information, the authors attempted to validate the correct information through external news articles or email contact with representatives of the project.

## THE OLPC PROJECT

### *History and Current Status of the Project*

The OLPC project idea was formulated in 1999 when Nicholas Negroponte and his family founded a school in a remote village in Cambodia, installed a satellite and generators, and gave the children laptops. The laptops illuminated households that had no electricity. Children taught their families how to use the computers, and school attendance increased substantially [6]. Negroponte envisioned a low-budget computer for children throughout the world, and developed the idea into a non-profit organization through MIT's Media Lab in 2005. Founding

<sup>\*</sup> Sponsored by the U.S. Department of State under a Fulbright Scholar Program grant

corporate members each gave 2 million U. S. dollars to fund the initial prototype design [3].

The project originally aimed for a price of 100 U. S. dollars per unit, and for that reason was often called “The \$100 Laptop Project”. In the interest of making the laptops as cheaply as possible, Negroponte has insisted on a large scale for the initial manufacture of the machine. Originally requesting orders of no less than 1 million units from interested countries, Negroponte later lowered the minimum order to 250,000 units, and according to OLPC representatives, smaller orders may be accepted [7]. As the initial full-scale production of the laptops approaches, OLPC estimates the laptops will cost 176 U. S. dollars per unit, although it is expected that the cost of the laptop will decrease over time. OLPC has produced its final beta version of the machine, the B4, in June 2007 and plans its first production run of some millions of machines by the end of 2007, for deployment in selected launch countries. Pilot trials at schools in Brazil, Nigeria, Peru, Thailand, and Uruguay are on-going, and according to OLPC representatives pilots in Ethiopia and India will commence soon [8]. Until full production begins and units are paid for and delivered, it will be difficult to tell exactly how many countries will be involved and how many units will be initially deployed. Reports range from 5 to 18 countries and 3 to 5 million units [9, 10]. Possible launch countries include Argentina, Brazil, Colombia, Costa Rica, Ethiopia, Kazakhstan, Kenya, Libya, Nepal, Nigeria, Pakistan, Panama, Peru, Romania, Russia, Rwanda, Thailand, and Uruguay. In addition, OLPC is actively working to sign up more countries; as many as 30 more countries are listed as “launch” or “post-launch” countries [11].

OLPC currently has no plans to sell their laptops to corporations or individuals; they say they may consider such options after initial launch [12]. It has been proposed that individuals might buy an XO at twice the price, thus funding one for a child in a poor country [6]. In addition, Quanta Computers, the Taiwanese firm manufacturing the laptops, has recently announced plans to sell a \$200 laptop utilizing much of the technology of OLPC [13].

Ghana is currently listed by the OLPC as a country which is currently seeking government support [11]. As of this writing, OLPC had received a serious expression of interest from relevant Ministries in Ghana to help advance OLPC in the country, and a preliminary meeting with OLPC representatives took place in September 2007 to discuss plans for moving forward with the project.

#### *OLPC Learning Goals*

All along, Negroponte has called the OLPC project an “education project, not a laptop project” [5]. Some of his critics point out, however, that by focusing on providing laptops (i.e. technology) to schoolchildren, without focusing on the educational content and methodology in which the laptops would be used, it is, in fact, a laptop project, not an education project [14]. Negroponte calls on the constructionist view of education, an educational philosophy founded by his MIT colleague and OLPC collaborator Seymour Papert, a philosophy of education in which children learn by doing and making, where they explore and discover

instead of being force-fed information [15]. Says OLPC literature, “With 1-to-1 access to connected laptops, children actively engage in knowledge construction and are not limited to passive reception of information. Each child can pursue learning in areas of strong personal interest and the classroom is not limited to a pre-determined, one-size-fits-all approach” [16].

Saturation of laptops into a community is an important aspect of the OLPC vision. Previous approaches to providing computers to schools typically involved an in-school computer lab. By issuing laptops to children, the laptops are available to the students for far longer than the just the time they are in school. The additional benefit of peer-to-peer teaching and learning is essential to the OLPC approach, since children teach each other, and their families, about what they are learning [5].

#### *Criticisms to OLPC and Response*

There are many ways to vocalize criticism to the OLPC project, from individual blogs and websites, to posting comments on the official project wiki, to posting on the independent blog [www.olpcnews.com](http://www.olpcnews.com), a self-described “independent source for news, information, commentary, and discussion of One Laptop Per Child's ‘\$100 laptop’.” Many people question the appropriateness of the use of resources to provide laptops for children in remote areas of the globe. Some argue that food and water and basic medical care should come first. Negroponte does not disagree, although he argues, “I have not met anybody who claims they are too poor to invest in education, nor anybody that said it was a waste of money. If somebody is dying of hunger, food comes first. If somebody is dying from war, peace comes first. But if the world is going to be a better place, the tools for doing so always include education” [9]. However, to truly equip the world's children with laptops would require an enormous amount of resources. The sheer numbers is what may lead India to back out. “We cannot visualize a situation for decades when we can go beyond the pilot stage.” Says India's Education Secretary. “We need classrooms and teachers more urgently than fancy tools” [7].

Other critics argue that if governments of poor nations spend what little money they have on laptops, they are necessarily spending less money on textbooks, teachers, and schools. The OLPC project holds the promise of bringing whole libraries of textbooks, and other educational resources, directly to the children. Negroponte, having seen the lack of educational resources, ineffective educational structures and methodologies, and the time it would take for some governments to bring basic educational resources to all its children, states, “Many children – especially those in rural parts of developing countries- have so little access to school – in some cases just a tree – that building schools and training teachers is only one way – perhaps the slowest way – to alleviate the situation” [5]. Other critics argue that it is simply the wrong technology, and providing internet connectivity via net-enabled cell phones, already a pervasive technology in even remote areas of the world, would be a better and cheaper solution. Negroponte responds, “Suggesting that cell phones are an alternative is like saying we can use postage stamps to read textbooks” [9].



## THE XO LAPTOP

### Overview

The OLPC laptop hardware is called the XO, a low-cost laptop for the unique environment of the developing world: a rugged environment, including rain, dirt, and wind; use of the laptop in bright sunlight; and low and erratic power conditions. The success of this research and development project is to be found in the specifications and components of this novel machine, and the successful manufacture of the Beta machines (initial prototypes in late 2006, and Beta 4 machines in June 2007). Recently, the OLPC XO was awarded the prestigious INDEX award for 2007, self-described as “the biggest design award in the world” [17].

The laptop itself is small: 224mmx228mmx30mm (9.5”x9”x1.2”). The screen is also small, 190mm (7.5”) diagonal, but pivots so that the machine can function as both a laptop and eBook reader. It is only 1.5 kg (under 3 ½ pounds), and has a dirt and moisture-resistant enclosure. Negroponte reports that the machine is so water resistant that you can pour water on the keyboard or carry it unprotected through the rain. It is similarly resistant to dust and dirt, and has passed 5-foot drop tests. [6, 18, 19]. The laptops have an internal video camera and microphone, an external microphone jack, WiFi antennae, a QWERTY keyboard (with multiple other keyboards, such as Brazilian, Portuguese, and Arabic, available), a touchpad cursor and stylus area, game cursor control keys, dual stereo internal speakers, and an SD multimedia slot. The laptop also provides 3 USB ports for external devices (such as printers, hard drives, more flash memory, or other external devices such as an inexpensive digital microscope being developed for the project) [18, 19].

Unlike modern computers, the XO is not attempting to use the latest and greatest general purpose hardware, but instead has specified exactly the hardware needed for the low-cost laptop. This does not mean that the laptop is devoid of technological innovation; in particular, its power conservation measures, screen, and ruggedness are all quite innovative.

### Processor

The XO processor is a modest AMD Geode running at 433 MHz, using only 0.8 Watt of power. Instead of a separate graphics controller, it is integrated with the Geode processor. The processor utilizes a novel “extreme suspend” technology, in which the processor goes to sleep after 2 seconds of inactivity, but can wake itself up within 0.3 sec of requested activity, thus contributing to the laptop’s low power consumption [18, 20].



Figure 1. The XO Laptop, with pivoting LCD screen

### Memory and Storage

Because of the intended rugged environment, there is no hard disk in the XO; mass storage consists of 1 Gigabyte of flash ROM with a high speed controller, and internal memory is just 256 Mbytes of DRAM. There is a separate display control chip, with memory, that allows the display to be active when the processor is suspended. This is another engineering innovation that allows for low power consumption of the laptops. Due to the modest processor, no cooling fan is necessary, further reducing necessary power consumption. Although clearly not as powerful as today’s multimedia and video game-ready computer systems, OLPC makers claim the laptop has plenty of power for its intended uses. An external hard drive or additional flash ROM could be added via USB, if desired [18, 20].

### LCD Display

The 152x114mm (6”x4.5”) LCD display screen has a higher resolution than most laptops on the market. It consists of a lower-resolution color display overlaid on top of a higher-resolution monochrome display. The 1200x900 mono resolution (200 dpi) display is reflective, allowing for high resolution viewing in full sun, while the lower resolution 800x600 (133 dpi) color display is transmissive and requires a backlight; a more robust and lower energy consuming white LED backlight is used instead of the conventional cold cathode fluorescent lamp. This overlaid display combination gives the appearance of a higher resolution (and more expensive) color display, while still providing full sun viewing capabilities. The screen uses only 0.1 Watt with no backlight, and between 0.2 and 1 Watt with the backlight on [18, 20, 21].

### Power

Depending on the use conditions (backlight, processor consumption), the overall power consumption for the XO is between 0.1 Watt and 3 Watts, less than a tenth the power usage of a typical laptop [22]. This attention to power consumption makes the XO well-qualified to conditions in which electricity is not available, or unreliable. There is a 2-pin DC power adaptor which can use 10-20V of usable input. The XO battery is fully enclosed in a hard case and is also a novel technology: there are 4 cells with 2 chemistries: Nickel Metal-Hydrate (NIMH) and Lithium Ion (LiFeP); combined, the batteries will last 6 to 24 hours on a full charge. In addition, the battery has at least 2000 charge/discharge cycles (to 50% of a new battery life). It appears that there will be multiple battery charging devices available, all external: a “yo-yo” pull-cord device, a foot pedal device, a solar panel, and a hand crank. The manual power sources should provide 30 minutes of intensive computing power time for 10 minutes of effort [4, 18, 20].

### Networking

The key to the internet capabilities of the laptops is its mesh networking capability. The mesh network assumes a broadband point of internet connectivity per mesh (presumably at a school). There are several different possibilities for the internet connections, including satellite, cellular, DSL, and WiMax. The laptops themselves use the new 802.11s wireless networking standard, which has increased bandwidth and a range of up to 1.5 km (a little under a mile). When in operational mode, even if the main

processor is suspended, the laptops automatically connect to other laptops, providing router capabilities in a peer-to-peer fashion for other computers in the mesh. As long as there is at least one computer operational within range, and the same is true in a path to the internet server, then all computers in the mesh have internet access. School servers provide the internet connectivity, and also act as a repository for a set of documents that are originally assembled by the school, region, and country, and may be updated later by students and teachers in the mesh network [18, 23].

#### *Software*

For software, the OLPC project has maintained an open source philosophy. The operating system, called Sugar, is supplied by Red Hat and is a stripped down version of their Fedora (Linux) core operating system. Sugar takes up a mere 130 Mbytes of memory (by comparison, Windows XP requires 1.65 Gbytes) [4]. The user interface displays other connected laptops graphically, and allows access to tools and information on other laptops, thus providing ingenious collaborative opportunities. Icons replace written menus throughout the interface. The operating system's storage is not based on the usual hierarchical based approach, but is instead based on most recently accessed items or in terms of who is connected to the mesh [4]. Application software included with the XO are a word processor, a document and PDF viewer, Firefox web browser, email and chat facilities, media player, and drawing tools. Interpreters for several programming languages, such as Python, JavaScript, and LOGO will also be included. Other software and content, such as Wikipedia and SimCity, have been offered to OLPC as well [18, 21]. Independent software development for the XO is also taking off globally; applications being developed include a Qur'anic Studies application in Pakistan, original learning games in Brazil, and a calculator activity that "shows its work" in Argentina [24].

#### *Theft Security*

Theft protection for the laptops is important, especially in poorer areas where the sale of device valued at 100 to 200 U.S. dollars could provide desperately needed income for a family. To deter theft (and also increase durability), valuable components of the laptops are soldered onto the motherboard, and the unique design of the laptop will make them be instantly recognizable as OLPC laptops [22, 25]. Upon activation, each laptop is issued a UUID (Universally Unique Identifier), which is stored with its serial number and activation code on the school server. A stolen laptop, when reported to the school, would be deactivated via the mesh network. Furthermore, a country may request a "lease" system, in which each laptop is required to check into its mesh network every so often (e.g. 21 days, or 90 days); in that case, laptops that do not check in to their mesh networks before its lease expires are also deactivated. In case of server failure, leases may be manually extended via the activation server [25]. This does not alleviate the problem of a laptop being taken over by a relative or someone else who remains in the mesh. However, the laptops are intended to be shared by family members, who might also learn to use the technology for opportunities they would not otherwise have. By saturating schools and villages with laptops for children,

the need to steal a laptop within the mesh should be limited, as everyone would likely know someone with a laptop.

#### *Breakage*

Sustainability of the hardware is another important consideration in poorer countries. Many failure-prone design elements have been removed from the laptops; for example, the motherboard lies directly behind the LCD screen, so no connecting cable (which might fail or become dislodged) is needed. As a sealed unit with no moving parts, OLPC designers do not anticipate the need for many repairs. According to OLPC representatives, the laptop has been designed to be easily taken apart, by using a screwdriver and removing 12 screws. The LED backlight can be easily replaced for about 1 U.S. dollar. The LCD screen might be replaced through government-run repair depots, or private enterprises as they develop. If a major piece of the electronics failed, the unit may need to be replaced [20]. Governments might need to provide budgets for maintaining both the laptops themselves and the necessary servers and internet connectivity.

### APPLICABILITY TO GHANA

#### *Human Resource Development and Education*

Human resource development remains one of the principle agendas for Ghana's development. According to the Ghana Poverty Reduction Strategy II, which is currently the main development plan for Ghana, "the discerning Ghanaian electorate feels compelled to raise its sights from the minimal ambitions of preventing gross poverty and distress, and instead aim at sharing in the commonly observed standards of living in the early 2000 Global Economy. .... This is to be done by achieving the status of a middle-income economy." Later, the same report states, "The lesson is that the single most crucial key to the attainment of economic success is the educational quality of a nation's work force. Government has accordingly decided that Ghana must nurture a workforce which is equipped with more than the basic levels of educational attainment, as defined in the MDG goals" [26].

Unfortunately, the current state of primary and secondary education in Ghana is poor. The adult literacy rate is approximately 60%, with up to 40% of persons over age 6 without any formal education. In 2002, some reports state that approximately 70% of primary school-aged children attended school, but enrollments were only 24% at the junior secondary level and 6% at the senior secondary level (although there are discrepancies about these numbers). Only 3-4% of students enroll in tertiary institutions [27, 28, 29, 30]. Causes of educational issues might be classified in terms of access and quality.

#### *Access to Quality Education*

In Ghana, access to equal educational opportunities and facilities is a fundamental right guaranteed by the constitution [31]. This mandate has received the government's attention and support, represented in programs like the Free Compulsory Universal Basic Education (FCUBE) program [32]. Although tuition is free at the primary level, the poor economic status of many households, with 40% of households below the 1 U.S. dollar per day poverty line [27], results in the reality that education is not a priority. Many children are needed at home to perform

subsistence chores such as carrying firewood and water, and gathering and preparing food for their families. In addition, the need for uniforms and school supplies limit the enrollment of students at all levels. Lastly, many children in rural areas walk long distances to school, although in the last 5 years nearly 4,000 new primary and JSS school blocks have been built, which in some cases has greatly reduced travel time for students [26, 29].

Another issue of access, which also overlaps with issues of quality, is the availability of materials and resources for education. Textbooks are still not issued in a 1:1 ratio in all schools (1 textbook per subject per student), although the situation is improving. For example, the percentage of primary schools having at least one English textbook per pupil was only 21 percent in 1988 but 72 percent in 2004; for math books in Junior Secondary School (JSS) these figures are 13 and 71 percent, respectively. This still means that in 2004, up to 30% of schools did not have enough textbooks for their pupils [29]. Teachers, perhaps a student's most valuable resource, are sometimes untrained and in short supply, especially in the rural areas. In 2000, 5% of primary schools had no or one teacher for the school [33]. Nationally, basic public school teacher:pupil ratios are 28:1, with some regions as high as 50:1. Teacher qualification also makes a difference. Reports show that at the national level, 30% of basic public school teachers are untrained, with percentages as high as 50% in some regions. [30]. Recent reforms and other initiatives have improved all of these statistics over the last 25 years, although there is clearly still substantial room for improvement, especially given the centrality of education for Ghana's future development [29].

Other quality factors affecting education in Ghana are teaching quality and methodology, and relative lack of ICT resources in schools. Until recently, emphasis in the education system has been on quantity much more than on quality. The President's Report on Education Reform agrees that "public education in Ghana has failed to meet expectations in terms of its coverage, quality, equitableness and economic utility." The use of multi-class teaching methods in some basic schools, whereby more than one class is grouped together and taught by one teacher, also lessens the quality of teaching. The report also recommends more practical methods of teaching and learning which will engage students and "unlock their potentials." [33]

#### *ICT and Education*

Probably the single most relevant and comprehensive document on ICT and development in Ghana is the ICT4AD policy. The mission of the policy is to "transform Ghana into an information-rich, knowledge-based and technology-driven high income economy and society." [27] The vision of the policy statement is to use ICT as the main engine for an accelerated and sustainable economic and social growth. Some of the strategies outlined by the policy to promote ICT in education, among others, are [27]:

- Mainstream ICTs throughout the entire educational system to promote life-long learning
- Develop an educational intranet to provide educational materials and tools at all levels of the educational system.
- Promote Internet access to all educational institutions including the schools, universities and colleges

- Transform the educational system to ensure that there is uninterrupted quality education for all Ghanaians from pre-school to age 17 to reduce poverty and create the opportunity for human development.
- Introduce computers into all primary, secondary, vocational and technical schools

The 2007 Budget for Ghana might address OLPC directly: "...to further enhance the usage of computers in schools, Ministry of Education, Science and Sports will be funded to take advantage of the new technology for the production of low cost computers designed specifically for basic education. The Ministry of Communication in collaboration with the Ministry of Education, Science and Sports will oversee this initiative." [34]

#### *OLPC for Ghana*

Clearly, many of these goals for Ghana's development and improvement in educational quality and increased use of ICT might be addressed by an implementation of OLPC in Ghana. Consider the stated mission of the OLPC project: "Most of the nearly two-billion children in the developing world are inadequately educated, or receive no education at all. One in three does not complete the fifth grade. The individual and societal consequences of this chronic global crisis are profound. ... At the same time, their governments struggle to compete in a rapidly evolving, global information economy, hobbled by a vast and increasingly urban underclass that cannot support itself, much less contribute to the commonweal, because it lacks the tools to do so." [35] Their assessment of the global educational crisis and its consequences is uncannily accurate for Ghana. In many ways, Ghana is exactly the country for which OLPC was developed. It must be noted, however, that a full OLPC implementation in Ghana would require enormous financial resources; for example, to provide laptops costing 176 U. S. dollars, including the associated support services, to each of the 3-4 million primary school children might cost up to 1 billion U.S. dollars. Additional monies for maintenance and for laptops for incoming students would be required each year. This amount of money, if spent in other ways such as improved teacher training, improved facilities and equipment including computer and internet access in all schools, curriculum enhancement, or other educational initiatives, might also have a tremendous impact.

However, the OLPC project has the advantage of being ready now, and not after a new generation of teachers have been trained and deployed (a complete turnover in teachers might be 40 years away). There is also an on-going fundamental problem with teachers unwillingness to go to the more rural areas in Ghana; even with improved teacher training, this is not likely to be resolved anytime soon. The current median age in Ghana is 20 years, with estimates of 60% of the population under age 25 [36, 27]. In order for Ghana to provide a quality education to its young citizens, and hope to propel itself from a Least Developed Country to a middle-income economy, reforms need to happen sooner rather than later.

The OLPC project would obviously address both access to and quality of educational opportunities in Ghana. Access, since ownership of a laptop would enable every student to have access to educational resources both at school and at home, via the laptop and interconnection network. And not

just access for school children: as children teach their parents, aunts, uncles, and grandparents how to use the machines, not only computer literacy, but, following constructionist learning theory up the age ladder, overall literacy and educational status would likely increase throughout Ghana.

Improvement in quality of education is a more complex issue. There is no question that students who are currently receiving a substandard education would benefit, and this might rightly be considered a large minority or even majority of Ghana's population (based on textbook, trained teachers, and school enrollment statistics). However, the efficacy of constructionist learning via the OLPC project has yet to be fully studied. Since pilot projects only started a few months ago, it is unrealistic to expect long-term independently researched studies analyzing the educational merit of the machines. So far, initial reports show increased attendance and participation, and more engaged learning, in schools in which the laptops have been piloted, although little data aside from this has been publicized [37, 38, 39]. Studies of OLPC in other countries facing similar challenges might further the assessment of OLPC applicability to Ghana. However, waiting too long might simply move Ghana further back in their quest toward improving education and human resource development. An OLPC pilot project, anywhere from one school to 250,000 units, might be a good approach for Ghana, if funds are available.

Is OLPC a good choice for Ghana? A full-scale implementation of OLPC in Ghana would have clear educational and development benefits, but would require an enormous amount of resources to fully implement. The main question is, are laptops the best use for such an investment? And, a related question, who exactly would pay? These are questions that need to be debated by Ghanaians over the coming months, perhaps in parallel with an OLPC pilot project, as the country decides to participate in the project, or not.

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# Institution and Capability Building in the Ghanaian Construction Industry

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**Abstract-**The particular needs for Institution (IB) and Capability Building (CB) in the Construction Industry (CI) for the upgrading of Building Technology (BT) education at two selected Polytechnics (PTs) in Ghana were identified by means of a needs assessment (NA). The NA study (2005) was part of an international cooperation project between the PTs at Sunyani and Cape Coast, the Kwame Nkrumah University of Science and Technology at Kumasi and the Eindhoven University of Technology. The project which lasts from 2005-2009 is carried out to contribute to the improvement of the CI by means of Technology and Knowledge Transfers (TKTs) for IB and CB at the PTs in Ghana. The methodological approach in the NA study is multidisciplinary. The paper discusses the Ghanaian CI; the Ghanaian education system, particularly education in BT; the state of art of education programs, staff capabilities, teaching materials and facilities for the BTech and MTech curricula in BT. It concludes with recommendations for strategies for TKTs, IB and CB, and the organisation and teaching in the Ghanaian context by including the transfer of knowledge from industry to the educational institutes.

**Keywords-**Institution and Capability Building, Technology and Knowledge Transfer, Construction Industry, Ghana

## I. INTRODUCTION

The world economy has significantly changed, due to globalisation, innovations and technology and knowledge transfers (TKTs). Globalisation - for many local construction enterprises in developing countries - has unfortunately become tantamount to a sustained acquisition of technologies from abroad, while making little use of the existing domestic technology stock. Literature points at a lack of capabilities -an extensive T&K base- in a strong innovation system as important factors for this situation for many construction industries (CI) in developing countries (DC)s. [1] Knowledge is acknowledged to be a key to socio-economic development.

The project "Capacity building in the Sunyani and Cape Coast Polytechnics to Improve Performance of the Building and Construction Industry in Ghana" aims at Institutional development, Capability Building (CB) and Strengthening of the network of the PTs in Sunyani and Cape Coast with other organizations and individuals in the innovation system of the CI in Ghana by using TKTs. The country is harmed by a fast growing population, a high rate of urbanisation and a shortage of qualitatively adequate housing and infrastructural facilities. It is expected that the results of the project positively influence the production performance of the CI, its contribution to overall socio-economic development, the competitiveness of the enterprises in the CI in Ghana and strengthen them to survive in the global knowledge based economy.

The Needs Assessment (NA) is part of this project. The NA is carried out to determine the particular technology and knowledge (T&K) gaps which need to be replenished by means of TKTs to be able to bring about IB and CB. The NA should provide data for the determination of the terms of reference for the development of the curricula for the Departments of BT of the Sunyani and Cape Coast PTs in order that the PTs will be able to offer Building Technology (BT) education that is qualitatively up to international standards..

This paper includes the following sections (1) introduction, (2) methodological approach which is multidisciplinary; it integrates building engineering, socio-economics and management studies, (3) the Ghanaian CI, (4) the Ghanaian education system, particularly education in BT, (5) the state of art of education programs, staff capabilities, teaching materials and facilities for the BTech and MTech curricula in BT, (6) Conclusions regarding strategies for TKTs, IB and CB, especially organisation and teaching in the Ghanaian context.

## II. METHODOLOGICAL APPROACH

The NA took place in 2005 by the authors of this paper by using a multi-disciplinary approach in which socio-economics, engineering and educational studies were combined. The NA included a number of sub-studies on (1) the Ghanaian construction industry, (2) the Ghanaian education system particularly BT education and (3) the state of art of the education at the two PTs in Cape Coast and Sunyani.

Data collection took place by means of (a) literature studies, (b) structured and un-structured interviews with the Principals of the PTs in Cape Coast and Sunyani, the Head of the Schools and the staff for the envisaged education programs on Building Technology; as well as with the staff of the KNUST at Kumasi and professionals working in the CI in Ghana, (c) Personal observation of the available teaching, library and ICT facilities, (d) a quick scan of the application of building systems and equipment in a sample of building projects both in rural and in urban areas by means of site visits and personal observations.

The main issues of the interviews and questionnaires included the management system and organizational set-up of the PTs; the management vision regarding IB and CB for BSc and MSc curriculum development in BT; the time planning for curriculum development and staff training. Data collection included also the data on the present BT education at the Cape Coast and Sunyani PTs, the teaching methodologies – theoretical learning, training of practical skills and competencies, industrial attachments – and needs for improvement; the state of art of teaching capabilities and educational background of the PT staff, staff preferences for involvement in particular teaching subjects and needs for staff training in order to enable them to successfully implement the envisaged curricula; the state of art of teaching materials – handbooks, lecture notes - and needs for acquisition and/or revision; the state of art of teaching and learning facilities (laboratories, workshops, furniture, equipment, tools) and ICT facilities (computer hardware and software) and needs for improvement and acquisition.

The assessment study among the staff at the PTs –all available teachers at Cape Coast (5 persons) and at Sunyani (16 persons) were interviewed.- resulted in an identification of the specific needs for training and monitoring and made clear what the most efficient way will be to address these needs.

Based on these data conclusions could be drawn on the particular needs for revision of the curricula for the Building Technology education programs at Cape Coast and Sunyani PTs relevant and in accordance to international standards; IB and CB in terms of teaching and learning facilities (study books and lecture notes, laboratories, workshops, furniture, equipment, tools) and ICT facilities (computer hardware and software) and staff development up to BSc, MSc and PhD level.

The findings were cross checked with Principals and Head of Schools of the PTs, staff of the KNUST at Kumasi and professionals working in the CI in Ghana.

## III. GHANA AND THE CONSTRUCTION INDUSTRY

Ghana has a large pool of inexpensive, unskilled labour. The educational attainment is relatively low. Of the economically active population (15 years and older) 2.3% is employed in the CI. [2] Although the housing needs –due to population growth and urbanization- is more of qualitative than quantitative nature, the infrastructural and housing needs put pressure on the output of the domestic CI which apparently has no sufficient capacity and capabilities to fulfil the needs. [3]

The CI in Ghana is characterised by a multiplicity of small firms. An important part (>75%-90%) of the construction activities take place in the so-called informal construction system in Ghana. The exact percentages are hard to assess. In 2002 the total number was 7095 formally registered construction firms, 90% of which are small contractors (no complex construction jobs, tender sum up to one million dollars) who belong to classes D3 and D4. Tawiah (1999) notes that the total amount of work executed by them ranges between 10% and 20% of the (formally registered) total construction output. He also mentioned that proprietors who have little or no knowledge in the CI head the Ghanaian owned firms. In their perception construction is a business, the only requirement is financial ability. The management of the firms' resources – labour, finances, materials and plant and equipment is carried out haphazardly and therefore does not promote an improved performance and growth of the firms. This becomes evident by the fact that the nation's major construction projects are awarded to the very few large mostly foreign contractors [4]. Moreover the majority of Ghanaian contractors do not have sufficient access to funds, credit facilities and do not have the appropriate technological capabilities, plant and equipment and key personnel to handle projects properly. They cannot compete with foreign contractors, especially when it concerns more complex projects. With these attributes the foreign firms have a competitive edge over the Ghanaians. It is increasingly evident that the foreign firms are more able to capture a major share of the local construction market than their local counterparts. About ten international construction companies are working in Ghana. Most basic building materials are at present produced in Ghana and sufficiently available. [3]

The development of new technologies - designs, materials and components have become more complex- the growing sophistication of customers and increasing competition between product and service suppliers have brought about profound changes in business practices in the CI. [5] Firms are urged to develop the expected capacities to meet the requirements in the industry. These emerging trends pose a great challenge to Ghanaian contractors.

## IV. BUILDING TECHNOLOGY EDUCATION IN GHANA

Capability building (CB) relates to the process of gaining knowledge and skills, which can take place in various ways, among which by formal training and education programs.

The National Council for Tertiary Education (NCTE) and the Non-Formal Education Division (NFED) have an important responsibility regarding the provision of education in Ghana.

Formal Technical/Vocational Education is provided in Secondary/Technical Schools, Technical Institutes, Vocational Schools /Training Centres and other post-basic education training institutions. This also applies for training and skills development in BT at secondary level: Construction Technology Courses (CTC). Basically, the purpose of technical and vocational education is to equip young men and women with the technical and professional skills needed for the rapid socio-economic development of the country. The emphasis is on training people for self-employment. In 1991 the Government launched the White Paper on Tertiary Education. The major objective was to expand access, improve quality teaching and learning and provide the much-needed infrastructural base for accelerated technical manpower delivery for sustainable economic development. The Ministry of Education Youth and Sports (MOEYS) is determined to assist the PTs to develop highly skilled middle-level manpower. To this end PTs are encouraged to introduce Post HND and Bachelor of Technology programmes. The Sunyani and Cape Coast PTs therefore have taken steps to establish first and second degree curricula in technology namely, Bachelor of Technology (B-Tech) and Master of Technology (M-Tech). However the enrolment in vocational training institutes for training in the construction trades is negligible [6]. The Ghanaian CI is dominated by many people who are not able to read and translate architectural drawings into reality. Training and education of personnel for the CI in Ghana –at least at vocational level- takes in majority place on informal basis by apprenticeship whereby young people –mostly men- learn the trade from more experienced masons, carpenters, etc. Informal training has limitations: (1) a restricted learning opportunity (learning by doing), (2) a narrow and static range of skills; (3) the difficulty of instruction in new technologies and techniques. Unfortunately the situation in many African countries shows that the informal apprenticeship system is not well developed and the master craftsmen who do the training may themselves have very limited skills.[7]. The informal method of technological knowledge acquisition and skill formation then does not any longer comply with the actual demand for construction output. The “learning-by-doing” system in this way is not "costless", but rather costly and time consuming with little pay back. Bell et al [8] argue this point further and suggest that firms cannot rely on “learning-by-doing” in order to develop their technological capabilities; they must invest in training and other knowledge creation. The acquisition and understanding of knowledge requires a deliberate allocation of resources. Seven of the 10 PTs in Ghana provide training in BT at Higher National Diploma (HND) level. They are expected to fill the void by training mid-level personnel capable of supervising the artisans so as to produce high quality buildings. These PTs however are confronted by the perennial problem of inadequate funding and poor working

conditions in the tertiary education sector in Ghana. The 7 PTs that offer BT produce about 350 graduates per year instead of the industry required 700. Furthermore, a majority of these graduates cannot join the CI because they lack practical skills and competencies. In discussions with professionals during the NA in Ghana was put forward that workers in the CI lack of taking initiative, have limited skills in problem solving, lack quality conscience and are not critical. The wish was expressed to include more practical exercises and practical experience in the education. The absence of practical training has led to a dearth of site technicians, quantity surveyors, qualified foremen, and middle level management for supervisory roles in the industry. Moreover a graduate from the PT with HND, who wishes to continue to obtain a degree (BSc) in BT at university level in Ghana is faced with the dilemma, either to begin in the first year with students who start with a secondary school diplom or forget it. This situation creates an additional need for the PTs to design and (re-)structure curricula, which address this problem. A revision of the curricula will not only contribute to improving the performance of the CI in Ghana, but at the same time it will also contribute to solving a serious problem in the field of academic qualifications.

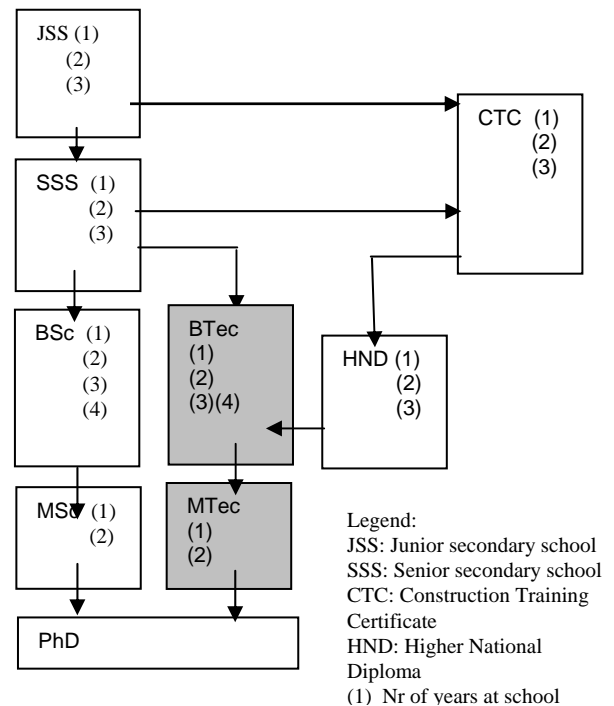


Figure 1. Proposed educational structure

The heads of the departments of BT of the PTs in Cape Coast and Sunyani prepared a first set up of a revised curriculum including topics for both Btech and Mtech programs. These were based on BSc and MSc curricula and combined with elements of the already existing HND curriculum. The main distinction between the Bsc/MSc and Btech/Mtech programs is that the Btech and Mtech



programs have a more practical focus whilst BSc and MSc programs follow basically a scientific and theoretical approach. The aim of such a B-Tech curriculum in BT is to propel the graduate for a career as a professional construction manager, concerned with planning, organizing and supervising the construction of buildings. The BTech curriculum will have to contain the basic technical topics to supply the graduate with the necessary basic engineering knowledge and skills as well as topics regarding the management of construction. BTech students also will be allowed to go for one year industrial training after the third year before completing the final year. The MTech curriculum will put particular emphasis on managerial aspects. In addition it is proposed to include in the MTech curriculum a new topic: Innovation management, which will cover issues like product development, building technology design, flexibility and durability, industrialization and prefabrication, maintenance, upgrading and renovation and innovative building technologies for the tropics. It will highlight the opportunities for the Ghanaian CI to adequately make use of the relevant state of art innovative technologies and knowledge. A primary condition for the envisaged curricula is that they have to meet first and for all the requirements of the Ghanaian Accreditation Board.

The Japan International Cooperation Agency [6] advocated the adoption of a Competency-Based Training (CBT) approach in the Technical, Vocational Education and Training sector of Ghana. It is considered as an appropriate solution to the diverse education and training needs for post-secondary and adult learners, particularly in technical and skill-oriented programs. This teaching methodology involves a systematic learning process, in which the primary focus is on the students' ability to demonstrate competencies required in the industry. The competencies comprise appropriate knowledge and skills required to perform workplace roles. The methodology is expected to provide learners with recognition and accreditation of previously acquired knowledge and skills, flexibility in scheduling learning activity, self-paced individualized study determined by the student's learning style, a learning continuum determined by student needs, and the possibility of starting and finishing a program at any time during the year. Within this methodology attachments to industry are a vital components. The elaboration of the methodology in education programs is based on the identification of job competencies relevant to the needs of industries.

#### V. STATE OF ART OF BUILDING TECHNOLOGY EDUCATION AT THE CAPE COAST AND SUNAYANI PTS

The staff of the PTs was requested to fill questionnaires and indicate -apart from personal data on their background etc.- which topics and in which way they are teaching at present at HND level and which Btech topics they like to teach in future. Those teachers who are expected to be qualified after graduation at university level during the collaboration project were asked to indicate which of the MTech topics they would like to teach in future. A distinction was made

between those who will qualify in future for HND teaching, Btech teaching and those who will qualify for Mtech teaching after the attainment of a certain education level during the project.

The results of the questionnaires among the PT staff show that theoretically most of the topics could be taught by the available staff. Some topics will be taught by teachers from other departments due to the typical specialisation (e.g. law etc.). It should be noted however that especially in the case of the Cape Coast PT the present teaching capacity is not sufficient. Only a limited number of teachers are at present employed in Cape Coast. Both PT's have indicated that they will attract new staff with a Bsc or Msc degree in near future, in order that the staffing problem is likely solved both in quality and quantity after the project period.



Figure 2. Interviewing Sunyani PT staff

The present level of education and expertise of the staff of both PTs is found to be below the level of requirements for adequate teaching at BTech and Mtech level. Interviews during the needs assessment showed that a number of the staff of both PTs hold a HND degree or lower, some have a BSc and only a few of them a MSc. Degree. The findings of the NA indicate a rather large gap between the present culture of teaching and learning as well as the capacities of the staff at the PTs and those required for application of the methodology advocated by JICA.[6]

At present teaching takes place mainly in the form of head-on lecturing by the teachers. The PTs show an inability at present to combine theoretical training with practical exposure in order to produce qualified graduates for direct absorption into industry.

Teaching materials presently consist mainly out of handouts made by the teachers. A limited number of books is available in the reference library and information is drawn from internet and accessible via the few available computers.

The specific needs for investments in laboratories, workshops, Information and Communication Technology facilities, educational materials and other equipment were identified in close collaboration with the PT staff. Both PT's have already some facilities for teaching like class rooms, workshops, laboratories, computer room and a library. However for the future it is foreseen that for each



PT a more spacious workshop, a larger laboratory and a larger computer room is needed in order to house equipment, computers and students. A list of indispensable laboratory equipment for testing and analysing properties and strength of building materials has been prepared. The access for both staff and students to ICT facilities like the Internet is almost a necessity. For the Departments of Building Technology at both the PTs it is needed that the already existing internet connections will be extended.

## VI. CONCLUSIONS

Based on the outcome of the NA the following activities were recommended for inclusion in the collaboration project Capacity Building in the Sunyani and Cape Coast Polytechnics to Improve Performance of the Building and Construction Industry in Ghana.

The teaching staff of the BT departments at both PTs need improvement of their capacity and qualifications to handle theoretical and practical issues related to BT and construction in general.

Two PhD candidates of the PTs in Cape Coast and Sunyani should carry out a PhD research project. This has to take place in a sandwich program, which means that they will work partly in the Netherlands and partly in Ghana with a joint supervision by the University of Technology at Eindhoven (TU/e) and the Kwame Nkrumah University of Science and Technology (KNUST). The field research has to be carried out in Ghana, during which periods the PhD candidates will be supervised by both the Dutch as well as the Ghanaian supervisors.

The PT teaching staff needs to be trained up to BSc and MSc level. In consultation with the KNUST was decided that this training can take place at KNUST at Kumasi in tailor made (summer) courses, in order that the current teaching duties at the PTs will not become in dispute. To become acquainted with recent developments and technological innovations in the CI the project should include visits to the TU/e in the Netherlands by the PT teaching staff of the BT departments to observe and learn about modern trends in the industry.

Next to the general attainment of a BSc, MSc or PhD degree, the PT staff has to be trained to upgrade their didactical skills and prepare for a proper curriculum development and implementation of the new curricula in line with innovative didactical methodologies. An opportunity for this specific training will turn up during the period when the staff is visiting the TU/e at Eindhoven. The staff can then be trained at Eindhoven by professionals of the Education Service Centre of the TU/e.

The need for revising the current curricula is fully understandable. The current HND curriculum contains mainly a traditional set of courses like mathematics, mechanics, building physics, building construction, etc. It is recommended to take the following requirements for the envisaged Btech and Mtech curriculum in BT into consideration.

- The curriculum must contribute to capacity and capability building in the CI, in order to achieve an improved performance of the CI in Ghana.
- The factors of the local, tropical and social-economic situation in Ghana should not be neglected in the renewal, revision and development of the curriculum. This refers for example to the teaching materials which must be specific for an effective and efficient use in the Ghanaian setting.
- The curriculum has to contain aspects in order to contribute to achieving improvements in the social-economic, gender and environmental situation in the country. This can be translated in terms of employment, income, housing, education, health care in particular for the low income groups in the Ghanaian society. [9]

It is further recommended that the CBT method should be considered in an adapted and appropriate form for application at the PTs. It should be applied as an instrument to achieve linkages between the educational institutions and the CI, business and community. Such an adaptation implies that Btech and Mtech teaching should include components of problem-oriented-teaching (POT). This means that apart from basic information provided by lecturing, the students will be trained in solving of practical problems that are indicated by the CI. This can be done through project work and by working in groups whereby the students have to find solutions for the practical problems by applying the theoretical knowledge and skills acquired during the lectures. The Education Support Services group at the Eindhoven University of Technology (TU/e) has been approached to assist in special training of the Ghanaian staff and development of an appropriate POT methodology.

Next to improving the curriculum and to solve the academic problem already mentioned before there is a good possibility to distinguish from the “standard” PT education in building technology. These goals can be achieved by introducing knowledge transfer in fields like advanced innovative building materials, building technology, construction technology, construction management, entrepreneurship and related skills.

With regard to the improvement of educational material for the envisaged BT curricula reference is made to extensive up-to-date lists of study books readily available for the traditional courses in BT like the City & Guilds’ package for BT education in the UK. Many PTs, in particular in former UK colonies are certified and take their exams in accordance with the City & Guilds guidelines. However the PT staff has to develop additionally new teaching material. Some of those materials can be drawn from the thesis resulting of the individual Bsc/Msc studies at KNUST.

The reference library needs to be improved, which can be achieved by acquisition of more books in the field of the new curricula topics. A basic library, including the subscription to one or two journals or periodicals in the field of Building Technology, is more than relevant. Internet will play an important role for information in the future education. Those materials which are not prepared

during the summer courses at KNUST can be developed by PT staff over the years.

Investments in teaching and learning facilities, tools and other equipment are required for the related disciplines at both PTs. Training equipment needs to be purchased and the laboratories, workshops and other teaching and learning facilities (including information and communication technology) need to be established. Investments in the facilities like a workshop, a larger laboratory and a larger computer room have been done by the end of 2005. Around 70 computers are made available by TU/e to the PT's.

In order to achieve the project objectives also the following aspects are addressed to fill the T&K gaps as determined by the NA: the implementation of (1) policies and procedures to stimulate staff to start long-term studies; (2) temporary replacement of staff engaged in long-term training; (3) a retention policy for staff with upgraded qualifications; (4) strategies to disseminate newly obtained knowledge and skills for example by using the BSc and MSc thesis material (or parts of it) prepared by the staff trained at KNUST as teaching material in the BTech and Mtech programs of the PTs.

To ensure the sustainability of IB and CB at the PTs it is recommended to make each of the PT staff responsible for the development of one or more courses offered in the new education programs. This implies that the Ghanaian teaching staff has to prepare and elaborate the envisaged Btech and Mtech programs. They also are expected to select, gather and prepare the necessary teaching materials such as study books, study guidelines, hand outs, sheets, etc. Thus all staff of the two PTs needs to be involved in the review of the existing curriculum and the development and implementation of a renewed BT curriculum.

The Dutch TU/e staff has to assist in reviewing and modifying the current curriculum, support the development of new teaching methodologies and the implementation of the revised curriculum as well as the writing of the course books. The latter also needs to be done in consultation with the Ghanaian KNUST staff who trains the PT teachers for their BSc and MSc degree. The Ghanaian PT staff member can be twinned with a TU/e expert as well as with experts of the KNUST for the development of the teaching program and material for a certain topic of the envisaged BSc. Next to the above TU/e staff is expected to give short introductory courses on a number of relevant BT topics when they are in Ghana during a mission. TU/e also have to assist in developing linkages with relevant industrial sectors and business fields in order to realise student attachment and staff exposure programmes. The arrangements for student attachments and staff exposure programmes can take place by using TU/e network with the CI.

The above mentioned recommended actions and policies involve transfer and exchange of T&K between the project partners of the international collaboration project "Capacity building in the Sunyani and Cape Coast Polytechnics to improve performance of the building and construction industry in Ghana". These TKTs -in the form of "training of the trainers", by which the Ghanaian PT staff gains the capabilities to develop and run the envisaged Btech and

Mtech curricula in BT- are expected to contribute to IB and CB at the PTs in Cape Coast and Sunyani. The sustainability of this TKT is enforced by the PhD research which contributes to the development of the Ghanaian R&D capacity for further independent development of higher education as well as for improvements in the CI in Ghana.

Through the PhD research carried out by two PT staff members with a joint supervision by TU/e and KNUST T&K is exchanged and transferred between the project partners. These TKTs contribute to an improved understanding and insight in The Netherlands and in Ghana on the nature and mechanisms of innovation of building products and building processes, The TKTs are thus beneficial for each of the project partners.

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## **CONFERENCE DIVISION:**

Agriculture, Food Science, Soil Science, Biochemistry,  
Horticulture, Botany & Nutrition

## **ENHANCING FOOD SECURITY IN GHANA THROUGH THE APPROPRIATE APPLICATION OF BIOTECHNOLOGY**

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The agricultural sector continues to be a crucial part of Ghana's economy, with approximately 36% of the Gross Domestic Product (GDP) and 48% of employment derived from this sector. To date however, the Ghanaian Agricultural sector has focused primarily on exploiting food resources rather than food transformation for the consumer market. Thus, most of the agricultural activities in the country mainly aim for primary products, without much thought given to the by-products and the associated environmental problems. Some of the primary produce is highly perishable, and it is not uncommon to find waste for various agricultural produce ranging from 25% to 50% of the total harvest. This cycle poses a lot of food security problems for the nation as a whole.

The estimation of FAO has shown that about 800 million people in the developing world, Ghana included, and a further 34 million people in the industrialized countries either do not have enough to eat or suffer from chronic food insecurity. In addition, food insecurity will persist in 2020 and beyond with 135 million children under five years of age becoming malnourished, out of which 40 million will live in Sub-Saharan Africa.

Among the emerging issues that could significantly improve the food situation in the world in general and Sub-Saharan Africa in particular is the potential of modern food biotechnology. Food Biotechnology holds great promise for increasing agricultural productivity, extending the shelf life of highly perishable Ghanaian primary produce and also fabricating high value-added commercial products from agricultural processing waste. These techniques, when appropriately applied, could be used to improve the quantity, quality and safety of food supply, especially in the developing countries, like Ghana which faces the dire problem of food insecurity.

**Keywords:** Food Security, food insecurity, biotechnology, agricultural waste

# DEVELOPMENT AND EVALUATION OF THE EFFICACY OF HEAT TOLERANT *PESTE DES PETITS RUMINANTS* (PPR) VACCINE IN NIGERIA

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## Abstract

*Peste des petits ruminants* (PPR) continues to be the most economically important viral disease of small ruminants (sheep and goat) in Nigeria. The prevention and control of the disease among animals are usually achieved using the homologous live attenuated PPR vaccine. However, the high ambient temperature prevailing in tropical environments continues to frustrate vaccination efforts due mainly to rapid deterioration of the live vaccine as result of environmental heat with eventual loss of vaccinal potency and efficacy. In order to ensure the heat tolerance of the existing homologous live attenuated PPR vaccine, we have used the *xerovac* process composing of trehalose in the dehydration stabilizer for the preparation of heat resistant variety of the vaccine. The potency and efficacy of the prepared heat tolerant variety were also evaluated for its suitability for protection of small ruminants against PPR disease. The results obtained indicate that a rapid dehydration of PPR vaccine following the *xerovac* method and in an excipient composed of a high concentration of trehalose, renders the product more heat tolerant. It was also demonstrated that the prepared heat tolerant vaccine maintained high potency for 14 days at 45°C and vaccinated animals (through intramuscular, subcutaneous, intranasal and oral routes) developed protective neutralizing antibody (titre  $\geq 1:10$ ) against PPR virus. The heat tolerant PPR vaccine has the potentials of overcoming the heat deterioration of the existing live vaccines and could ensure a long-standing immunity in vaccinated animals coupled with ease of vaccine administration.

**Keywords:** Thermostable PPR vaccine, small ruminants, Nigeria

## INTRODUCTION

*Peste des Petits Ruminants* (PPR) is a severe fast-spreading disease of domesticated and some wild small ruminants characterized by sudden onset of depression, fever, oculo-nasal discharges, stomatitis, pneumonia, diarrhoea and death [1]. The disease was formerly described by such terminologies as goat plague, pseudo-rinderpest, stomatitis-pneumoenteritis-complex, and 'kata' an adulterated English word for 'nasal catarrh' [2]. PPR is a classical example of animal diseases which are referred to as Transboundary Animal Diseases (TADs). These are defined for EMPRES as those diseases that are of significant economic, trade and/or food security importance for a considerable number of countries; and which can easily spread to other countries and reach epidemic proportions; and where control/management, including exclusion, requires co-operation between several countries. The OIE International Animal Health Code includes PPR in List A diseases, which are defined as "communicable diseases which have the potential for serious and rapid spread, irrespective of national borders; which are of serious socio-economic or public health importance and which are of major importance in the international trade of animals and animal products" [3].

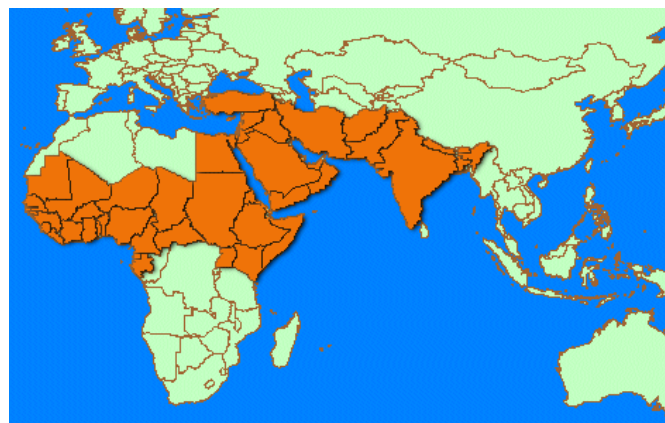


Figure 1. Probable global distribution of PPR virus infection: FAO Animal Health manual No. 5, 1999. Source: Obi, [2]

The FAO/EMPRES definition mentions the threat of TADs to food security while that of the OIE is concerned with their negative impact on international trade in animals and animal products.

Where the application of the stamping out policy of eradication is not feasible, the control of PPR has relied on preventive immunoprophylaxis using live attenuated tissue culture rinderpest vaccine (TCRV) and recently employing

the use of homologous live attenuated Vero cell cultures of PPR virus along with restriction of animal movement and other biosecurity measures [4].

PPR vaccination is the method that is currently in use in most African countries employing the use of homologous live attenuated vaccine (e.g. Caprippestovax<sup>®</sup>, LANAVET, Cameroon). Currently, TCRV and homologous PPR vaccine are in lyophilized form. Although relatively heat resistant, freeze-dried vaccines would still need to be preserved frozen (-20°C or below) in order to conserve the viability of the vaccine virus and reduce rapid vaccine deterioration due to high ambient temperature especially in tropical environments. The need to maintain a cold chain in the management and usage of current PPR vaccine puts additional cost to the price of vaccine. Besides, the lack of infrastructure (steady power supply, efficient transportation and other logistics) for maintenance of a cold chain further complicates the difficulty in preserving the potency of live attenuated vaccines in developing countries. The development of a system of vaccine dehydration that renders the product more thermostable would remove dependence on unavailable cold storage facility and prevent rapid vaccine deterioration due to high environmental temperature.

The freeze-drying procedure involving an initial regulation of vacuum pressure followed by extended secondary lyophilisation phase has been shown to yield rinderpest vaccine that is relatively thermostable [5]. However, the long lyophilisation period (at least 72 hours) involved in the procedure requires high-energy consumption and thus increased vaccine production cost. In addition, the procedure requires sublimation from ice and is usually affected by fluctuations in electric power supply. A rapid and inexpensive desiccation procedure for preservation of PPR and rinderpest vaccines has been described [6]. The procedure code-named *xerovac* employs the use of the disaccharide trehalose dehydrate ( $\alpha$ -D-glucopyranosyl- $\alpha$ -D-glucopyranoside) as the only excipient used for desiccative preservation. The aim of this study was to develop the heat tolerant PPR vaccine at a Vaccine Production Facility (LANAVET, Cameroon) using the *xerovac* process with the aim of assessing the reproducibility of the procedure and adapt it to wide application as well as evaluate the efficacy of the developed thermostable vaccine in protecting small ruminants against PPR.

## MATERIALS AND METHODS

### *Cell Culture*

Vero cells were propagated in Hanks LHY medium including 0.1% Trehalose, 10% Foetal bovine serum and used for the growth of PPR seed virus.

### *PPR Seed Virus*

PPR virus strain 75/1 seed used for the production of homologous live attenuated vaccine (Caprippestovax<sup>®</sup>, LANAVET, Cameroon) was adapted for the production of

heat resistant variety of the vaccine. The Vero cell was inoculated with sufficient PPR seed virus at a multiplicity of infection (MOI) of  $10^{-3}$  virus particles / cell.

### *Excipient*

Graded concentrations (w/v) of trehalose dihydrate were prepared using double distilled water and sterilized by autoclaving. Each concentration was used in the dehydration process.

### *Residual Moisture Determination*

The residual moistures (RM) were determined using a thermo-gravimetric method according to the protocol of [6]. The RM was determined following dehydration process using each concentration of trehalose.

### *Xerovac Process*

The process was carried out essentially according to the method described by [6]. The method involves the use of Edwards/Savant Supermoulyo freeze dryer for desiccation of PPR vaccine without the lyophilisation step of sublimation from ice. It exploits the unique property of trehalose to protect the tertiary macromolecules during desiccation. The drying procedure uses the freeze dryer to monitor and control condenser temperature and pressure, the shelf temperature and chamber pressure, the product temperature, and stoppering the vials under vacuum. By carefully maintaining a high vapor pressure at the product surface and creating a pressure gradient between the chamber and condenser by the injection of air to the chamber a very fast removal of water vapor is enabled. Virtually 75% of the water is removed within the first 30 minutes and the remainder to 10% residual moisture within 1 hour. The procedure involves primary and secondary drying processes.

### *Thermostability test*

The *xerovac* PPR vaccine prepared using the excipient containing 40% w/v trehalose was found to have the least RM and was used for the thermostability test. Samples from this batch of vaccine were incubated at 45°C for 0, 3, 8 and 14 days. The geometric mean of three vaccine samples was considered as the residual virus titre remaining following exposure to 45°C for the indicated time.

### *Determination of the efficacy of the xerovac PPR*

Eighty Sahel goats and 30 sheep on the Teaching and Research Farm of University of Maiduguri, Maiduguri, Nigeria were used for monitoring the efficacy of the *xerovac* PPR vaccine following determination of its thermostability at 45°C and RM level. Fifty of the selected goats were dewormed using Albendazole<sup>®</sup> before vaccination while the others were not dewormed. None of the sheep was

dewormed before vaccination. The animals were inoculated with the vaccine as indicated below:

Table 1. Route of inoculation of experimental animals with xerovac PPR vaccine

Animal	Total	Number inoculated per route of inoculation					Undewormed					
		Dewormed					Undewormed					
		S/C*	I/O	I/N	ORAL	I/M	Incontacts <sup>a</sup>	S/C	I/O	I/N	ORAL	I/M
Goat	80	10	10	10	10	10	25	0	0	0	5	0
Sheep	30	0	0	0	0	0	5	5	5	5	5	5

\*S/C: Subcutaneous; I/O: Intraocular; I/N: Intranasal; I/M: Intramuscular

<sup>a</sup>Five incontact animals to each of the dewormed routes

Blood samples for sera were obtained from experimental animals before inoculation (day 0) and on day 21 post inoculation with the vaccine. Sera were tested for presence of neutralizing antibodies to PPR virus. The geometric mean titre (GMT) of the reciprocal of neutralizing antibody titre was calculated for the animals in each group of vaccine inoculation.

## RESULTS AND DISCUSSION

The effect of trehalose concentrations on the residual moisture level is shown in Table 2 below. Thermostability at 45°C was not demonstrated at lower concentrations (5-20%) of trehalose due to relatively high residual moisture contents (2.3-2.5%). Low residual moisture level and hence vaccine thermotolerance was consistently achieved at a higher concentration of trehalose. Low levels of residual vaccine virus titers at 45°C have been attributed to high residual moisture [6]. Besides, previous studies [6] have shown that xerovac PPR vaccine required higher levels of trehalose to achieve thermotolerance. The results of this study further demonstrated the protective effect of trehalose and confirm that low residual moisture is necessary in order to ensure thermostability. The drop in the residual virus titre from 3.96 log<sub>10</sub> TCID<sub>50</sub>/mL to 3.1 log<sub>10</sub>TCID<sub>50</sub>/mL after exposure to 45°C for 14 days (Table 3) compares favorably with the expected fall in titre found in lyophilized 'thermostable' (Thermovax) vaccines and in xerovac PPR vaccine [6].

All goats inoculated through the intramuscular, subcutaneous, intranasal or oral route significantly seroconverted to a four or more fold rise in GMT of neutralizing antibody against PPR virus (Table 4). However, apart from goats that were incontact to the group inoculated intranasally, significant seroconversion was not demonstrated among the incontact animals. The seroconversion demonstrated among the incontact to the intranasal route could be attributed to the route of inoculation which allowed for sufficient vaccine virus replication at the upper respiratory tract and hence ensured rapid spread of high concentration of the virus by aerosol route. The degree of seroconversion was significantly highest through the intramuscular route (141-fold rise) [Table 4]. Relatively poor antibody response was demonstrated in sheep inoculated through the various

routes. The highest seroconversion obtained in sheep was through the subcutaneous route (Table 5)

Table 2. Dehydration of vaccine with various concentrations of trehalose stabilizer

Percentage of Trehalose	Percentage of Residual Moisture
5	2.5
10	2.3
20	2.3
35	1.2
40	1.128

Table 3. Heat stability of xerovac PPR in 40% trehalose stabilizer at 45°C

Day Post Xerovac	Residual Vaccine Virus Titre (log <sub>10</sub> TCID <sub>50</sub> /mL)
0	3.96
3	3.75
8	3.55
14	3.10

Table 4. Seroconversion following inoculation of Sahel goats with xerovac PPR vaccine

Group	Route of Inoculation	Preinoculation GMT value	Post inoculation GMT value	Rise in antibody titre (folds)
A	Subcutaneous	44	453	10
B	Intraocular	67	297	4
C	Intranasal	6	237	40
D	Oral	51	226	4
E	Intramuscular	6	844	141
F	Incontact of A	211	231	1
G	Incontact of B	56	61	1
H	Incontact of C	18	205	11
I	Incontact to D	201	352	2
J	Incontact to E	6	6	1
K	Oral Undewormed	201	875	4
L	Noninoculated control	160	426	3

Table 5. Seroconversion following inoculation of sheep with xerovac PPR vaccine

Group	Route of Inoculation	Preinoculation GMT value	Post inoculation GMT value	Rise in antibody titre (folds)
A	Subcutaneous	27	1470	54
B	Intraocular	6	13	2
C	Intranasal	8.3	16	2
D	Oral	21	77	4
E	Intramuscular	12	133	11

The xerovac process is suitable for the development of thermostable PPR vaccine by providing a high level of vaccine virus protection, employing a very short simple, 18-hour production cycle, thus reducing production cycle time and energy costs. Basic drying equipment is all that is required, although sophisticated microprocessor controlled freeze dryers can also be used, but are not strictly essential. The process can readily be adapted to thermostabilising all the existing live attenuated vaccines for use in tropical environments where ambient temperatures are high (a times  $>42^{\circ}\text{C}$ ). The heat tolerant PPR vaccine has the potentials of overcoming the heat deterioration of the existing live vaccines and could ensure a long-standing immunity in vaccinated animals coupled with ease of vaccine administration.

It is envisaged that the developed thermostable vaccines will be adapted to feed and administered to the scavenging indigenous livestock in Nigeria in the form of feed-based vaccine.

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#### ACKNOWLEDGMENTS

This study was supported fully by Raw Materials Research and Development Council, Federal Ministry of Science and Technology Abuja, Nigeria, Project RMRDC/AF/36/SEC/XVII/2994. We are grateful to Dr. Abdulkadiri Souley, Director General, Laboratoire National Veterinaire (LANAVET, Cameroon) for the collaboration and use of their facilities.



# Evaluation of Neem Leaf extracts (*Azadirachta indica* (A.) Juss) From Five Agro-Ecological Zones of Nigeria For Toxicity To Cowpea Anthracnose Pathogen.

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**Abstract** A survey carried out to determine the variation in the fungitoxicity and effectiveness level of aqueous and ethanol neem leaf extract from savanna agro- ecological zones (AEZs) viz derived savanna (DS 1, and 2), Southern guinea savanna (SGS 1, 2 and 3), Northern guinea savanna (NGS 1 and 2), Sudan savanna (SDS 1and 2) and Sahel savanna (SHS) zones of Nigeria. Graded extracts at concentration of 0, 5, 10, 25 and 50% were tested on *Colletotrichum destructivum* for fungitoxicity and effectiveness levels as highly, effective, moderately, slightly and not effective across AEZs. Data were subjected to ANOVA. Ethanol extract significantly ( $P \leq 0.05$ ) reduced growth than aqueous extract. Effectiveness level of extracts were slightly to highly effective and significant ( $P \leq 0.05$ ) across concentrations and locations. Growth inhibition of ethanol leaf extract ranged from 39.0% (SGS 1) to 64% (SHS 1) relative to 8.13% (NGS1) and 64% (SGS 2 and SHS) aqueous.

**Keywords:** aqueous and ethanol neemleaf extract, *Colletotrichum destructivum*, savanna agro- ecology, Effectiveness level.

## INTRODUCTION

Anthracnose disease of cowpea in Nigeria, induced by *Colletotrichum destructivum* O' Gara causes economic yield losses on susceptible varieties in the rainforest zone of Nigeria where conditions are wet and humid for the main part of the growing season [13]. It is a stem and foliar disease that can cause up to 50% yield loss in Nigerian rainforest zone [21]. Control ptions include growing cowpea resistance to anthracnose Adebintan. [2], and application of appropriate amounts of  $P_2O_5$  [3]. Synthetic pesticides constitute threats to human, livestock and wildlife health, in addition to their harmful effects on beneficial organisms. This facts simulated preference of biopesticides synthetic pesticides. Adequately applied biopesticides are safe, environmental friendly, biodegradable with soft mode of action,[15]. Some plant extracts had been evaluated *in vitro* for the control of *C. destructivum*. Neem-derived pesticides possess these characteristics;[17], Dales.[7]. The origin of neem tree has

been traced down to the arid and semi- arid parts of India. In Nigeria, neem tree are abundant especially in the north and are found arrayed either in the wild or as plantings in the shelter belts, parks and sides of the streets in the cities. Although they may appear similar, neem tree exhibit some variation as has been reported by [18], the differences being attributable to genetic and environmental effects. However, little attention had been paid to the diversity of neem trees found in the savanna agro-ecological zones of Nigeria in the studies of neem-derived biopesticides. Toxicity of neem extracts on plant pathogens across agro-ecological zones has also received little or attention. In particular, *Colletotrichum destructivum* is not among the three and nine fungal species that [12] reported in their review as having being studied in this respect. Although, [16] reported 51% *in vitro* inhibition of radial mycelial growth of *C. destructivum*, his neem seed were collected from only one Nigeria location. The objective of the present study is to evaluate the *in vitro* efficacy of leaf extracts of neem growing in various agro-ecological zones of Nigeria on cowpea anthracnose pathogen. *Colletotrichum destructivum*.

## MATERIAL AND METHODS

### Preparation of Culture Medium, Isolation and Maintenance of *C. destructivum*

Pathogen was cultured on acidified potato dextrose agar (APDA) which was prepared by dissolving 39 g of potato dextrose agar powder (PDA) in 1L-distilled water inside a conical flask. The flask was sterilized by autoclaving at 121°C for 15 min at 1.06kg/sq.cm. After the autoclave had cooled and the pressure returned to zero, 1ml lactic acid was added to the solution before pouring into Petri-dishes of 9-cm diameter. *C. destructivum* isolate used for this study was isolated using blotter method as described by Waller *et al.*(1998) from infected germinating cowpea grown on IITA cowpea demonstration field (7°26'N; 3°54'E). Pure cultures of the isolates were stored in sterile-distilled water inside the McCartney bottles at 4°C in a

refrigerator until required.

### **Collection of Leaf Samples from Different Locations.**

In this study, leaves were collected from 10 locations across the five savanna AEZs of Nigeria (Table1). The leaves were collected from September 5<sup>th</sup> to 12<sup>th</sup>, 2002. Samplings of trees from which leaves were collected based on tree trunk diameter, tree height and the AEZ. About 20-25 mature trees were sampled per zone. Selection of trees to be sampled was restricted to those that were fruiting and had a trunk diameter of at least 30cm at about 1 meter above soil level. Approximately 3 kg of leaf samples were collected. The samples were collected in paper bags properly labeled, and taken to IITA Ibadan for air-drying on laboratory bench.

### **Extraction of Neem Leaf Extract**

Fresh leaves of the selected plant samples were washed under running tap water and spread out on the laboratory benches at temperatures of 30 ± 3°C to dry to crispiness. Dried leaves were pulverised into powder by blending for 2 to 4 min in a Warring<sup>R</sup> blender. For each sample, 5, 10, 25 or 50 g leaf powder was extracted in 100 ml of ethanol (96%), or 100 ml of distilled water. The suspension of leaf powder in ethanol or distilled water was heated over water bath at 60°C for 2hr. It was then filtered through Whatman<sup>R</sup> No 1 filter paper and the filtrate kept in the refrigerator at 4°C. Ethanol extracted filtrates were concentrated to 2.5 ml with Buchi rotary evaporator model R-124 manufactured in New York, while aqueous extracts were concentrated using 0.45µ millipore filter. These were kept as stock solutions for fungitoxicity test. As described by Onalo, [18] all prepared extracts were used within 48 hr of preparation and storage

### **Fungitoxicity Test**

All *in vitro* studies to test efficacy of the botanicals were done using APDA. Five, 10, 25 and 50% (w/v) concentration of the extracts were prepared, by extracting the equivalent weights of plant materials in 100ml of water, or ethanol. The 2.5ml - concentrated extracts were made up to 100ml by adding the equivalent volume of molten PDA and dispensed into 9 cm - diameter Petri dishes. Fifteen millilitres of molten APDA (at 45°C) was dispensed into each Petri dish. Mycelial agar plugs were taken with cork borer 3 mm in diameter from the margin of 1 week-old culture of *C. destructivum*, and inoculated at the center of each Petri dish. The plates were then incubated at 28 - 30°C for 7 days in an incubator. Observation of fungitoxic effect was made daily for 7 days beginning at 2 days after inoculation.

Radial mycelial growth was measured as the mean growth in millimeter along two axes on two pre-drawn perpendicular lines on the reverse side of the plate.

TABLE 1  
SITES FROM WHICH NEEM LEAF SAMPLES WERE COLLECTED IN NIGERIA

Agroecological zones of collection sites	State	Location of collection site
Derived Savanna1	Oyo	Ogbomosho (8°13'N,4°26'E)
Derived Savanna2	Kwara	Ilorin (8°50'N,4°55'E)
Southern Guinea Savanna1	Niger	Mokwa (9°18'N,7°38'E)
Southern Guinea Savanna2	Niger	Bida (9°05'N,6°01'E)
Southern Guinea Savanna3	FCT	Kubwa (9°08'N,7°30'E)
Northern Guinea Savanna1	Kaduna	Kaduna (10°52'N,7°44'E)
Northern Guinea Savanna2	Kaduna	Zaria (11°11'N,7°38'E)
Sudan Savanna1	Kano	Kano (11°58'N,8°30'E)
Sudan Savanna2	Jigawa	Gumel (12°63'N,9°80'E)
Sahel Savanna 1	Jigawa	Hadejia (12°45'N,10°05'E)

Where FCT=Federal Capital Territory

Percentage fungitoxicity was expressed as described by Awuah [6] as:

$$MP = \frac{M1 - M2}{M1} \times 100 \quad \text{where,} \quad (1)$$

MP = percentage inhibition of mycelial growth,

M1 = Mycelial radial growth in control Petri dish without neem extract, and

M2 = Mycelial radial growth in Petri dish containing extract

### **Minimum Inhibitory Concentration and Level of Effectiveness**

Minimum inhibitory concentration (MIC) as described by Ejechi and Souzey.[8] is the lowest concentration of the extract that prevented fungal growth. It was determined to guide in the selection of effective concentration of neem leaf extracts and the most suitable AEZs for the production of fungitoxic extracts from neem leaves. The leaf extracts were rated based on their inhibitory effects using the modified scale as described by [19]:

-0 % = stimulatory (ST),

0 % inhibition = no effect (NE),

1-20% inhibition = slightly effective (SE),

21-40% inhibition = moderately effective (ME),

41-60% inhibition = effective (EE),

61% inhibition and above = highly effective (HE)

### **Data Analysis**

Analysis of variance was conducted using general linear model (GLM) procedure of SAS (SAS institute version 8, 2001) to compare treatment effects on the parameters studied. Standard error of means was used for treatment means comparisons. Statistical significance level was taken at P ≤ 0.05.

## RESULTS

Fungitoxicity tests revealed variations in the response of the pathogen to neem extracts obtained from different AEZs. Statistical analysis of the data showed that there was significant difference (P ≤ 0.001) in the efficacy of extracts across the locations.

TABLE 2

THE EFFECT OF SITE OF COLLECTION OF NEEM LEAF AND OF CONCENTRATION OF NEEM LEAF EXTRACTED IN ETHANOL ON RADIAL GROWTH OF *COLLETOTRICHUM DESTRUCTIVUM* IN ACIDIFIED APDA.

Location of seed collection site	Radial growth inhibition (%) in APDA at ethanol leaf extract concentration (%) of <sup>a</sup> :				Mean concentration	MIC <sup>b</sup>	Level of effectiveness <sup>c</sup>
	5	10	25	50			
Ogbomosho	40.9	48.4	59.7	64	53.25	5	HE
Ilorin	30.6	38.7	40.9	53.8	41.0	5	EE
Mokwa	29.6	32.8	45.2	49.5	39.27	5	EE
Bida	51.6	53.2	59.1	71.5	58.85	5	HE
Abuja	48.4	47.3	59.1	80.1	58.75	5	HE
Kaduna	ND	ND	62.9	71.5	57.20	ND	HE
Zaria	32.3	38.2	76.3	96.2	60.75	5	HE
Kano	53.8	60.2	65.6	76.9	64.13	5	HE
Gumel	14.5	50.5	55.4	67.7	40.03	5	HE
Hadejia	51.6	53.2	59.1	71.5	58.85	5	HE
Mean Location	39.25	46.94	58.3	70.3			
SE ±	4.2	2.8	3.1	4.2			

Values are means of three replicate plates per treatment. Where NE=Not effective; ME=Moderately effective; EE= Effective; HE=Highly effective; MIC = minimum inhibitory concentration; ND = Not determined.

### Effect of Ethanol Neem Leaf Extracts on Mycelial growth of *C. destructivum* in Acidified Potato Dextrose Agar

The results showed that ethanol leaf extracts were moderately to highly effective across both concentrations and locations (Tables 2). The mean of the reduction in mycelial growth across location varied from 39.0% (at 5% concentration) to 70.0% at 50% concentration of leaf extract. Similarly, across concentrations of neem leaf extracts,

mycelial growth inhibition ranged from 39.0% (for southern guinea savanna 1) to 64% (for sudan savanna 1). At the lowest concentration tested (5%) inhibition of radial mycelial growth varied from 15% (for sudan savanna 2) to 54% (for sudan savanna 1). At 50% concentration, of ethanol leaf extract, the radial mycelial growth reduction ranged from 50% for southern guinea savanna 2 to 96% for northern guinea savanna 2. These differences are significantly  $P \leq 0.05$  significant. The interaction between location and leaf extract concentration is also significant  $P \leq 0.05$ . However, there was no consistency trend in the effect of agroecological zones from which the leaves were collected and toxicity of extract from the leaves to *C. destructivum*.

### Effect of Aqueous Neem Leaf Extracts on Mycelial Growth Reduction of *C. destructivum* in Acidified Potato Dextrose Agar

Aqueous leaf extracts were slightly effective to highly effective across both concentrations and locations (Tables 3). The mean of the reduction in mycelial growth across location varied from 28.8% (at 5% concentration) to 48.08% (at 50% concentration) of leaf extract. Similarly, across concentrations of neem leaf extracts, mycelial growth inhibition ranged from 8.13% (for northern guinea savanna 1) to 64% (for Sahel savanna). At the lowest concentration tested (5%) inhibition of radial mycelial growth varied from 0.3% (for northern guinea savanna 1) to 51.1% (for both northern guinea and sahel savannas). At 50% concentration of aqueous leaf extract, the radial mycelial growth reduction ranged from 24.7% for northern guinea savanna 1 to 71.5% for southern guinea savanna and Sahel savanna. These differences are significantly  $P \leq 0.05$  significant. The interaction between location and leaf extract concentration is also significant  $P \leq 0.05$ . As seen in the case of ethanol leaf extract against *C. destructivum*, there was no consistency trend in the effect of agro ecological zones from which the leaves were collected and toxicity of extract from the leaves to *C. destructivum*.

TABLE 3

EFFECT OF SITE OF COLLECTION OF NEEM LEAF AND OF CONCENTRATION OF NEEM LEAF EXTRACTED IN WATER ON RADIAL GROWTH OF *COLLETOTRICHUM DESTRUCTIVUM* IN ACIDIFIED APDA.

Location of seed collection site	Radial growth inhibition (%) in APDA at aqueous leaf extract concentration (%) of <sup>a</sup> :				Mean concentration	MIC <sup>b</sup>	Level of effectiveness <sup>c</sup>
	5	10	25	50			
Ogbomosho	11.3	26.9	50	64	38.05	5	HE
Ilorin	14	51.6	62.4	ND	42.67	5	HE
Mokwa	3.2	-8.9	28.5	ND	7.6	5	ME
Bida	51.1	62.4	71	71.5	64.03	5	HE
Abuja	33.3	34.4	54.8	52.7	43.80	5	EE
Kaduna	0.3	0.5	7	24.7	08.13	5	ME
Zaria	43.5	38.2	39.2	38.2	39.78	5	ME
Kano	44.1	41.9	36.6	31.2	38.45	5	ME
Gumel	29	40.9	39.8	38.9	37.40	5	ME
Hadejia	51.1	62.4	71	71.5	64.00	5	HE
Mean Location	28.8	35.0	49.2	48.08			
SE ±	5.6	7.1	5.2	6.4			

Values are means of three replicate plates per treatment. Where NE=Not effective; ME= Moderately effective; EE= Effective; HE=Highly effective; MIC = minimum inhibitory concentration; ND = Not determined.

## DISCUSSION

Generally, ethanol extract of the leaf were effective than aqueous extract across both concentration and locations.

The percentage reduction in radial growth of *C. destructivum* produced by ethanol extract of neem were consistently superior to those of aqueous extracts across all location and concentration except for Sahel savanna and southern guinea savanna 2. Although the minimum effective concentration of both ethanol and aqueous leaf extracts were the same ethanol extract of the leaf from eight of the ten locations were rated as highly effective

compared to only three locations for the aqueous extract. These observations suggest that ethanol is a better extractor of fungitoxic substances of neem leaves than water. This agreed with the report of [12], who showed that ethanol extracted more potent insecticidal components of either neem seed or seed oil than aqueous or hexane extracts. Regardless of the extracting medium, there were significant differences in the toxicity of leaf extracts to *C. destructivum*. However, neem leaf extract toxicity to the pathogen did not show the agroecological zones of the sites from which the leaves were collected. Thus although, across concentrations leaves from southern guinea savanna 2 had the highest toxicity, similar extracts from southern guinea savanna 1 had the least but two toxicity. In respect of the aqueous extract, the most efficacious extract across concentration was obtained from leaves collected from Hadejia (Sahel savanna) and in southern guinea savanna which are two contrasting agro-ecological zones especially in respect to annual rainfall (1200-1500mm for southern guinea savanna and 300-500mm for Sahel savanna) and length of growing season (7-9 months, for southern guinea savanna and 3-4 months for Sahel savanna). Since the neem *in vitro* result of the present study suggests that leaf extract toxicity to *C. destructivum* is probably location specific, leaves for extraction should be collected from sites where leaves gave the highest toxicity, depending on the extraction medium. The results of the present studies were obtained from *in vitro* studies in the laboratory. Since *C. destructivum* is a shoot pathogen, further studies are needed to evaluate relative efficacies of the extracts as foliar sprays. However, this is probably the first report of a study in which the fungitoxicity of botanicals were related to sites of collection across a wider range of agro-ecological zones.

Water was generally inferior in the extraction of fungitoxic components in neem leaf. The predominant active ingredients in neem leaf extracts are the azadirachtins [14] [17]. However, in order to benefit maximally from neem leaf extracts, ethanol extraction is suggested provided it is cost effective. Evaluating neem leaf extracts in this regard will need high concentrations such as those produced in ethanol. In a recent development, the United Nations Industrial Development Organisation (UNIDO) has embarked on a major initiative to promote appropriate low-cost, but sustainable technologies and techniques for large scale production of biopesticides from neem in West Africa (UNIDO, APRIL 2007, unpublished information)

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## **CONFERENCE DIVISION:**

[Water Management, Dams & Civil Engineering](#)

# Impact Assessment of Water Scarcity at Somntongo in the Lowveld Region of Swaziland.

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**Abstract** - A survey was conducted to assess the impact of water scarcity in Somntongo, in the low veld region of Swaziland. The study adopted the use of questionnaire, interview schedules and focused group discussions. Information sought included sources of water, distances between water sources and places of residence, and the effect of water scarcity on the various aspects of human activities. The study revealed that only two rivers and five boreholes were the major sources of water while distances of as much as 5 – 20km were covered in search of water. In about 84% of the homesteads, the water use was about 2.7litres/head/day while in about 88% of the homesteads, it was 2.3 litres/livestock/day. These are quite low compared to the minimum standards of 8-20 litres/head/day, and between 5 and 45 litres/livestock/day. Water scarcity has resulted in the death of livestock; some cultivated crops have withered while others are not cultivated for lack of irrigation water. In some instances, schools have temporarily been closed due to water shortages. Construction of more boreholes and dams can reduce the water scarcity and promote the standard of living in the community.

**Keywords**-Swaziland, water, scarcity, harvesting, irrigation, agriculture

## 1. INTRODUCTION

Water is one of the most basic needs for the sustenance of life, and its utilization can be categorized into industrial, agricultural and domestic. Globally about 70 % of water resources is used for agriculture, 22 % for industrial while domestic use accounts for only 8 %. However, because of the differences in levels of technology, while developing countries devote as much as 88% of their water to agriculture, the developed nations use less than half for agriculture [1, 2].

Water as a natural resource should be readily available and affordable but in many instances, it is scarce and beyond the reach of many people [3, 4, 5, 6]. Reference [2] reported that of about 2.5% of the water resources that can actually be consumed, only one-third of it is accessible as the balance two-thirds are confined in glaciers and permanent snow cover. References [2, 7] reported that about 17% of the world population, majority of whom are living in developing countries have no access to fresh water to meet their domestic and other requirements. Reference [2] reported that Africa is already one of the driest continents

in the world, and with an increase in population and a decrease in amount of rainfall, its countries are facing water stress and scarcity.

Water scarcity leads to the destruction of the environment and conflicts are common as industries, agriculture, and domestic needs compete for the limited available water [8]. Tensions over the distribution of water can escalate into discord between groups dependent on a shared resource. In water crisis situations, the poor are the ones who suffer most. To them, water shortages can mean long walks to fetch water, high prices to buy it, food insecurity and diseases due to drinking of dirty water. Water should not only be adequate in quantity but must also meet certain standard qualities. Polluted streams create problems for fish, wildlife and humans [9]. Sediments, fertilizers, pesticides and manure are the main reported pollutants of drinking water [10].

Swaziland is located between latitudes 30° 30'E and 32° 30'E of the Greenwich and between longitudes 25° 30'S and 27° 30' S of the Equator. The country covers a total area of 17,363 km<sup>2</sup>, out of which 17,203 km<sup>2</sup> is land and the remaining 160 km<sup>2</sup> is water. The country is divided into four ecological zones: the Highveld, Middleveld, Lowveld and Lubombo (Fig. 1). Due to droughts in recent years, many areas of Swaziland are facing aggravated water scarcity. One of such areas is Somntongo where the water scarcity has inflicted injuries on the social and economic lives of the populace. It is imperative that such impacts are quantified and appropriate remedial measures taken. The work reported in this paper was undertaken to assess the impact of water scarcity in Somntongo, in the Lowveld region of Swaziland.

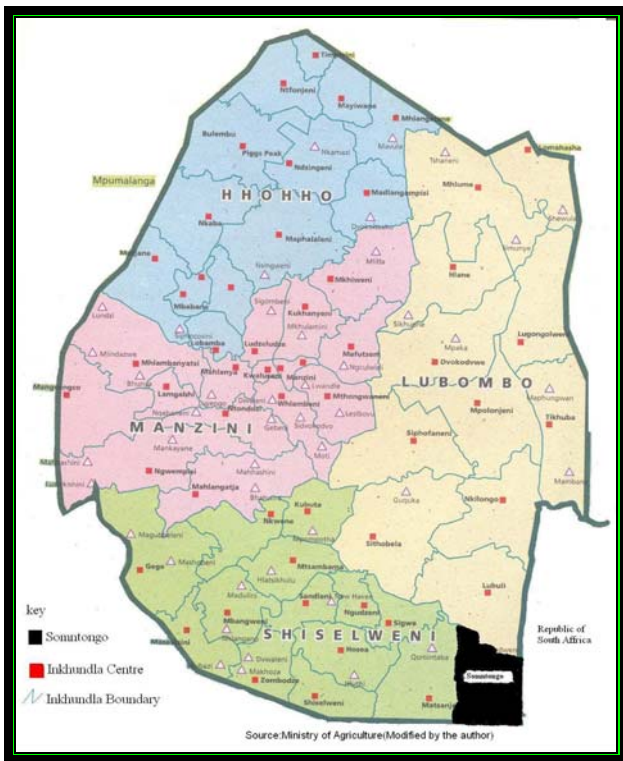


Figure 1. Map of Swaziland showing study area as shaded

## 2. METHODOLOGY

The study was carried out through the use of questionnaire, interview schedules, personal observation and focused group discussions. Questionnaire and interview schedules were developed which among others sought for information on the sources of water available to the respondents, various water uses, distances between places of residence and water sources, reliability and adequacy of water sources, problems experienced with water collection and the effect of limited water availability on various human activities.

The target population was the Somntongo community members and 150 homesteads were selected. The instruments were administered in February 2006. In addition to these instruments, secondary information was obtained from the libraries of the University of Swaziland, the ministry of agriculture, Mbabane and the Swaziland National Library, Mbabane. Information was also sourced from the Internet.

The Statistical Package for the Social Sciences (SPSS) was used to analyse the data. All data collected were interpreted using frequencies and percentages, and the results were presented in bar and pie charts.

## 3. RESULTS AND DISCUSSION

### a) Water availability

Two rivers and five boreholes were the sources of water available in Somntongo. While 30% of the populace depended on the rivers, the boreholes were the water sources for the remaining 70%. In most cases, the discharge from

these sources were very low and got dried during the dry season. During the dry season the inhabitants who have the means go to the Ingwavuma river which is about 20 km from the community. The Ingwavuma river was not only far from the community but it was used for sugarcane irrigation upstream such that the volume downstream, and where some members of the community relied on, was very low.

Rainwater harvesting as a source of water had very little impact in Somntongo. Besides the low annual rainfall received over a short period of the year, many of the homesteads were of thatched roofs with very low harvest potential compared to corrugated iron sheet roofs. Because of the seriousness of water scarcity, dews have become a source of water in Somntongo as in other drought affected communities, (Plate 1), [11].

### b) Burden of water Collection

The distances between places of residence and nearest water sources are presented in Fig. 2. Ideally, water source should be between 250–500 m away from the place of residence [12]. Since only 8% of the population at Somntongo fell within this range, it implied that 92% of the residents did not have an easy access to water.

The number of households sharing a water source varied from as low as 20 to as much as over 60, as presented in Fig. 3.



Plate 1. A pot used to collect dew to be used as drinking water (Source: Times of Swaziland, Friday November 4, 2005 Page 11)

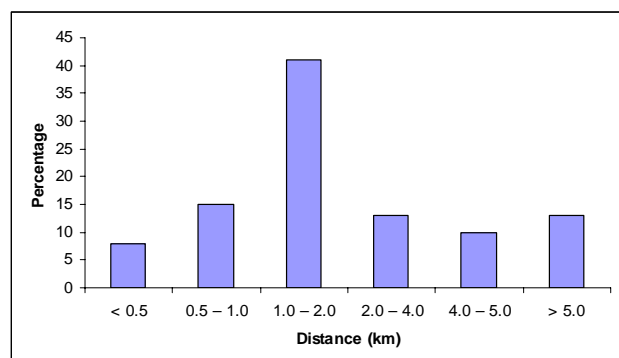


Figure 2. Distances between residence and water sources



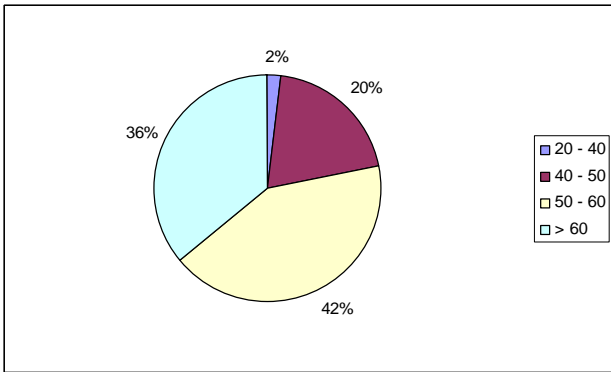


Figure 3. No of households sharing a water source.

The large number of households sharing a source resulted in high rate of depletion. People often queue and wait for as long as three hours to collect water. Sometimes people wait and when it gets to their turn, the source becomes completely depleted and they have to go back without water. Some people spend part of the night at the source and this poses danger to their lives. Children and women, who are the major water collectors in the homesteads, spend much of their time scouting for water.

Water collection can be done by motor vehicle, livestock or head carriage. About 78% of the respondents earn an annual income of below US\$160.00, and can neither afford to own a vehicle nor pay the cost of transporting water. A few make use of their livestock while a majority transport their water by head carriage over a wide range of distances.

Most water collection is done on foot mostly by women who have other engagements and school children. Because of the time spent on water collection, other jobs especially domestic chores are affected while lateness to school by children whose first job is the collection of water was very common.

### c) Water consumption

The various uses and quantities of water in Somntogo are presented in Fig. 4. Water is used mainly for domestic and livestock and no irrigation activities are carried out. About 84% and 16% of the homesteads with an average population of 11, use less than 30 litres and between 30 and 50 litres of water per day, respectively, for their domestic purposes. This gives an average of between 2.7 and 4.5 litres/head/day. Compared with the recommended values of 8 - 20 litres/head/day [13], this is grossly inadequate and the community is subjected to water stress.

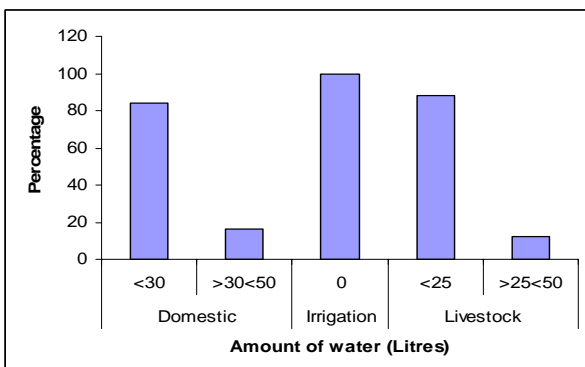


Figure 4. Amount of water used

About 88% and 12% of the homesteads use less than a total of 25 litres and between 25 and 50 litres of water per day for their livestock, the average population of which is 11 and comprises of various animals. This average of between 2.3 and 4.5 litres/animal/day is below the recommended minimum values of 15–45 litres for cattle, 5–15 litres for sheep and goat, and 10–27 litres for pig [13,14]. Livestock were subjected to water stress and there were reported cases of livestock lost due to water scarcity as shown in Fig. 5.

About 22 % of the respondents reported to have lost one animal whilst 6% and 2% lost two and three animals respectively. Cattle were the most affected species, yet they are the most important livestock especially as they are used for the settlement of bride price or *lobola*.

As a result of water scarcity, domestic practices such as regular bathing and washing were compromised resulting in poor hygienic situations in the homesteads, dirty water such as from washing was given to livestock since the little available was insufficient to meet the human needs. Livestock were driven for more than 15km to the river since the earth dams were dried. Somntogo is suitable for the commercial production of maize, potatoes, cassava, beans and sorghum but these were only cultivated on small scale due to lack of water for irrigation. Irrigation was not practiced in the area due to lack of water. Cotton is the only commercial crop cultivated because of its limited water requirement. Sugarcane which is a major cash crop in Swaziland is not cultivated because of its high water demand. During the study, the researchers were informed that financial institutions were unwilling to give loans for sugarcane production in the area because they had no confidence in the success of such investments. These situations constitute threats to the attainment of food security and economic empowerment programmes of the kingdom.

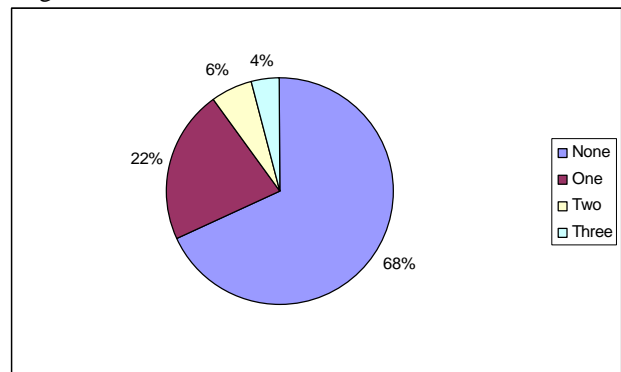


Figure 5. Number of livestock lost due to water scarcity.

### d) Impacts of water scarcity

The impacts of water scarcity in Somntogo include the following:

a) A lot of time and energy are expended in water collection and in some instances the water may not be obtained after a long search. As a result of this, there is a reduction in the time available for productive work while domestic chores suffer. Children, who are mainly involved in water collection, go to school late and their future is being

mortgaged. Information obtained from schools confirmed that the performances of most of such affected children have declined. In some instances, when the water sources in schools are depleted, classes are suspended until water is available. The HIV/AIDS pandemic prevalent in the country is made worse by poor quality water. Clean water prolongs lives, thus, it is as necessary as medicine and proper diet.

b) As a result of its scarcity, water is expensive. The cost of 100 litres of water was US\$0.70 while a 5,000 litre tanker load costs US\$42.00. The annual income of over 80% of the populace was less than US\$160.00. Expenditure on water reduces the income available to meet other domestic responsibilities and this is a burden on the rural poor and further complicates their poor economic situation. The severity of water scarcity and inability to pay for its supply, had compelled some people to depend on dewdrops for their water need (Plate 1). Schools were compelled to use funds earmarked for other projects for water supply.

c) With a population of about one million people, the predominant occupation in Swaziland is agriculture. About 70 % of the populace is engaged in subsistence agriculture producing both crops and animals while agriculture accounts for about 17% of the country gross domestic products [15]. Water is a basic requirement for effective agricultural production and its scarcity in Somntogo has resulted in the loss of livestock and limited the type and extent of crops that can be cultivated. This has not only reduced the income potentials of the inhabitants but has increased food deficits within the community. This is a threat to the attainment of the food security goal of the Kingdom.

#### 4. CONCLUSIONS AND RECOMMENDATIONS

##### a) *Conclusions*

Somntogo depends on two rivers and five boreholes for water supply. These sources are inadequate as a result of which domestic practices such as bathing and regular laundry were compromised while unclean water was fed to livestock. Livestock have been lost due to water scarcity while the variety and scale of crop production have been reduced due to lack of water for irrigation. The burden and cost of obtaining water has reduced the time available for productive work, educational programmes have been affected while income available for domestic responsibilities has been reduced.

##### b) *Recommendations*

a). The laudable efforts of the Swaziland Water Crisis Assessment Team (SWCAT) at providing water at short notice to distressed areas has been hampered by lack of transport. The unit should be adequately funded in order to be able to discharge this function.

b). Members of the community should take steps towards solving the problem of water scarcity. Some of the existing thatched roofs should be replaced with materials having higher rain water harvesting potentials and acquiring high

volume storage containers so that rain water can be collected and stored to serve the family especially during the dry season.

c) Agriculture is the main source of income for most Swazi families and the backbone of the food security programme of the kingdom. The government should ensure adequate provision of water to meet domestic, irrigation and livestock needs through drilling of boreholes and construction of reservoirs.

#### ACKNOWLEDGEMENTS

The authors are grateful to the Department of Land Use and Mechanization of the University of Swaziland for facilitating this research work.

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# Variance Analysis for a Daily Rainfall Disaggregation Model

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**Abstract-** Rainfall data at fine time scale are required for erosion modelling of small landscapes such as railway and road embankments. Limited availability of such data leads to the option of daily rainfall disaggregation. Daily rainfall data can be gathered easily from various sources. One of these sources is the Australian SILO Data Drill facility that generates continuous daily rainfall data from 1889 to current date for any set of coordinates on the Australian continent. This paper is concerned with the relationship between daily and fine simulation timescale variance required by a daily rainfall stochastic disaggregation model [1]. For Queensland, it is found that the relationship between the daily and six-minute variances exhibit a well pronounced seasonality. Incorporation of the seasonality of the variance relationship into the stochastic disaggregation model significantly improved the performance of the model in terms of the reproduction of the different aggregation level statistics.

**Keywords-** Rainfall, Stochastic, Disaggregation, Fine time scale, Daily, Variance

## I. INTRODUCTION

Fine time scale rainfall data are required for environmental modeling particularly where erosion is an issue. However, fine time scale rainfall data are scarce and costly to gather. Therefore, disaggregation of daily rainfall data, which is readily available, is a necessity. The Australian SILO Data Drill facility generates continuous daily rainfall data from 1889 to current date for any set of coordinates on the Australian continent. To use these daily rainfall data effectively for erosion modelling, a robust disaggregation model that generates sub-daily time series fully consistent with the daily totals while preserving multiple sub-daily time scale stochastic structure is required [1]. Stochastic models attempting to address the disaggregation problem can generally be divided into two groups. The first group of models [1]-[8] is based on point process theory of the Bartlett-Lewis and Neyman-Scott rectangular pulses proposed in [9] and [10]. Scale invariance theory of cascade, fractal and multifractal approaches fall into the second group of models for disaggregation [11]-[15].

A Stochastic Disaggregation model [1], which incorporates repetition techniques and a proportional adjusting procedure [16] into a regionalized hybrid model [6], has been demonstrated to have the capability of preserving the multiple fine timescale stochastic structure. This model is a product of the binary nonrandomized Bartlett-Lewis rectangular pulse model [10] and a

lognormal autoregressive model used as a jitter [3]. Some important aspects of the model such as the preservation of sub-daily stochastic structure need further investigation in order to improve the simulation performance for all months at sites without fine timescale data. A new approach has been adopted to incorporate seasonality into the relationship between six-minute (simulation timescale) and daily variance required by the model.

In the next section a brief introduction of the stochastic disaggregation model is presented. Estimation of the model parameters for Queensland, Australia, is presented in the following section. The next two sections discuss the analyses and simulation of variances, respectively. The paper concludes in the final section.

## II. THE STOCHASTIC DISAGGREGATION MODEL

The disaggregation of daily rainfall in this paper is based on the hybrid regionalized stochastic model [1], [3] and [6]. This model is composed of a binary chain (wet and dry sequence) and an autocorrelated jitter (intensity) process. Limited fine scale data are required to calibrate the binary chain model parameters for a region.

### A. The Hybrid Model

The hybrid model is a product of a binary chain  $\{Y_t(h)\}$  and an autocorrelated jitter  $\{A_t(h)\}$  expressed as

$$\{\bar{Y}_t(h)\} = \{A_t(h)\} \{Y_t(h)\} \quad (1)$$

Here  $h$  represents the simulation timescale. The jitter process is assumed to be lognormal,  $A_t(h) = \exp[Z_t(h)]$ , where  $[Z_t(h)]$  is a stationary Gaussian process. The variance  $\sigma_z^2(h)$  and lag-1 autocovariance  $c_z(h)$  of  $[Z_t(h)]$  are given, respectively by [2]

$$\sigma_z^2(h) = \ln \left[ \frac{\sigma_{\bar{Y}}^2(h) + \mu_{\bar{Y}}^2(h)}{\sigma_Y^2(h) + \mu_Y^2(h)} \right] \quad (2)$$

$$c_z(h) = \ln \left[ \frac{c_{\bar{Y}}(h) + \mu_{\bar{Y}}^2(h)}{c_Y(h) + \mu_Y^2(h)} \right] \quad (3)$$

## B. The Binary Chain

The binary chain generates only two values, a '0' for a dry period and a constant value  $w(h)$  for a wet period. The moments of the binary chain are given by [17]

$$w(h) = \frac{\mu_{\bar{Y}}(h)}{1 - P(h)} \quad (4)$$

the variance  $\sigma_Y^2(h)$  as

$$\sigma_Y^2(h) = \left[ \mu_{\bar{Y}}(h) \right]^2 \frac{P(h)}{[1 - P(h)]} \quad (5)$$

and the lag-1 autocovariance  $c_Y(h)$  as

$$c_Y(h) = \left[ \mu_{\bar{Y}}(h) \right]^2 \left\{ P_{00}(h) - 2P_{01}(h) \left[ \frac{P(h)}{1 - P(h)} \right] + P_{11}(h) \left[ \frac{P(h)}{1 - P(h)} \right]^2 \right\} \quad (6)$$

where  $P(h)$  is the probability that an interval  $i$  of duration  $h$  is dry. The joint probabilities are defined as

$$\begin{aligned} P_{00}(h) &= P(2h) \\ P_{01}(h) &= P(h) - P(2h) \\ P_{11}(h) &= 1 - 2P(h) + P(2h) \end{aligned} \quad (7)$$

In (7),  $P(2h)$  is the probability of two consecutive wet periods being dry.

The non-randomized Bartlett-Lewis model [9] has been used to generate the binary chain. This non-randomized rainfall model assumes that storms arrive in a poisson process of rate  $\lambda$  ( $h^{-1}$ ). Followed by each storm origin is the Poisson arrival of the cell origin at a rate  $\beta$  ( $h^{-1}$ ). Cell arrival ceases after a time, exponentially distributed at a rate  $\gamma$  ( $h^{-1}$ ). It is assumed that one cell arrives at the storm origin. The duration of each rectangular cell is exponentially distributed at a rate  $\eta$  ( $h^{-1}$ ). Dimensionless parameters  $\kappa = \beta/\eta$  and  $\phi = \gamma/\eta$  are also introduced. Ref. [9] has derived the probability  $P(h)$  of an interval  $i$  of duration  $h$ , as

$$P(h) = \exp\left[-(h + \mu_T - C)\lambda\right] \quad (8)$$

where the expected duration of a storm  $\mu_T$  and the constant  $C$  are integral functions of model parameters  $\beta, \gamma$  and  $\eta$ .

## III. ESTIMATION OF THE BINARY MODEL PARAMETERS

The Australian continent has been divided into a number of rainfall regions (districts) by the Bureau of Meteorology (Fig.1). Regions 35, 39 and 40 in Queensland have been selected for analyses.

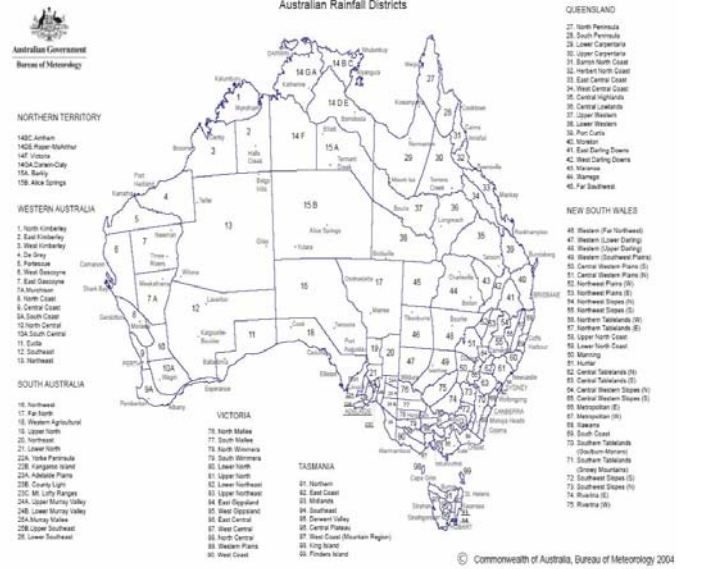


Figure 1. Australian Rainfall Districts

Limited fine timescale (six-minute) observed data for 65 sites from the selected regions were used to calibrate the model parameters. The model is tested for three stations namely, Brisbane, Rockhampton and Dingo. Model parameters  $\beta, \gamma$  and  $\eta$  were considered as constants and only parameter  $\lambda$  was considered as site specific determined by the monthly  $P(24)$  values and (8).

The NLFIT Bayesian non-linear regression software [18] was used for parameter estimation. The global optimization search strategy [19] over a hypercube was employed to refine the posterior distribution of the initial multinormal approximation. The parameters were then sampled from the posterior distribution by the Metropolis algorithm [20]. Table 1 shows the estimated parameters.

Table 1  
Queensland Parameter set

Parameter	Multinormal approximation		Metropolis	
	Mean	Standard deviation	Mean	Standard deviation
$\beta$	0.200	0.011	0.166	0.010
$\eta$	0.510	0.013	0.473	0.013
$\gamma$	0.090	0.002	0.082	0.003

## IV. ANALYSES OF VARIANCES IN QUEENSLAND

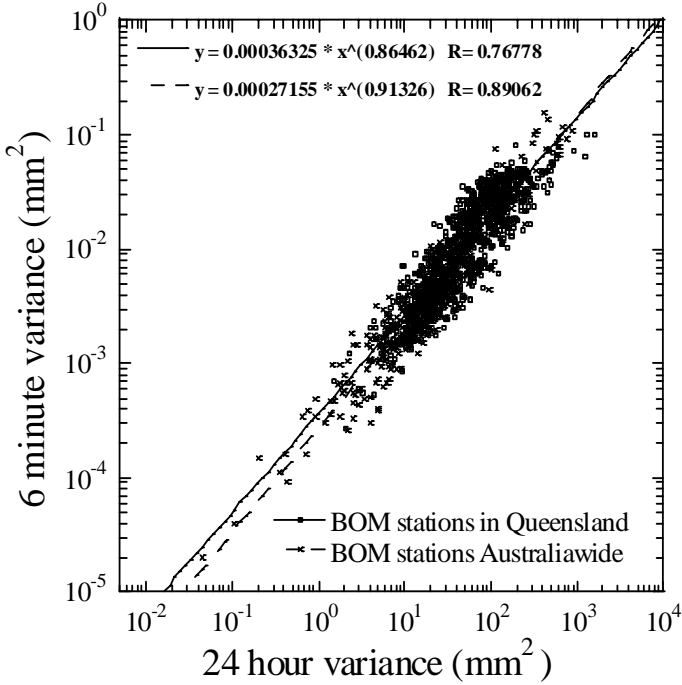
An empirical scaling relationship between daily variance and the fine scale variance (six-minute) was established for selected sites throughout Australia in ref [1] as,

$$\sigma_{\bar{Y}}^2(0.1) = 0.000272 \sigma_{\bar{Y}}^2(24)^{0.913} \quad (9)$$

No apparent seasonality was observed in this data set. An observation of six-minute lag-1 autocorrelation for the stations revealed that this statistic could be assumed as a constant value of 0.71 throughout Australia [1].

Fig. 2 shows that there is subtle difference between the regionalized fit and the Australia wide fit power curves. Both display significant scatter of many station-months

from the fitted power curves. To minimize the scatters, seasonality was investigated for the relationship between six-minute and daily variances in the selected three regions of Queensland.



**Figure 2.** Fitted power curves between six-minute and 24-hour variances in Queensland and Australia wide

After a thorough investigation of the monthly six-minute and 24-hour variances in Queensland, it was found that the scaling constant,  $a$  and exponent,  $b$  demonstrate a clear seasonality and an equation of the following form:

**Equation 1**

$$\sigma_Y^2(0.1) = a \{ \sigma_Y^2(24) \}^b \quad (10)$$

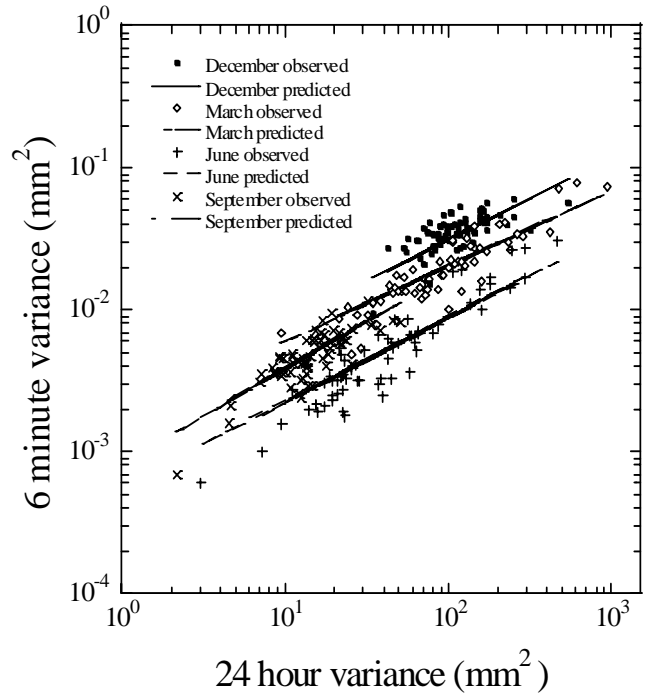
where scaling parameters  $a$  and  $b$  are defined as,

$$a = a_0 + a_1 \cos(2\pi m/12) + a_2 \sin(2\pi m/12) \quad (11)$$

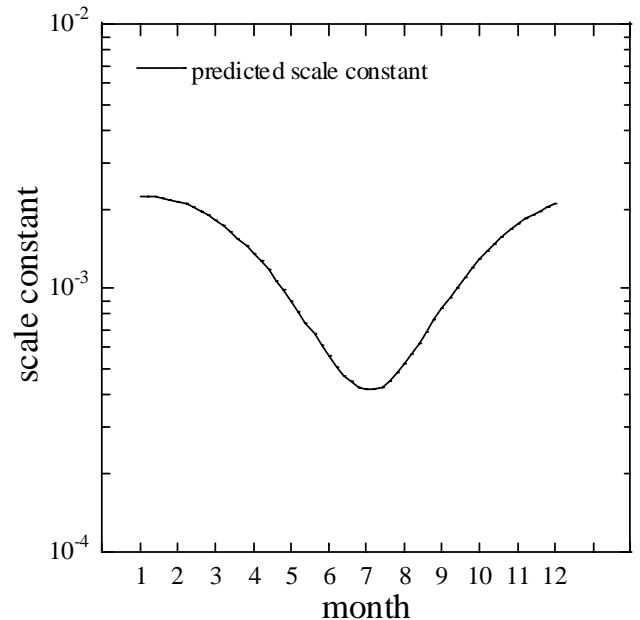
$$b = b_0 + b_1 \cos(2\pi m/12) + b_2 \sin(2\pi m/12) \quad (12)$$

was adopted.

Fig. 3 shows the monthly variation of the downscaling relationship for four equally spaced months and Figs. 4 and 5 show the seasonal variation of the scaling parameters of (11) and (12).



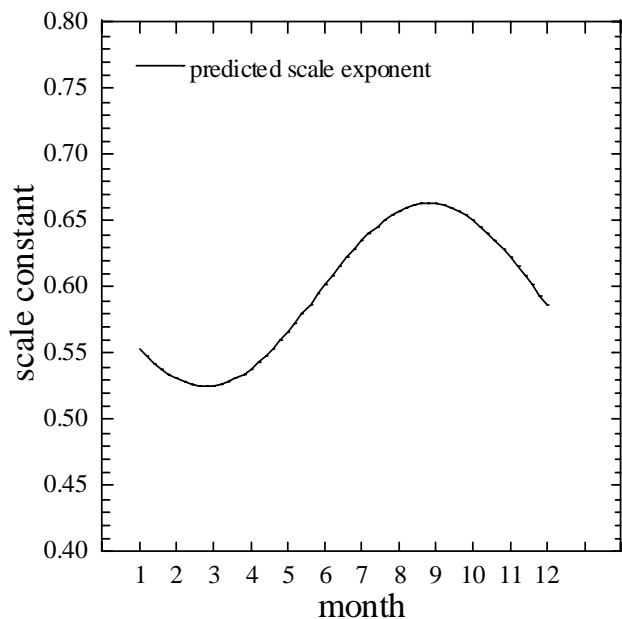
**Figure 3.** Seasonal variation of the variance relationship for Queensland



**Figure 4.** Seasonal variation of the scaling constant  $a$

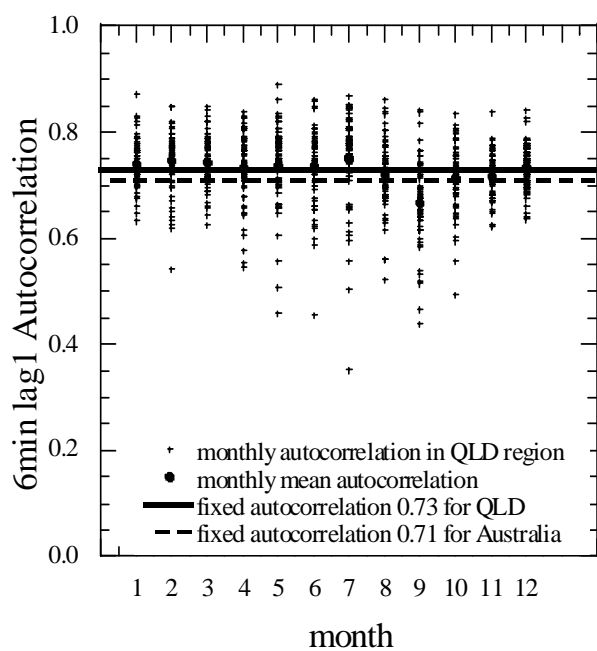
## V. SIMULATION RESULTS

The data and results were analyzed at 12 aggregation levels (0.1, 0.2, 0.3, 0.5, 1, 2, 4, 6, 8, 12, 18 and 24 hours). The simulated variances using Australia wide fitted equation are shown in Figs. 7 and 8 for some selected station-months in Queensland.

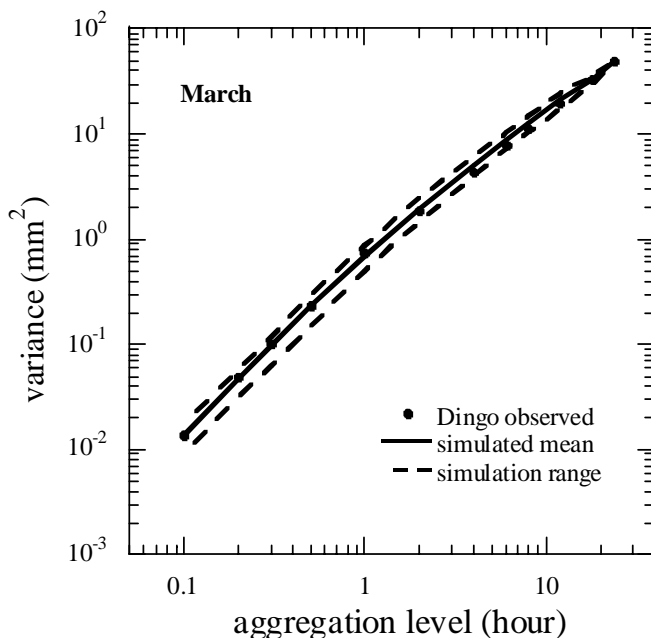


**Figure 5.** Seasonal variation of the scaling exponent  $b$

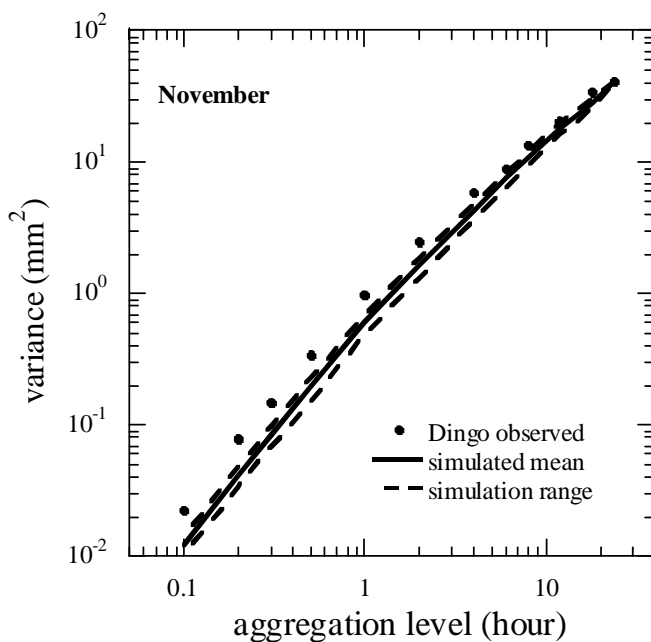
The monthly means of the six-minute autocorrelation for Queensland did not show any seasonality. A constant value of 0.73 (Fig. 6) is adopted for Queensland.



**Figure 6.** Monthly autocorrelation for Queensland



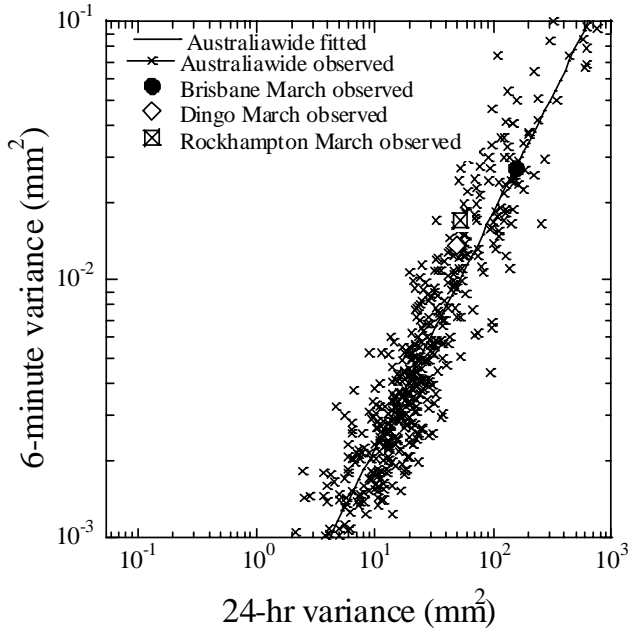
**Figure 7.** March variance at Dingo using Australia wide fitted equation



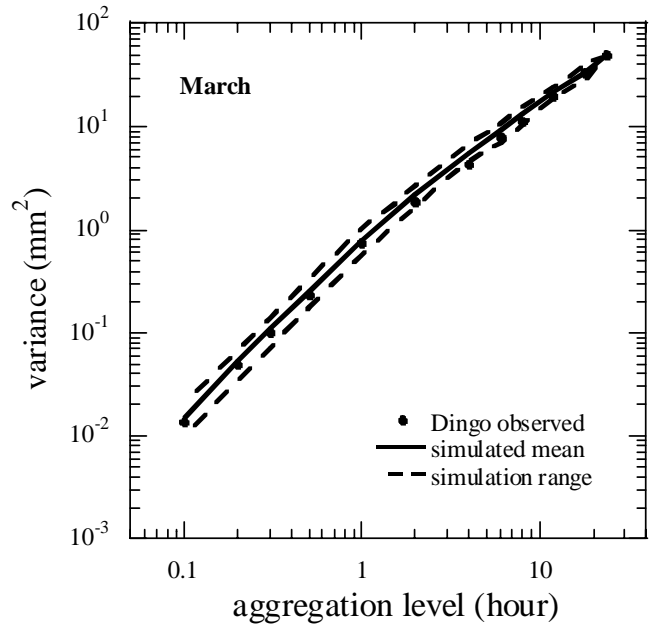
**Figure 8.** November variance at Dingo using Australia wide fitted equation

The simulated variances showed excellent results particularly from December to March (Fig.7). But for months from April to November the results were not encouraging (Fig.8). As shown in Figs. 9 and 10, the closer the observed station-months' variances to the Australia wide downscaling fitted power curve the better the simulation results.

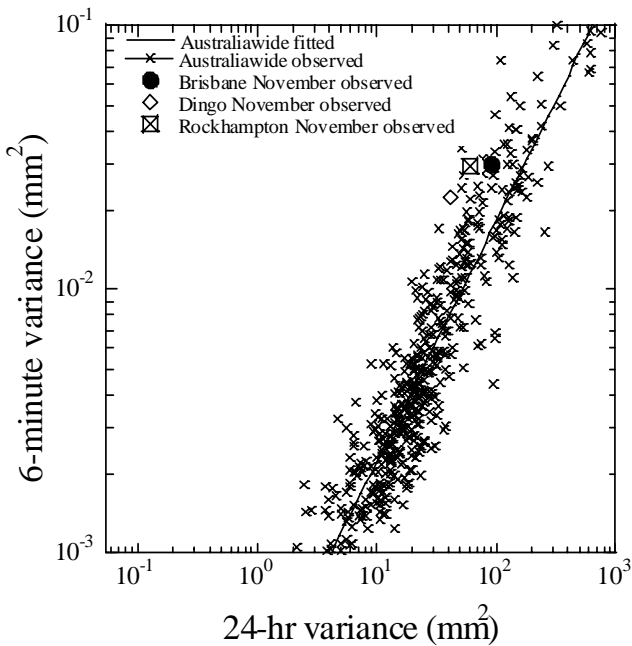
The regionalized downscaling equation with seasonality for variance and autocorrelation were incorporated into the disaggregation model and used to simulate rainfall for the selected three stations. Figs. 11 and 12 show the simulation results of the six-minute variances at Rockhampton and Dingo for the same months that were simulated earlier without seasonality. Improvement in simulated November-Dingo is observed.



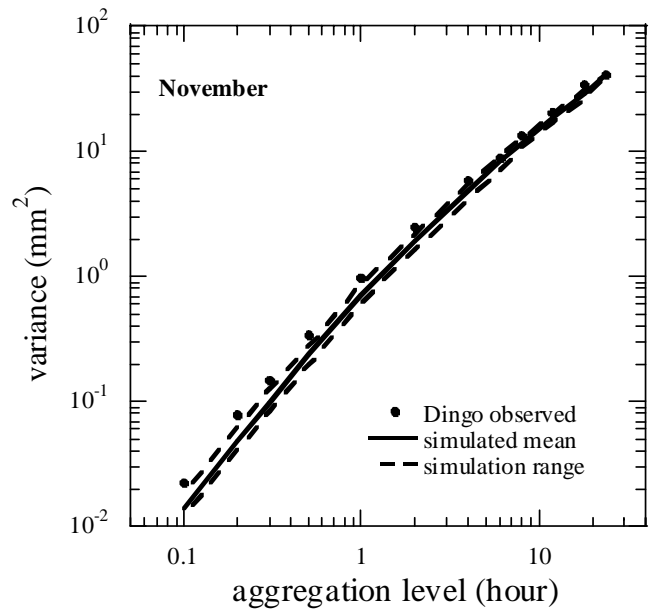
**Figure 9.** Comparison of selected March station-months and the Australia wide variance relationship



**Figure 11.** March variance at Dingo with regionalized seasonality equation



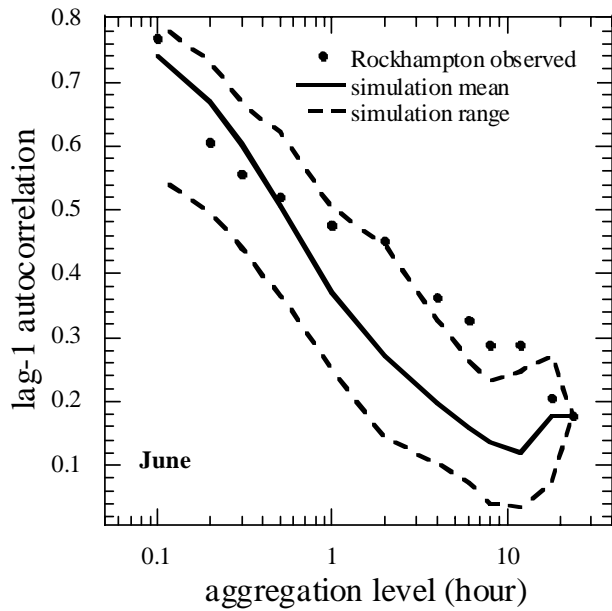
**Figure 10.** Comparison of selected November station-months and the Australia wide variance relationship



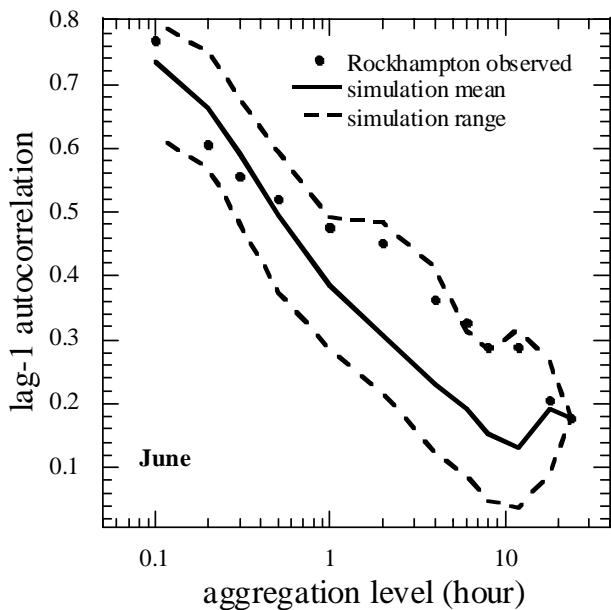
**Figure 12.** November variance at Dingo with regionalized seasonality equation



A significant improvement is also achieved in the simulation of variances at other sites with the introduction of the new approach into the downscaling technique. The autocorrelation is also improved with the regionalized value of 0.73 for Queensland compared to the Australia wide (Figs. 13 and 14).

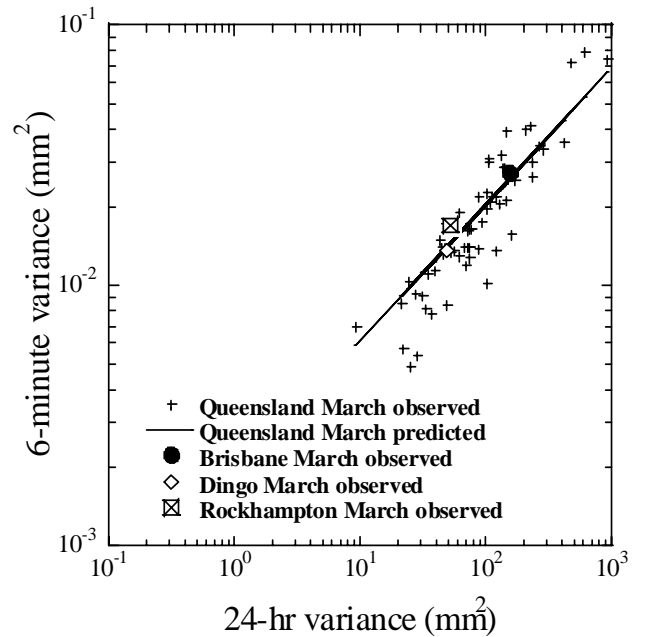


**Figure 13.** June lag-1 autocorrelation at Rockhampton using Australia wide fitted equation

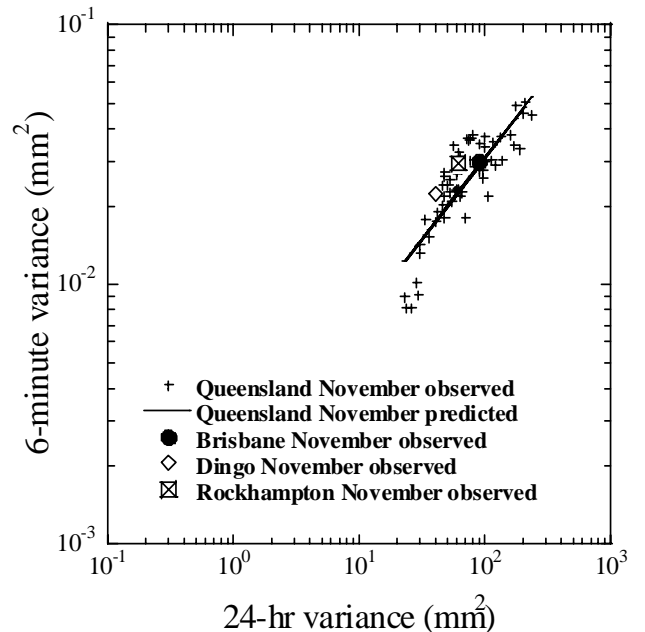


**Figure 14.** June lag-1 autocorrelation at Rockhampton with regionalized seasonality equation

The extent of improvement in the model prediction of variances is also examined for the selected sites. Figs. 15 and 16 show their scatters after seasonality and regionalization incorporated into the variance relationship. It was observed that data-lengths have no significant effect on the variance relationship.

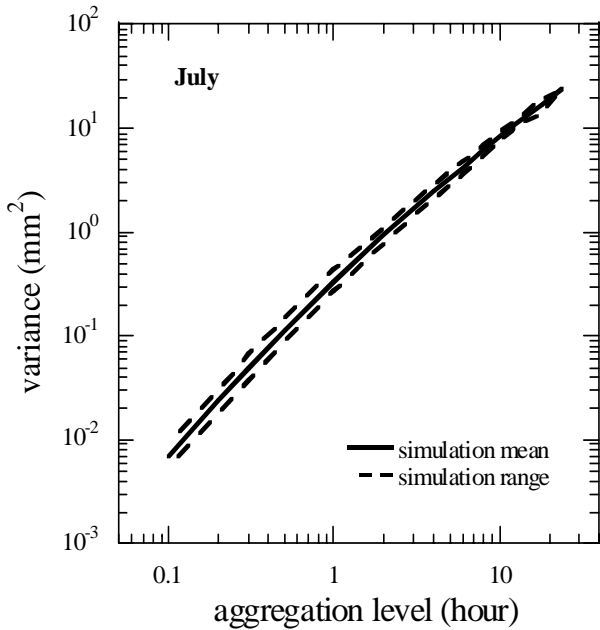


**Figure 15.** March scatter of the Queensland selected sites with seasonality incorporated into the variance relationship

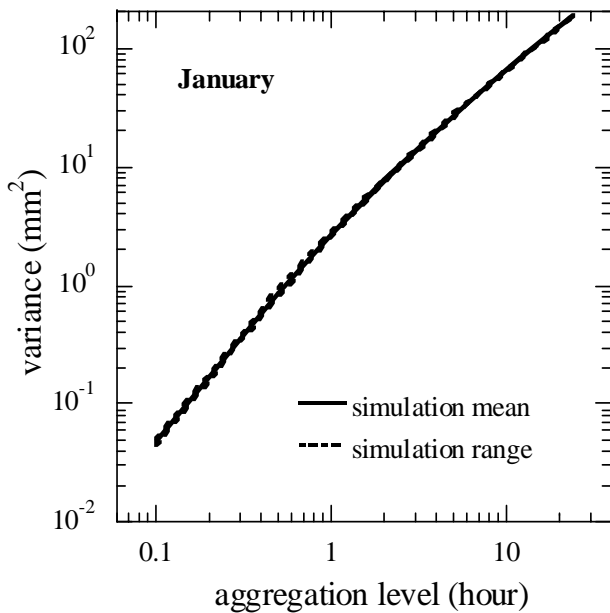


**Figure 16.** November scatter of the Queensland selected sites with seasonality incorporated into the variance relationship

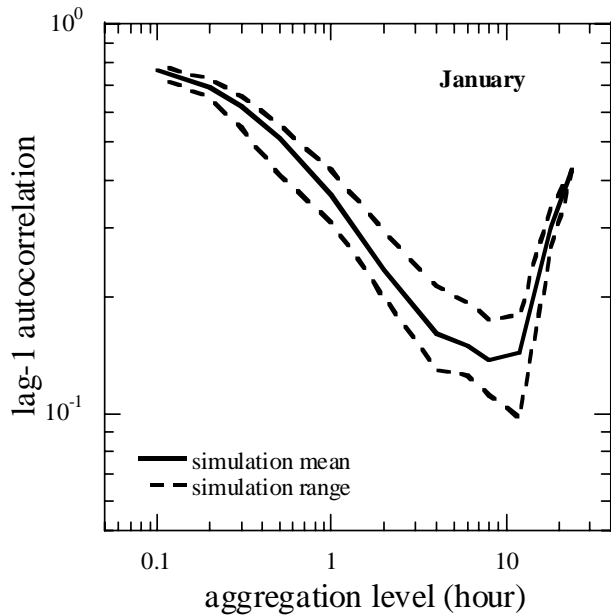
With this confidence the same approach was adopted for disaggregation of the synthetic daily rainfall data generated from SILO datadrill at these three sites. The results are plotted in Figs. 17, 18 and 19. The data length being long (118 years), the simulation range is quite small.



**Figure 17.** July variance of Dingo from disaggregated SILO data



**Figure 18.** January variance of Brisbane from disaggregated SILO data



**Figure 19.** January lag-1 autocorrelation of Rockhampton from disaggregated SILO data

The data lengths of different months may vary between the SILO data and the observed data sets. The disaggregation model preserves the means of the observed data in the simulated fine timescale storm profile. Hence a comparison between any observed data and the simulated SILO data is not practical.

## VI. CONCLUSION

An analysis of the discrepancy of the simulated fine timescale variances has been performed. It is found that the downscaling relationship between the six-minute variance and the daily variance, required by the disaggregation model, exhibits seasonality for Queensland, Australia. Hence a new approach conforming to the seasonality of the downscaling relationship has been incorporated into the disaggregation model. The six-minute autocorrelation statistics is also found to assume a slightly different regional constant value for the Queensland region. The results with the new approach are very encouraging even for the earlier worse predicted station months. These findings prompted the use of the same approach for disaggregating daily rainfall at selected sites in Queensland with synthetic data from SILO datadrill. A smaller simulation range is observed for the SILO data as a result of over 100 years of synthetic data.

Further investigations can be done on the regional seasonal pattern throughout Australia. Improvements of other statistics such as the autocovariance and intensity are also currently being investigated.

## ACKNOWLEDGMENT

Central Queensland University scholarship to the first author is very much appreciated. Continuing financial support by Queensland Rail (QR) to the second author

through the HEFRAIL project is gratefully acknowledged. We would also like to thank George Kuczera for providing the NLFIT software.

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# Advances in Steep Slope (Batter) Erosion Control

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**Abstract-** Embankments and cuttings are integral parts of rail and road networks that support the economy of every country including Australia. Water induced erosion from the steep slopes (batters) of these civil engineered structures costs tax-payers in terms of ongoing operation and maintenance of the land transport networks. Also the environment is degraded and sediments transported from sites have the potential to pollute the nearby water bodies downstream. This paper provides an overview of advances made in Queensland, Australia, to mitigate the erosion problems of railway formation batters. Our research effort has been focused on strategies to aid quick establishment of grasses on the batters. The strategies include defining the topsoil quality of the batters, modification of batter topsoils to provide a conducive growth medium for the grasses, and seed treatment including pre-germination to accelerate the germination process. Provision of a cheap mulch to protect grass seeds/ seedlings and ameliorants from washout by high intensity and short duration rainfall events is another strategy. Development of a cost-effective drip irrigation system that sources water from either an existing pressurised water main or a temporary excavated pond/ dam (with solar pump) to supplement the unpredictable natural rainfall is a major strategy. It has been established that the target of 60% grass cover reduces erosion by over 90% compared with the bare scenario. The plot-scale verification work and experiences have already been successfully incorporated into large scale railway projects such as the 110 km Bauhinia Regional Railway Project spur line construction.

**Keywords-** Erosion control, Steep slopes, Batters, Drip irrigation, Grass seeding.

## I. INTRODUCTION

Water erosion of the steep slope (batter) soils is caused by a two-part process. Raindrop impact and runoff cause soil particles to detach, and detached soil particles are transported by runoff. Erosion from batters may occur in different forms such as splash, sheet, rill, gully and tunnel (piping) erosion. The main objectives for preventing erosion and sediment production from batters are to quickly protect bare soil from rainfall impact, and to also manage water runoff. Sedimentation is managed by slowing flow and creating areas where sediment can be trapped or allowed to settle. While there have been numerous studies on runoff and erosion processes by others [eg 1, 2, 3], they are confined largely to agricultural fields with mild slopes, and laboratory experiments using rainfall simulators. There remains a lack of knowledge of the embankment/ cutting landscapes with steep slopes over compacted subsoils.

Upper layers of soils in much of the area of the Bowen Basin coal deposits in Central Queensland (CQ) are generally highly dispersive. The steep slopes required for earthworks within the narrow corridors of the export coal rail network are therefore particularly susceptible to water erosion, resulting in sediment transport and siltation of waterways. Some of the embankment and cutting batter erosion problems within Queensland Rail (QR) corridors are highlighted in Fig. 1. In Australia the erosion problems are not confined to CQ only, but they abound all over the country. Wherever soil is exposed there is erosion potential and the risk is aggravated by the steepness of embankment and cutting batters. Traditionally embankments have been designed and constructed without due regard to the hydrological processes and effects on the environment.

High maintenance costs, train delays due to speed restrictions and increasing environmental degradation persuaded QR to fund extensive research into cost effective and sustainable methods of erosion control in this ecologically sensitive area. This ten-year collaboration between QR and Central Queensland University (CQU), under the banner of HEFRAIL Project, has produced integrated systems to optimise the establishment of protective grass cover on steep slopes using fast growing non-invading plant species accepting of local conditions. These include seed treatment, amendment of sodic/saline/extreme pH soils, appropriate fertilization, innovative drip irrigation systems designed for site specific conditions with a view to being extremely economical with water use, and the management of fire risk to the protective grasses when it is necessary to burn off [4, 5, 6, 7, 8, 9]. By monitoring runoff and soil loss associated with rainfall events on field trial plots at the Gregory experimental site, it has been established that 60% grass cover on a railway batter reduces erosion by over 90% compared with the bare scenario [5, 9]. This paper provides an overview of the advances made on mitigation of erosion problems within QR corridors.

## II. SEED GERMINATION ENHANCEMENT

The drought tolerant and quick regeneration after fire properties of Buffel Grass make it a preferred species for erosion control of railway batters in the semi-arid regions of

Queensland. It has a larger and deeper root system capable of providing greater strength against erosion than other grasses [10]. However, poor germination of Buffel seeds sown on railway batters due to inherent seed dormancy makes it difficult to achieve the rapid cover required for effective erosion control [11]. In the literature various physical, mechanical, chemical and biological measures have been used to overcome grass seed dormancy [12, 13]. This section presents experiments conducted at CQU on the use of sulphuric acid ( $H_2SO_4$ ) to break Buffel seed dormancy for railway batter revegetation [13].



Boundary Hill Site: eroded sediments fouling ballast in a cutting



Boundary Hill Site: eroded sediments chocking culverts



Laleham Site: rill erosion on an embankment batter

Figure 1. Examples of erosion problems on embankment and cutting batters within QR corridors.

Different concentrations of  $H_2SO_4$  were applied to Buffel Grass seeds for various soaking (dipping) durations in order to improve the germination process. The factorial combinations of five concentrations of  $H_2SO_4$ , i.e. 0% (distilled water), 25, 50, 75, and 100% and eight seed soaking durations (1, 2, 3, 4, 5, 10, 20, and 30 minutes) comprising a total of 40 treatments were tested. Each treatment consisting of 100 uniform seeds was replicated five times. After soaking for the desired period, seed batches were taken out of the solution, drained of acid, and washed under running tap water for a minute before placing in the potting mix. The number of germinated seeds was recorded daily for 15 days.

Fig. 2 shows the final germination percentage after 15 days. The final germination percentage of Buffel Grass seed increased with increasing concentrations of  $H_2SO_4$ . The 100% concentration of  $H_2SO_4$  treatment recorded 94% germination compared to 20-25% without acid treatment. However, an interaction effect between  $H_2SO_4$  concentration and duration of soaking treatment was significant, revealing that at 100%  $H_2SO_4$ , the seed final germination level peaked at 4 minutes, and declined with longer seed soaking duration to almost nil germination after 10 minutes of soaking. At lower concentrations of  $H_2SO_4$ , soaking for more than 5 minutes decreased the seed germination rate significantly. Seed treatment with  $H_2SO_4$  is promising but there are safety issues that call for cautious handling, and mechanized treatment for large applications is recommended.

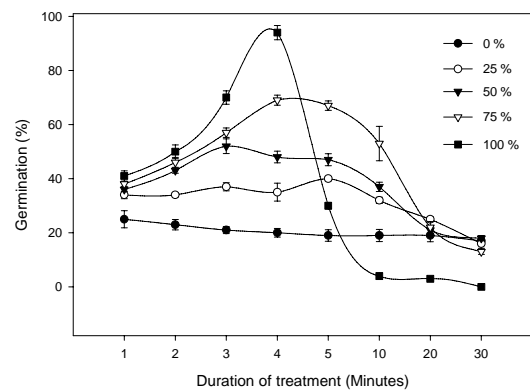


Figure 2. Final germination percentage of Buffel seeds at 15 days [after ref. 13].

An alternative simpler and large-scale practical approach for improving the Buffel seed germination was by soaking the seeds in water and pre-germinating in potting mix or soil media maintained at a constant soil moisture close to field capacity. Maintenance of constant soil/media moisture helped improve germination of soaked Buffel seeds in the experiment [11]. However, results showed that a prolonged period of soaking in deep water reduced the seed germination rate. It was observed that soaking the seeds between 5 and 15 minutes before pre-germinating in potting mix yielded about 30% germination rate. Optimum soaking helps seed imbibition and initiates the germination process of otherwise dormant seeds. Soaking possibly also helps to



remove germination inhibitors associated with the Buffel seeds.

Plastic covers on seeded batters in winter were found to speed up the germination process. It helped build up heat and prevented evaporation, maintaining the moisture content at field capacity. However it was found that if the plastic cover is left longer than required, the built up heat could kill the seedlings.

### III. SOIL MODIFICATION

The soil profile in many parts of Central Queensland is duplex. The top 0.5 m may consist of good quality topsoil but beneath this layer the soil properties are significantly different and of poor nutritional quality to support vegetation growth. This explains why, for some cutting batters, vegetation growth is confined to the top sections and there is a lack of vegetation cover on the subsoil used to construct the embankments. Therefore, the high salinity (indicated by chloride and electrical conductivity levels) and sodicity (reflected by exchangeable sodium percentage levels), and extreme acidity (pH levels) of the soils need to be improved for the soils to provide a conducive environment for sustained grass growth [14]. A cheap source of calcium is used to counteract the negative effects of high sodium content, thus decreasing the exchangeable sodium percentage value. For a sodic soil with pH level below 7 (the neutral value), lime is applied to the soil before seeding. Apart from supplying calcium, lime also raises the pH level. Gypsum being neutral is applied to sodic soils if a change of pH is not required. Application of calcium to sodic soils also increases soil porosity, increases structural stability, reduces soil swelling and shrinkage, increases soil infiltration and hydraulic conductivity, reduces surface crusting and improves root penetration and seedling emergence rates [15]. Suitable fertilisers need to be added to the soil to provide nutrients required for the growth of the grasses. Rates of application of the ameliorants and fertilisers depend on the soil chemical properties. Where the soil properties are found to be very poor, the batters are topsoiled in lieu of chemical modification.

### IV. MULCHING

The risks of washout of seeds/ seedlings and ameliorants by high intensity and short duration rainfall events that characterise the semi-arid environment need to be minimised. Limited use of waste ballast and erosion control blankets as mulch has been quantitatively investigated [7]. The mulch will help reduce raindrop impact and runoff velocities. The inter-ballast voids will increase water storage and retention time, thereby increasing hydraulic gradient and hence increasing infiltration. The grass will anchor the ballast from washout or gravity sliding/ rolling. Should fire occur after establishment of the grasses, the ballast would be in place to minimise erosion on the batters, before a revegetation program becomes effective. This is to say, the ballast provides a degree of permanent protection against erosion. The blankets can be costly where laid on all batter

sections. Therefore, attention is focused on laying the blankets on critical sections of the batter in order to reduce costs. For an embankment the most critical section is the topmost batter section where the blanket is expected to spread runoff thereby reducing the risk of rill erosion before the grasses are established.

## V. IRRIGATION SYSTEM

### A. Water Sources

Water can be sourced from existing dams, existing creek water holes, from earthworks construction water tanks, and from road delivery to temporary tanks located within the rail corridor. The overriding factor is the cost of the water which can range between AU\$1/kL and AU\$10/kL.

### B. Advantages of Drip Irrigation

Drip Irrigation is the most efficient and manageable system by which water is supplied directly near the root zone of the plants as per the demands of the plants through drippers or emitters, used interchangeably. The emitter is enclosed and inseparably welded to the inside wall of the tubing as it is extruded in the manufacturing process. Fig. 3 shows some elements of the drip line (lateral) network.



Figure 3. Elements of drip lines.

The specific benefits of drip irrigation as related to railway batter applications are [8]:

- enormous water savings as little water is lost to evaporation;
- grasses undergo less stress from variations in soil moisture, enhancing appearance;
- slow application rate prevents excess surface water build-up;
- the low application rate and the use of automatic timers result in precise water control, allowing variation of water demand to fit grass growth stages;
- system's low flow rate allows irrigation of larger areas from a small water source, and economical to use in dry weather conditions;
- less labour requirement for monitoring and maintenance once the system is established and in operation;
- low labour and installation costs since there is no hole punching, emitters are factory spaced at equal intervals, and low risk of handling damage;
- water is kept off top of embankment, ballast and track section, access roads, thus preventing weed growth in these areas;
- the multi-outlet emitters/drippers provide highly uniform discharge rate and precise irrigation pattern;
- the jointless design guarantees longer lateral lengths, and makes it ideal for railway batters;
- being rugged, lightweight and very flexible, installation is very easy, and drip lines can be recovered mechanically regardless of grass cover levels;
- easy roll-up and storage make it easy for re-use from site to site, cutting down cost considerably;
- if irrigation water is mixed with fertilizer, it offers a more effective way of applying fertiliser and chemicals into the root zone.

### C. Design and Layout

Emitter discharge varies along the lateral with maximum value at upstream and zero at the end. Consider the lateral in Fig. 4 having inlet pressure head  $H_0$  and discharge  $Q_0$ , and equal emitter spacing  $s$ . The discharge  $q_i$  ( $L \cdot h^{-1}$ ) from an emitter  $i$  is determined by the rating curve

$$q_i = kH_i^x \quad (1)$$

where  $H_i$  (m) is the pressure head in the lateral at the emitter  $i$ ,  $x$  is the emitter discharge exponent characterizing the flow regime and emitter type, and  $k$  is emitter discharge coefficient.

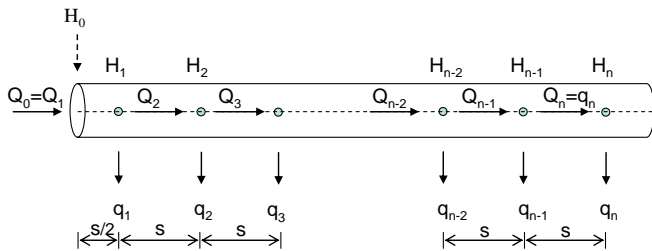


Figure 4. Hydraulics of drip line.

The Forward-Step Method equation [4, 16, 17]

$$H_{i+1} = H_i + \frac{3}{2gA^2} [Q_i^2 - Q_{i+1}^2] - \left[ \frac{8s}{\pi^2 g D^5} f_{i+1} + \frac{\alpha}{2gA^2} \right] Q_{i+1}^2 - s s_o \quad (2)$$

is used to solve for the emitter pressure and discharges forwards. In (2)  $s_o$  is the constant slope of the lateral (positive for uphill and negative for downhill),  $D$  (m) is diameter,  $A$  ( $m^2$ ) is cross-sectional area,  $H_i$  (m) is the pressure head at emitter  $i$ ,  $Q_i$  (m) is discharge flowing to emitter  $i$ , and  $f_{i+1}$  is the Reynolds number. Ref. [4, 16] provided the solution of the hydraulic equation for a network of drip lines such as shown in Fig. 5 for Holmes cutting site, Fig. 6 showing the actual site with the emitter wetting front.

A 40 mm poly pipe is used to deliver water at the desired pressure to the irrigation controllers. A rain sensor attached to the controllers increases the efficiency of the automated drip irrigation system and avoids wastage of water. The submains taking water from the controllers to the bays are 25 mm poly pipe. A 20 mm dripline with an emitter maximum discharge of 2.5 L/h and 0.3 m spacing has been found to be adequate. The total area to be irrigated is divided into bays, making sure the maximum bay water demand does not exceed the supply rate.

## VI. RESULTS TO DATE

The integrated systems developed to combat the steep slopes erosion problems have been tested on a large scale at several locations in Queensland (Fig. 7) with excellent results. With the developed strategies, the threshold grass cover of 60% is achievable between 8 and 14 weeks after seeding depending on the establishment season, maintenance, water source reliability and soil quality. The photographs shown in Figs. 8 through 13 best demonstrate the success stories of the advancements made in controlling erosion on railway formation batters. No maintenance has been carried out at any of these sites, briefly discussed below, after treatment. Given the environmental risks associated with erosion, and the estimated cost of about AU\$11.73/m<sup>2</sup> every 10 years in maintenance if the railway batters are not treated, the estimated total cost of between AU\$3/m<sup>2</sup> and AU\$7/m<sup>2</sup> of batter area treated with irrigation is justified.

### A. Boundary Hill Site

As shown in Fig. 1, this cutting site (650 m long, 1.3 km batter length) had serious erosion problems; excessive scouring of rill and tunnel erosion on the batters, tunnel erosion on the access road and adjacent property, ballast fouled by eroded sediment, shallow seated slope failures, batter surface crusting (hard setting) and off-site sedimentation problems. The erosion problems were largely due to the soil being acidic (pH = 4.4), strongly alkaline and sodic. A catchment-based approach was adopted in the mitigation of the erosion problems, viewing the cutting as an integral part of a drainage system that extends beyond the railway easement. Several earth banks and catch drains were constructed to divert runoff away from the railway cutting crest. A series of rock check dams were put in the catch

drains to help control flow velocity, stop erosion, and trap sediment. All erosion pipe inlets and outlets were excavated and filled with basalt spoil material obtained from the nearby mine. The site was well graded to prevent ponding of runoff water on the disturbed areas before treatments were imposed in February and March 1999. Pressurised water was tapped at the hydrant of the nearby mine 600 m away [18].

**B. Laleham Site**

The soil at this embankment site (300 m batter length) is characterised as strongly alkaline, moderately saline, and strongly sodic, and was exhibiting severe rill and tunnel (piping) erosion on the batters and access road before HEFRAIL treatment (Fig. 1). Previous attempts made by QR workers to improve the access road by filling the pipes with soil and ballast did not work. Owing to the severe and extensive nature of rill and piping erosion, the embankment shoulder had to be reconstructed before treatments were imposed. Water was tapped at an air valve of a high pressure main 1.3 km away [19].

**C. Riverside Mine Site**

This embankment site consisted of four batter sections of a combined batter length of 1.2 km. There were numerous erosion pipe inlets on the top of the embankment, and erosion pipe inlets and outlets on the batters as a result of the acid soils prohibiting vegetation colonisation. The erosion pipe inlets under some overhead traction mast foundations could topple the masts with devastating consequences. The diameter of the pipe inlets ranged between 0.3 m and 2 m, with depths varying between 1 m

and 3 m. Rill erosion, as a result of concentrated surface flow, and inter-rill (sheet) erosion were also occurring on the embankment batters. The embankment sections were widened to repair the erosion damage and also to improve the access roads. Two sections were first treated in February 2001, and after grass establishment the irrigation materials and equipment were used to treat the other two sections in December 2001. This is an example of progressive treatments to save costs. Water was tapped at a scour valve of a high pressure main 700 m away [20].

**D. Black Mountain Derailment Site**

This site demonstrated an advanced technology cost-effective drip irrigation system design and setup on the environmentally sensitive elevated batters of a coal train derailment site. The final profile of the coal burial site consisted of six batters and associated berms with a drop in elevation of about 35 m, and a total batter length of 542 m. A small dam constructed downstream of the confluence of the two main drainage channels at the site supplied water for irrigation, and also served as a sediment trap. Water was periodically pumped from the small dam to three storage tanks using a petrol pump. Three solar pumps drew water from the storage tanks and dam to irrigate the top four batters. Contactors, pressure switches and irrigation control valves in turn shared a single solar power source between the solar pumps. Level balls (floating switches) placed in the storage tanks cut the solar power supply to the pumps when the storage tanks were nearly empty. The automated system cut labour costs considerably. Treatments were imposed in December 2001 [6].

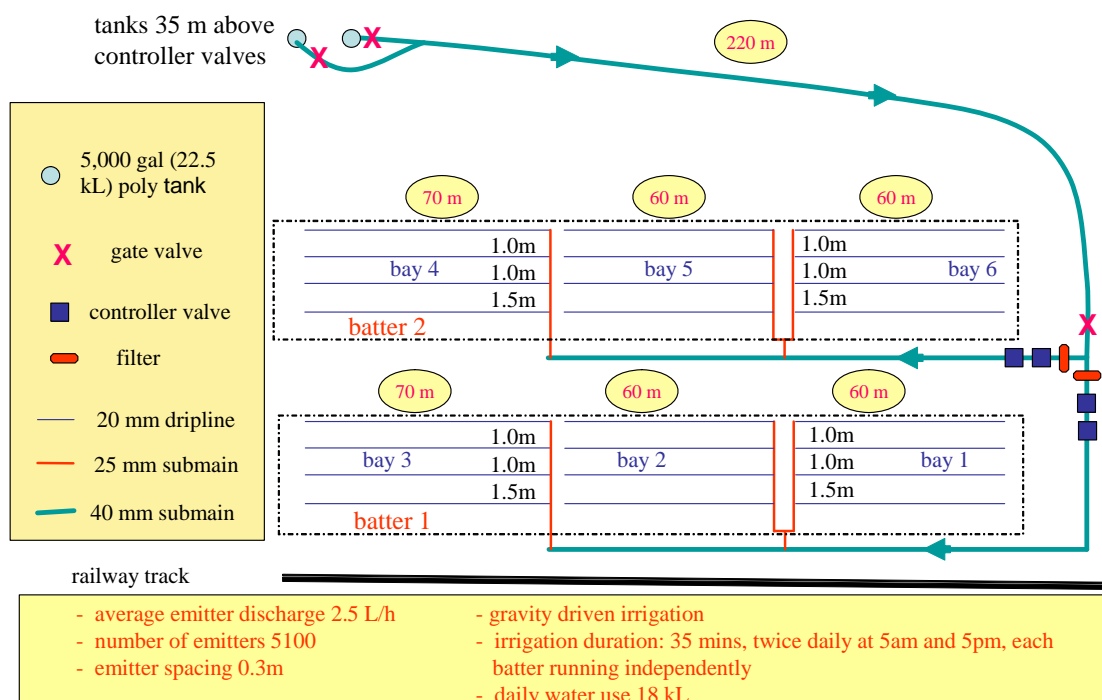


Figure 5. Line diagram of drip lines for the lowest two batters of Holmes Cutting.





Figure 6. Holmes cutting site – lowest two batters showing emitter wetting fronts.



Figure 8. Boundary Hill Site. Drip lines were laid on all batter sections at row spacing between 1 m and 2 m.



Figure 7. QR network showing the field trial sites.



Figure 9. Laleham site. Drip lines were laid on all batter sections at row spacing between 1 m and 2 m.



Figure 10. Riverside Mine site. Drip lines were laid on all batter sections at row spacing between 1 m and 2 m.





Figure 11. Black Mountain Derailment Site. Drip lines were laid on all batter sections at row spacing between 1 m and 2 m.



Figure 12. Bauhinia Site. Grasses established before track was laid. Three rows (1 m spacing) of drip lines were laid at the top batter section only.



Figure 13. Holmes cutting – four rows (1 m spacing) of drip lines were laid at the top section only.

#### E. Bauhinia Regional Railway Project

The Bauhinia Regional Rail Project is the first commercial application of HEFRAIL erosion control processes developed so far. It was a 110 km new spur line including several embankments that needed to be protected against erosion. The progressive treatments were integrated with the earthworks construction. In order to reduce the treatment costs, the embankment batters were categorised with different levels of treatment. The top 3 m of batters of all embankment sections exceeding 4 m in height and embankment batters on the downstream side of the two major flood plains (37 sites with a total embankment length of 15.1 km, treating both sides) received the full HEFRAIL erosion control treatment. The remaining embankment batters were treated but without irrigation. Water from existing dams and creek water holes, from earthworks construction water tanks, and from road delivery to temporary tanks located within the rail corridor were used to supply the irrigation water. To increase the germination rate and accelerate the germination process the seeds were soaked for 5 minutes in water and pre-germinated in potting mix before spreading on the batter surface [11]. The project spanned between October 2004 and June 2006.

#### F. Holmes cutting

At this site QR eased the track curves, that is increased the curvature radii, at this section of the Toowoomba range. This activity resulted in fresh cuttings (Fig. 6) and spoil placed in embankment berms above the cuttings. The batters of the cuttings and embankments were progressively treated between August 2006 and October 2007. Four rows of drip lines were laid at the top sections only. The two poly tanks located about 40 m above track level (Fig. 5) were periodically filled by a water truck. This site is an example of gravity driven irrigation system.

### VII. SUMMARY

Research on erosion control of railway formation steep slopes (batters) has been carried out by QR and CQU for the last 10 years. This paper provides advances made in this research effort which has been focused on strategies for quick establishment of grasses. The strategic erosion control plan is customized to suit the local conditions. In general, the erosion control strategies involve some or all of the following:

- topsoiling or amelioration of the surface soil with lime or gypsum where it is established that the surface soil is dispersive, sodic, saline and/or has an extreme pH;
- fertilisers spread to provide a medium conducive to rapid growth of grasses;
- cheap mulch (waste ballast) or erosion control blankets are spread or laid to protect grass seeds/seedlings and ameliorants from washout by high intensity and short duration rainfall;
- grass seeding with non-invading species that are fast growing and accepting of local conditions;

- a cost effective drip irrigation system to aid grass establishment is an integral part of the erosion control process options; the choice of water source depends on availability and cost;
- in order to reduce the treatment costs, the embankment and cutting batters may be categorised for different levels of treatment.

The key benefits of erosion control are:

- minimisation of maintenance costs;
- minimisation of interruptions to normal train operations;
- minimisation of the risks of moisture and erosion induced formation failures and associated outages or derailments;
- minimisation of failures of railway signalling systems due to fouling of ballast by sediment;
- aesthetically pleasing batters and surrounds enhance your corporate image;
- minimisation of the risk of lawsuits resulting from sediment delivery from your easements to nearby water courses (e.g. creeks, stock ponds);
- compliance with environmental legislative requirements.

The RAPID GRASS trademark has been established by QR and CQU to advance HEFRAIL Project into a commercialisation phase, extending our expertise beyond QR corridors.

#### ACKNOWLEDGMENT

This research is part of HEFRAIL Project which is fully funded by QR, and this support is gratefully acknowledged. HEFRAIL Project Steering Committee Members are thanked for their significant contributions.

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# Impact Assessment of Water Scarcity at Somntongo in the Lowveld Region of Swaziland.

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**Abstract** - A survey was conducted to assess the impact of water scarcity in Somntongo, in the low veld region of Swaziland. The study adopted the use of questionnaire, interview schedules and focused group discussions. Information sought included sources of water, distances between water sources and places of residence, and the effect of water scarcity on the various aspects of human activities. The study revealed that only two rivers and five boreholes were the major sources of water while distances of as much as 5 – 20km were covered in search of water. In about 84% of the homesteads, the water use was about 2.7litres/head/day while in about 88% of the homesteads, it was 2.3 litres/livestock/day. These are quite low compared to the minimum standards of 8-20 litres/head/day, and between 5 and 45 litres/livestock/day. Water scarcity has resulted in the death of livestock; some cultivated crops have withered while others are not cultivated for lack of irrigation water. In some instances, schools have temporarily been closed due to water shortages. Construction of more boreholes and dams can reduce the water scarcity and promote the standard of living in the community.

**Keywords**-Swaziland, water, scarcity, harvesting, irrigation, agriculture

## 1. INTRODUCTION

Water is one of the most basic needs for the sustenance of life, and its utilization can be categorized into industrial, agricultural and domestic. Globally about 70 % of water resources is used for agriculture, 22 % for industrial while domestic use accounts for only 8 %. However, because of the differences in levels of technology, while developing countries devote as much as 88% of their water to agriculture, the developed nations use less than half for agriculture [1, 2].

Water as a natural resource should be readily available and affordable but in many instances, it is scarce and beyond the reach of many people [3, 4, 5, 6]. Reference [2] reported that of about 2.5% of the water resources that can actually be consumed, only one-third of it is accessible as the balance two-thirds are confined in glaciers and permanent snow cover. References [2, 7] reported that about 17% of the world population, majority of whom are living in developing countries have no access to fresh water to meet their domestic and other requirements. Reference [2] reported that Africa is already one of the driest continents

in the world, and with an increase in population and a decrease in amount of rainfall, its countries are facing water stress and scarcity.

Water scarcity leads to the destruction of the environment and conflicts are common as industries, agriculture, and domestic needs compete for the limited available water [8]. Tensions over the distribution of water can escalate into discord between groups dependent on a shared resource. In water crisis situations, the poor are the ones who suffer most. To them, water shortages can mean long walks to fetch water, high prices to buy it, food insecurity and diseases due to drinking of dirty water. Water should not only be adequate in quantity but must also meet certain standard qualities. Polluted streams create problems for fish, wildlife and humans [9]. Sediments, fertilizers, pesticides and manure are the main reported pollutants of drinking water [10].

Swaziland is located between latitudes 30° 30'E and 32° 30'E of the Greenwich and between longitudes 25° 30'S and 27° 30' S of the Equator. The country covers a total area of 17,363 km<sup>2</sup>, out of which 17,203 km<sup>2</sup> is land and the remaining 160 km<sup>2</sup> is water. The country is divided into four ecological zones: the Highveld, Middleveld, Lowveld and Lubombo (Fig. 1). Due to droughts in recent years, many areas of Swaziland are facing aggravated water scarcity. One of such areas is Somntongo where the water scarcity has inflicted injuries on the social and economic lives of the populace. It is imperative that such impacts are quantified and appropriate remedial measures taken. The work reported in this paper was undertaken to assess the impact of water scarcity in Somntongo, in the Lowveld region of Swaziland.



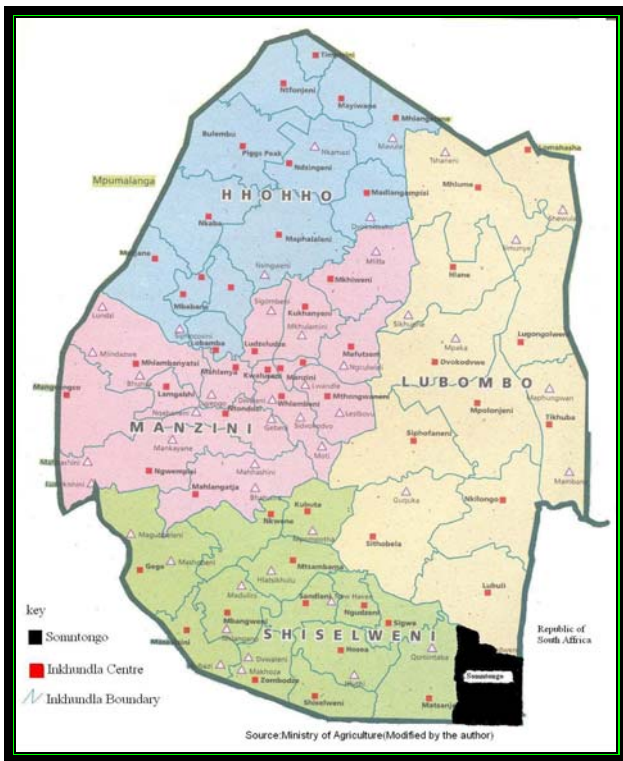


Figure 1. Map of Swaziland showing study area as shaded

## 2. METHODOLOGY

The study was carried out through the use of questionnaire, interview schedules, personal observation and focused group discussions. Questionnaire and interview schedules were developed which among others sought for information on the sources of water available to the respondents, various water uses, distances between places of residence and water sources, reliability and adequacy of water sources, problems experienced with water collection and the effect of limited water availability on various human activities.

The target population was the Somntongo community members and 150 homesteads were selected. The instruments were administered in February 2006. In addition to these instruments, secondary information was obtained from the libraries of the University of Swaziland, the ministry of agriculture, Mbabane and the Swaziland National Library, Mbabane. Information was also sourced from the Internet.

The Statistical Package for the Social Sciences (SPSS) was used to analyse the data. All data collected were interpreted using frequencies and percentages, and the results were presented in bar and pie charts.

## 3. RESULTS AND DISCUSSION

### a) Water availability

Two rivers and five boreholes were the sources of water available in Somntongo. While 30% of the populace depended on the rivers, the boreholes were the water sources for the remaining 70%. In most cases, the discharge from

these sources were very low and got dried during the dry season. During the dry season the inhabitants who have the means go to the Ingwavuma river which is about 20 km from the community. The Ingwavuma river was not only far from the community but it was used for sugarcane irrigation upstream such that the volume downstream, and where some members of the community relied on, was very low.

Rainwater harvesting as a source of water had very little impact in Somntongo. Besides the low annual rainfall received over a short period of the year, many of the homesteads were of thatched roofs with very low harvest potential compared to corrugated iron sheet roofs. Because of the seriousness of water scarcity, dews have become a source of water in Somntongo as in other drought affected communities, (Plate 1), [11].

### b) Burden of water Collection

The distances between places of residence and nearest water sources are presented in Fig. 2. Ideally, water source should be between 250–500 m away from the place of residence [12]. Since only 8% of the population at Somntongo fell within this range, it implied that 92% of the residents did not have an easy access to water.

The number of households sharing a water source varied from as low as 20 to as much as over 60, as presented in Fig. 3.



Plate 1. A pot used to collect dew to be used as drinking water (Source: Times of Swaziland, Friday November 4, 2005 Page 11)

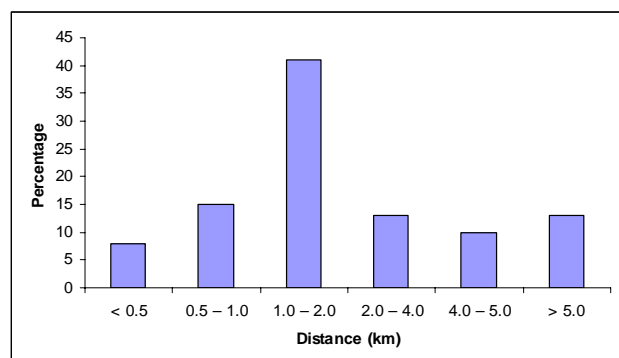


Figure 2. Distances between residence and water sources

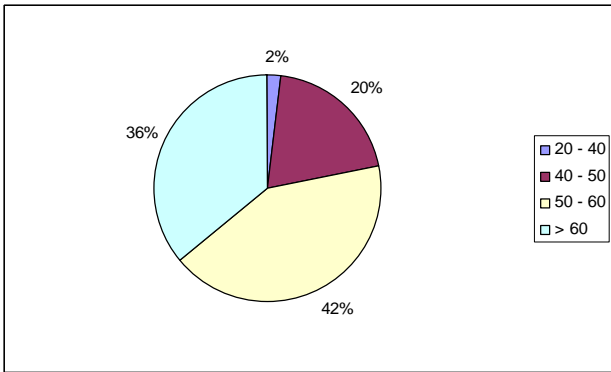


Figure 3. No of households sharing a water source.

The large number of households sharing a source resulted in high rate of depletion. People often queue and wait for as long as three hours to collect water. Sometimes people wait and when it gets to their turn, the source becomes completely depleted and they have to go back without water. Some people spend part of the night at the source and this poses danger to their lives. Children and women, who are the major water collectors in the homesteads, spend much of their time scouting for water.

Water collection can be done by motor vehicle, livestock or head carriage. About 78% of the respondents earn an annual income of below US\$160.00, and can neither afford to own a vehicle nor pay the cost of transporting water. A few make use of their livestock while a majority transport their water by head carriage over a wide range of distances.

Most water collection is done on foot mostly by women who have other engagements and school children. Because of the time spent on water collection, other jobs especially domestic chores are affected while lateness to school by children whose first job is the collection of water was very common.

### c) Water consumption

The various uses and quantities of water in Somntogo are presented in Fig. 4. Water is used mainly for domestic and livestock and no irrigation activities are carried out. About 84% and 16% of the homesteads with an average population of 11, use less than 30 litres and between 30 and 50 litres of water per day, respectively, for their domestic purposes. This gives an average of between 2.7 and 4.5 litres/head/day. Compared with the recommended values of 8 - 20 litres/head/day [13], this is grossly inadequate and the community is subjected to water stress.

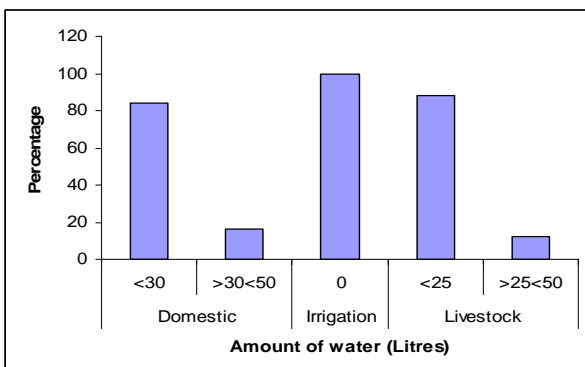


Figure 4. Amount of water used

About 88% and 12% of the homesteads use less than a total of 25 litres and between 25 and 50 litres of water per day for their livestock, the average population of which is 11 and comprises of various animals. This average of between 2.3 and 4.5 litres/animal/day is below the recommended minimum values of 15–45 litres for cattle, 5–15 litres for sheep and goat, and 10–27 litres for pig [13,14]. Livestock were subjected to water stress and there were reported cases of livestock lost due to water scarcity as shown in Fig. 5.

About 22 % of the respondents reported to have lost one animal whilst 6% and 2% lost two and three animals respectively. Cattle were the most affected species, yet they are the most important livestock especially as they are used for the settlement of bride price or *lobola*.

As a result of water scarcity, domestic practices such as regular bathing and washing were compromised resulting in poor hygienic situations in the homesteads, dirty water such as from washing was given to livestock since the little available was insufficient to meet the human needs. Livestock were driven for more than 15km to the river since the earth dams were dried. Somntogo is suitable for the commercial production of maize, potatoes, cassava, beans and sorghum but these were only cultivated on small scale due to lack of water for irrigation. Irrigation was not practiced in the area due to lack of water. Cotton is the only commercial crop cultivated because of its limited water requirement. Sugarcane which is a major cash crop in Swaziland is not cultivated because of its high water demand. During the study, the researchers were informed that financial institutions were unwilling to give loans for sugarcane production in the area because they had no confidence in the success of such investments. These situations constitute threats to the attainment of food security and economic empowerment programmes of the kingdom.

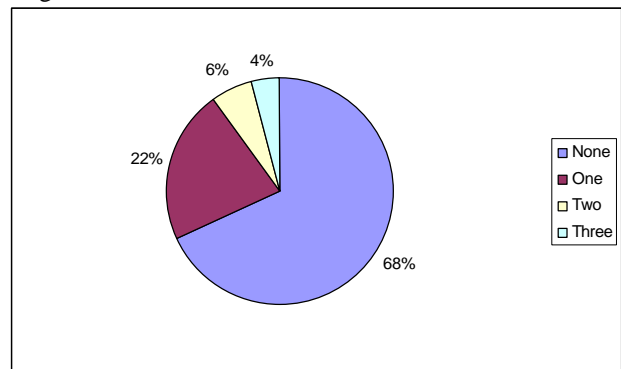


Figure 5. Number of livestock lost due to water scarcity.

### d) Impacts of water scarcity

The impacts of water scarcity in Somntogo include the following:

a) A lot of time and energy are expended in water collection and in some instances the water may not be obtained after a long search. As a result of this, there is a reduction in the time available for productive work while domestic chores suffer. Children, who are mainly involved in water collection, go to school late and their future is being

mortgaged. Information obtained from schools confirmed that the performances of most of such affected children have declined. In some instances, when the water sources in schools are depleted, classes are suspended until water is available. The HIV/AIDS pandemic prevalent in the country is made worse by poor quality water. Clean water prolongs lives, thus, it is as necessary as medicine and proper diet.

b) As a result of its scarcity, water is expensive. The cost of 100 litres of water was US\$0.70 while a 5,000 litre tanker load costs US\$42.00. The annual income of over 80% of the populace was less than US\$160.00. Expenditure on water reduces the income available to meet other domestic responsibilities and this is a burden on the rural poor and further complicates their poor economic situation. The severity of water scarcity and inability to pay for its supply, had compelled some people to depend on dewdrops for their water need (Plate 1). Schools were compelled to use funds earmarked for other projects for water supply.

c) With a population of about one million people, the predominant occupation in Swaziland is agriculture. About 70 % of the populace is engaged in subsistence agriculture producing both crops and animals while agriculture accounts for about 17% of the country gross domestic products [15]. Water is a basic requirement for effective agricultural production and its scarcity in Somntogo has resulted in the loss of livestock and limited the type and extent of crops that can be cultivated. This has not only reduced the income potentials of the inhabitants but has increased food deficits within the community. This is a threat to the attainment of the food security goal of the Kingdom.

#### 4. CONCLUSIONS AND RECOMMENDATIONS

##### a) *Conclusions*

Somntogo depends on two rivers and five boreholes for water supply. These sources are inadequate as a result of which domestic practices such as bathing and regular laundry were compromised while unclean water was fed to livestock. Livestock have been lost due to water scarcity while the variety and scale of crop production have been reduced due to lack of water for irrigation. The burden and cost of obtaining water has reduced the time available for productive work, educational programmes have been affected while income available for domestic responsibilities has been reduced.

##### b) *Recommendations*

a). The laudable efforts of the Swaziland Water Crisis Assessment Team (SWCAT) at providing water at short notice to distressed areas has been hampered by lack of transport. The unit should be adequately funded in order to be able to discharge this function.

b). Members of the community should take steps towards solving the problem of water scarcity. Some of the existing thatched roofs should be replaced with materials having higher rain water harvesting potentials and acquiring high

volume storage containers so that rain water can be collected and stored to serve the family especially during the dry season.

c) Agriculture is the main source of income for most Swazi families and the backbone of the food security programme of the kingdom. The government should ensure adequate provision of water to meet domestic, irrigation and livestock needs through drilling of boreholes and construction of reservoirs.

#### ACKNOWLEDGEMENTS

The authors are grateful to the Department of Land Use and Mechanization of the University of Swaziland for facilitating this research work.

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## **CONFERENCE DIVISION:**

[Energy & Electrical and Electronic Engineering](#)

# Neuro-Fuzzy Approach to Diagnose Porcelain Insulators under Contaminated Conditions

Dr. V. Krishnan, Pradipkumar Dixit and Dr.H.G.Gopal

**Abstract**— This paper describes an attempt made to reckon the three stages of arc growth on the surface of artificially contaminated porcelain insulators, identified on the basis of reported results of last five decades. Adaptive Neuro Fuzzy Inference System (ANFIS) based architecture has been suggested to do this task. To generate training and testing data, the input parameters have been chosen from the well known Ayrton's equation (I, A and n). Monte Carlo Simulation (MCS) technique along with experimentally determined arc gradient values have been adopted to generate separate I, A and n values for the three stages of arc growth as training data. The experimental setup used is also explained in detail in this paper. Proposed models for three different stages have been trained and tested. Results show that ANFIS architecture with 64 if-then fuzzy rules for each output stage give minimum error.

**Index Terms**— Adaptive systems, Ceramic Insulators, flashover, neuro-fuzzy modeling and pollution

## I. INTRODUCTION

Insulators are the devices used on electricity supply networks to support, separate or contain conductors at high voltage. All insulators used for outdoor applications are susceptible to the deposition of various salt materials, dust (SiO<sub>2</sub>), snow and ice in the form of a thin layer on their surfaces. This level of pollution depends on different environments in which insulators are used. This salt like thin layer acts as a conducting surface which carry leakage current. The consequences range from surface degradation to complete bypassing of electrical insulation by flashover. Thus insulator failures are perhaps the most severe and well recognized

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Authors wish to thank the authorities of All India Council for Technical Education (AICTE), New Delhi, India for sponsoring this work under R&D scheme.

problem in power transmission lines. Performance of outdoor insulators under contaminated conditions is an ever important design criteria in overhead transmission lines. Different methods and techniques have been reported for monitoring salt contamination on insulators.

Based on the reported results of last five decades, the flashover of contaminated insulators under service voltage can be roughly characterized by the following three stages that can better be explained interms of arc gradient [1,2].

- i) Weak inception current flow leading to partial arcing with a continuous hissing noise.
- ii) Growth of these partial arcs along the insulator surface leading to strong local arcs without flashover but causing surface degradation.
- iii) Further growth of these partial arcs leading to final flashover.

Most of the analytical models proposed for predicting the critical withstand and/or pollution flashovers are mainly based on well known Ayrton's arc voltage gradient equation  $E(i) = A I^n$ , when E(i) is the arc gradient, I is the arc current, A and n are Ayrton's arc constants. Several investigators have used different numerical values for I, A and n to tally their theoretical results with their / standard experimental findings. Thus there is a large variation in the values of these variables that lead to more imprecision and uncertainty. In this paper an attempt is made to reckon the above mentioned three different stages starting from weak inception current flow to the final flashover interms of I, A and n.

One hybrid system that is the most visible today is Neuro-Fuzzy systems which applies a combination of Artificial Neural Network (ANN) and Fuzzy system. The combination of ANN and fuzzy sets offers a powerful method to model and reckon/identify some important features of quite randomly behaving systems which are not crisp. Hence, Adaptive Neuro Fuzzy Inference System (ANFIS) based architecture is suggested in this paper to identify the three stages in the growth of arc knowing the values of I, A and n.

The most prominent feature of ANFIS is to learn from examples, and then adapt themselves based on actual training data sets. After training, testing data will be applied to the system to check the validity of the model. So it is very much necessary to have sufficient training and testing data.

Since I, A and n are chosen as input parameters for the ANFIS, Monte Carlo Simulation (MCS) technique has been adopted. For this simulation technique, first the ranges for the I, A and n are fixed based upon literature survey made (since 1939 to 2005) [3]. After fixing the ranges for I, A and n values, arc gradient (E(i)) ranges for the three stages of arc development has to be decided. An experimental setup has been made to decide arc gradient ranges.

For better presentation, the work done is explained in three phases. The first phase explains the experimental details and its outcome. The second phase describes the architecture of proposed ANFIS model. The third phase explains generation of training data using the experimental results and ranges selected for input parameters.

## II. EXPERIMENTAL DETAILS

Experimental setup used is as shown in Fig.1. To study air breakdown, two Al electrodes (2.5mm dia.) were used. The gap distance is varied as 1cm, 2cm, 2.8cm, 3cm, 3.2cm, 4cm and 5cm. For each case, inception and breakdown voltages were noted. A set of seven such readings are taken, of which the first two are ignored because they aim at burning away the impurities present in the path of arc and the average of the remaining five readings is taken. Using these average values obtained for each gap distance, a straight line is fitted using LSR technique. Next inception and the breakdown gradients are calculated with the straight line fitted.

As a next step in the experiment on the specimen (white glazed ceramic 3cm x 10cm) the Al electrodes are fitted and gradients are calculated for different gap distances as in the above case. This is for dry condition.

To simulate wet condition, 0.25g NaCl per litre of distilled water solution is sprayed on the specimen between the gap. Gradient values are calculated for each gap distance.

To calculate the gradients for the practical disc insulators the experiment is repeated by fitting Al electrodes to the adjacent ribs of disc (70kN & 120kN) insulators with wet condition.

Finally, 2.5mm dia Cu electrodes replaced Al electrodes and gradients are calculated for practical disc insulators and flat specimen with wet condition.

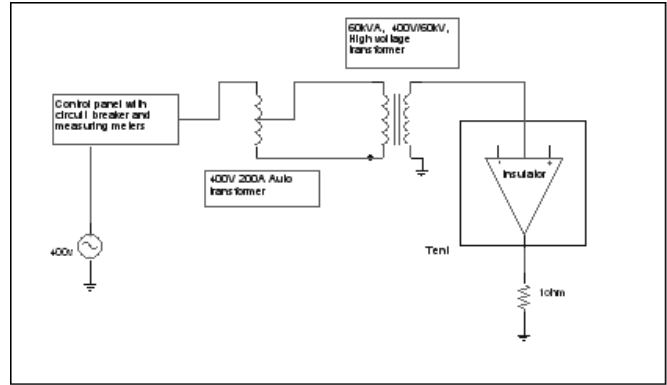


Fig.1 Experimental setup

### A. Results and Discussions

Fig. 2 & 3 shows inception and breakdown gradients plotted for different gap arrangements for the following cases;

- i) inception gradient with flat specimen, wet condition (INPNGAL & INPNGCU)
- ii) inception gradient with practical disc (70kN & 120kN) insulators, wet condition (ING120AL, ING120CU, ING70AL & ING70CU)
- iii) air breakdown (BDVGAIR)
- iv) with specimen, dry condition (BDVGDRY)
- v) with specimen, wet condition (BDVGAL & BDVGCU)
- vi) 120kN disc insulator, wet condition (BDG120AL & BDG120CU)
- vii) 70 kN disc insulator, wet condition (BDG70AL & BDG70CU)

From the Fig. 2 & 3, the following observation can be made,

- i) The inception and breakdown gradients calculated for flat specimen case with wet condition show insignificant difference for Al and Cu electrodes.
- ii) For the case of two practical insulators the inception and breakdown gradients show very less difference.
- iii) There is reduction in breakdown gradient when experiment is conducted with specimen than in air.

From the results, it can be seen that there is reduction in the breakdown potential between air and with specimen dry condition. Further there is a tremendous decrease for the wet as compared to dry condition.

In all the test conditions, the scintillation inception gradient is very less as compared to the breakdown gradient. The effect of electrode material is insignificant.

There is no much significant change in the breakdown gradient for different salinities when gap distance is greater than 2cm.

Breakdown gradients calculated from MINM across the wet ceramic surfaces vary from 1.7kV/cm to 1.9kV/cm [4]. From the same MINM, breakdown gradients for practical disc insulators lie between 2.1kV/cm to 2.8kV/cm. The gradient values obtained from the present experimental work vary from 2.21kV/cm to 2.84kV/cm for flat ceramic specimen and for practical disc insulators it varies between 1.45kV/cm to 2.0kV/cm.

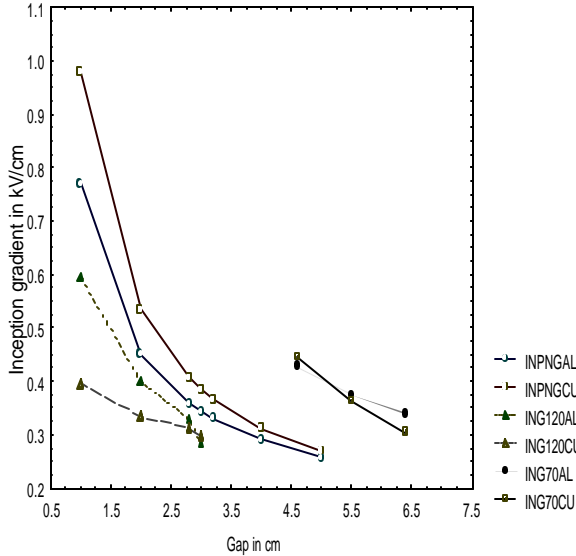


Fig.2 Inception gradient for different test conditions

### III. PROPOSED ANFIS MODEL

ANFIS is a multilayer feed forward network which implements fuzzy decision rules and reveals its decision criterion. The proposed model consists of five layers with three inputs (I, A and n) and one output as shown in Fig.4. Since, it is necessary to identify one of the possible three stages in the arc development based upon input parameters I, A and n, three separate ANFIS models were chosen, one for each stage. Each of Sugeno's type models was tried with 8, 27, 64, 125 and 216

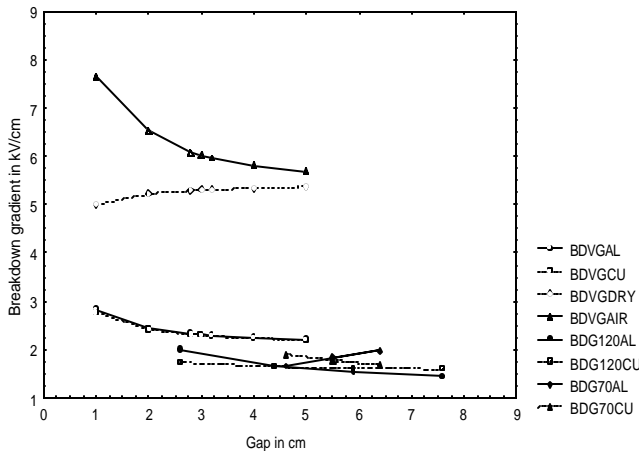


Fig.3 Breakdown gradient for different test conditions

fuzzy if-then rules for each stage. It was found that 64 fuzzy if-

then rules gave minimum error in all the three models.

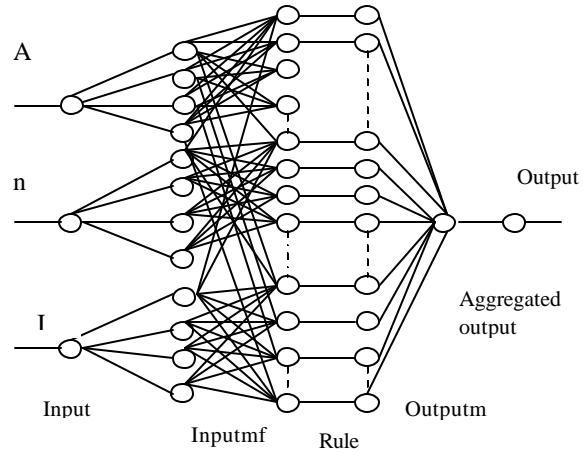


Fig.4 Architecture of Adaptive Neuro-Fuzzy Inference System (ANFIS)

### IV. TRAINING DATA ACQUISITION

In order to train the system, the inputs A, n and I for a given arc gradient  $E(i)$  have to be generated. Results obtained from experiments conducted according to IEC 507 standard as explained in section II have been used to fix the ranges for arc gradient (mentioned below), for the three stages of arc growth on the surface of artificially contaminated porcelain insulators. For arc inception stage,  $E(i)$  has been found to vary between 0.28kV/cm to 0.6kV/cm. For flashover,  $E(i)$  got range from 1.45kV/cm to 2kV/cm. Hence it is taken that the range from 0.61kV/cm to 1.44kV/cm will fit for arc propagation stage.

Taking these  $E(i)$  ranges for three stages of arc development, I, A and n values are generated as training data. For this purpose Monte Carlo Simulation (MCS) technique has been adopted with the following ranges for I, A and n.

$$0.05 \leq I \leq 3.4(A), 10 \leq A \leq 200000 (V / m) \& 0.32 \leq n \leq 1.38$$

An in-house C-code has been developed for computational work using MCS technique. Simulations have been carried out for 30,000 Monte Carlo runs with the above mentioned ranges for the time dependent I, A and n treated as random numbers. The rejection boundary for each stage was determined by the range of  $E(i)$ . Thus for each stage 100 data set has been generated as training patterns.

### V. RESULTS

The proposed ANFIS model has been trained with generated

data set using MATLAB toolbox. The toolbox function ANFIS constructs fuzzy inference systems (FIS) whose membership function parameters are tuned using a combination of least squares estimation and backpropagation for membership function parameter estimation. To verify the validation of the model, testing data has been fed and plots have been observed for three stages of output. The distances between testing data and FIS output decides the average error defined as the sum of the squared difference between actual and desired outputs. Table I shows the details of the results obtained with average testing error for each stage.

TABLE I  
RESULTS OF ANFIS MODEL FOR THREE STAGES

Stage	Number of training samples	Number of testing samples	Number of fuzzy rules	Average testing error
Inception	100	20	64	0.05897
Propagation	100	20	64	0.02646
Flashover	100	20	64	0.02737

## VI. CONCLUSIONS

ANFIS based models have been developed to identify three stages in the arc development process for given values of I, A and n. Since the models combine the advantages of fuzzy modeling and neural networks, error measure as estimated by the toolbox is found to be minimum. When error is minimum, more number of testing data points fall very close to or coincide with FIS output. Minimum error obtained show that proposed ANFIS models could predict pretty well the three stages in the arc development based on I, A and n values. Thus, it could be stressed that experimental observations combined with Ayrton's arc gradient equation throw some light on the prediction of pollution flashovers in outdoor insulators which is one of the sever threats to power system engineers.

## ACKNOWLEDGMENT

Authors are grateful to the Principal & Management of Bapuji Institute of Engineering & Technology, Davangere and the Principal & Management of M.S. Ramaiah Institute of Technology, Bangalore for their constant support and encouragement, in carrying out this research work.

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# Comparative Performance of Polymer Insulators by Salt Fog Test and Multi Stress Ageing

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<sup>3</sup> *Abstract-* Present study aims at studying the behavior of polymer insulating material under different ambient conditions and to evaluate the best polymer material to suit Indian conditions. 1000 hours Ageing tests were performed on different insulators as per IEC 61109. Many insulators with different material weather sheds withstood the tests. Diagnostic tests were also performed on aged polymer insulator to determine the extent of degradation of the material. The tests include average flashover test, hydrophobicity test, Energy Dispersion X-ray (EDX) and X-ray diffraction (XRD) analysis. It was possible to conclude from the tests that the performance of polymer insulator is mainly based on material used for the insulators. Multi stress ageing tests on various samples were carried out. 5000 hours of ageing is completed. Interesting result is that some of the insulators which passed 1000 hours of salt fog ageing test failed during multi stress ageing test. Experimental investigations revealed that 1000 hours tracking and erosion test can be taken as minimum requirement for the polymer insulator material and 5000 hours multi stress ageing shall be made mandatory to achieve the long term performance of polymer insulators.

*Index Terms*—Erosion, Hydrophobicity, Multistress ageing, Salinity.

## I. INTRODUCTION

PORCELAIN and Glass insulators have been in use ever since transmission line came into existence. In spite of the shortcomings of glass and porcelain insulator like their weight, lower strength to weight ratio, susceptibility for vandalism, damage due to gun shots resulting in high replacement and maintenance cost, use of porcelain and glass insulators are fully established. At present, composite insulators of different shed materials are being used as a replacement to glass and porcelain insulators. Many test methods have been suggested by many forums and no conscientious have been reached. As the level of transmission voltage is increased, lightning, dynamic over voltages and withstand ability of the insulator under polluted conditions are the most important factors, which determine the insulation level of the system. The continuous operation of the system mainly depends on the environmental conditions, which cause flashover of polluted insulators. Flashover leads to system

outages. It is therefore, necessary to check the withstand capability of the insulators by carrying out artificial tests, under polluted conditions. External insulation does not pose any problem under dry conditions even if contaminants are present on the surface of the insulator. It gives problem whenever these contaminants get wet due to light rain or fog and humid conditions. Therefore, it is necessary to check the withstand capability of the insulators by artificial test methods. Several polymers are offered as alternatives to glass and porcelain such as Silicon rubber(SR), Ethylene propylene rubber (EPR), Ethyl vinyl acetate (EVA) and Ethylene propylene Diene Monomer (EPDM) etc. Among these, Silicon rubber and EPDM have been used since 1960's. They are gaining broad recognition as the best performers among all the polymers in use. Every major manufacturer of high voltage insulators is now offering Silicone rubber and EPDM insulators.

Ageing and life expectancy of polymer insulators depend on a number of factors, many of which are associated with natural weathering while others are related to operating conditions. Weathering, which was considered some years ago to be the main factor of limiting life, has not really held up to this expectation. Although, weathering has shown to age polymer materials, there is a growing body of experience suggesting that non-ceramic insulators' life is more related to design weaknesses and/or quality control during their manufacture.

Early utility experimentation with the first generation of polymeric insulators led to mixed results [1]. A variety of design and construction problems were encountered including tracking and erosion of shed, shed puncture, insulator surface chalking and reduction in contamination flash over strength, deterioration of mechanical strength and loosening of end fitting.

The performance of composite material can be improved by using shed materials having hydrophobic properties, The glass fibre used must be immune to damage in presence of moisture and under combined effect of mechanical and electrical stresses[2]. Laboratory research works have been performed in order to set-up accelerated ageing tests, both of electrical and environmental/mechanical type, trying to characterise the long term performance of insulator and to obtain indications

on their service life [3]. Silicone rubber weather shed materials have outstanding properties [5]. Composite insulators had been installed in United-States for 60kV and 132kV lines [6]. The units showed surface degradation which lead to flash-over, cracks in the housing but the core remained mechanically sound at a location of severe marine pollution .Filler materials are used to improve tracking and erosion properties of composite insulators[7]. Accelerated ageing test in a fog chamber on polymeric material has been conducted and researchers have obtained good correlation with service experience at low conductivity than at high conductivity of water. Also it was found that lower level of filler is sufficient for silicone rubber materials, Pollution ageing test for 4000 to 5000 hours, adopting daily cycle reproducing main ambient stresses like rain, contamination, solar radiation simulation, temperature variation and drying periods normally encountered in service have been conducted. The ageing cycle was derived from CIGRE working group 22.10 [10]. Silicone materials exhibit recovery of contact angle after exposure to corona discharge while EPDM do not show any recovery [12]. The effect of fog conditions on ageing deterioration of silicone rubber by the different two salt fog conditions generated by ultrasonic humidifier and IEC nozzle with the air pressure 7 Kgf/cm 2 . under same particle size have got comparable results on ageing of silicone rubber insulators[18].

The following aspects of performance evaluation of polymeric insulators are still to be analysed.

- Evaluating the ageing cycle for polymeric insulators
- Type of filler material on the pollution performance of the insulators
- Establishing the Life expectancy of polymeric insulators based on the ageing studies.

In the present study different polymeric insulators were exposed to 1000 hours salt fog test and 5000 hours multi stress ageing. EDX, XRD analysis and rapid flashover tests were conducted on virgin and aged samples.

II. EXPERIMENTAL SET UP AND TEST PROCEDURE

Three Silicone Rubber insulators of different manufacturers (SR0, SR1, SR2) and one EVA insulator were used for ageing test. The SR0 insulator is shown in fig 1.



Fig. 1 Insulator used for ageing test

A. 1000 HOURS AGEING TEST ON POLYMERIC INSULATORS (TRACKING AND EROSION)

In order to assess the long term suitability of the composite insulator, ageing test was performed .The daily cycle for the test was 24 hours with salt fog conditions. The voltage was continuously applied for all the 24 hours. This daily cycle was repeated every day. The salinity of the salt solution was 10 kg/m<sup>3</sup> and the other requirements of the test were as per IEC-61109. All the samples used for the test were having a creepage length of 588mm. The voltage applied during the test was 17 kV (rms). A test source of 33 kV, 66 KVA testing transformer is used for ageing test. The test arrangement for the test is as shown in fig 2. Fig 3 shows the detail of the ageing cycle. Leakage currents were measured during the entire period of ageing test.

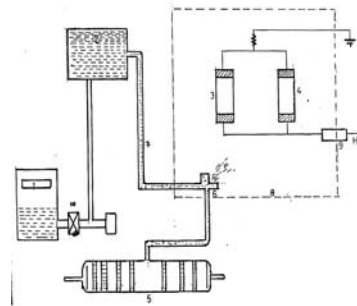


Fig. 2. Schematic diagram for ageing test on composite insulators.

Application of voltage										
Salt fog (10 Kg/m <sup>3</sup> )										
Time in hours ( 0 - 24 hrs)										

Fig. 3. Daily ageing cycle used for the ageing tests for AC voltages

B. MULTISTRESS AGEING TEST ON POLYMERIC INSULATORS

The procedure adopted simulates different environmental conditions in a chamber. The daily ageing cycle of “CIGRE 5000 hours ageing test” consisting of application of voltage to the specimen and the environmental conditions such as de mineralized rain, heating at 50 degree centigrade, solar radiation simulation, humidification and salt fog at a salinity of 10 kg/cubic-meter is chosen. Each and every parameter is applied in particular time slots based on daily ageing cycle as shown in fig 4.

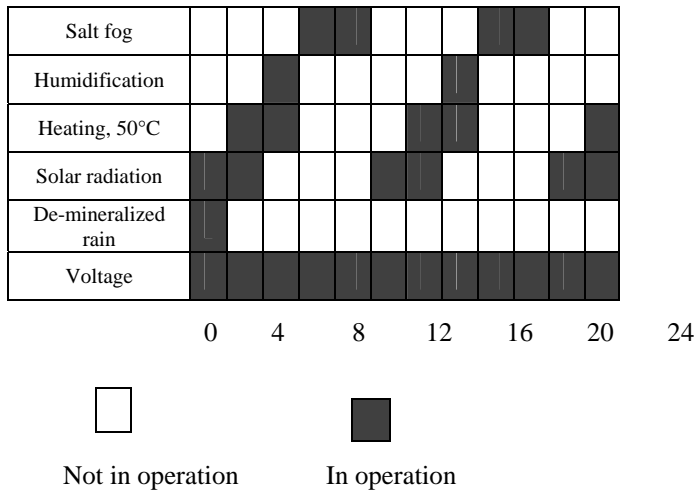


Fig. 4. Daily Ageing Cycle

**C. TEST CHAMBER**

A fully automated environmental chamber of 2 m X 2.5 m X 2 m (W X H X D) was used for the ageing test. The specimens were placed in side the chamber. In this chamber the environmental conditions like heating, humidification, solar radiation, salt-fog and rain are simulated as per the above mentioned cycle. The required voltage for this chamber is 440V AC, 50 Hz, three-phase with neutral. A test source of 33 kV, 66 kVA and a lead-in cable is used for the application of voltage to the specimen. The environmental parameters are simulated as per the program setting in the microprocessor. The internal parts of environmental chamber consists of a dry heater for the purpose of increase in temperature, a wet heater for humidification, eight nozzles to simulate rain, two nozzles to emerge salt fog and nine UV lamps to simulate solar radiation.

The test setup consists of one EVA insulator and three SR insulators, assembled as shown in fig 5. The measurement of the surface leakage currents were recorded with the help of the voltage drop across the resistance which were connected in series with the insulators. The resistance value was chosen such that it is convenient for the measuring range.

**D. ANALYTICAL TESTS ON POLYMERIC INSULATORS**

The analytical studies are main tools in evaluating the degree of degradation of polymer material. The studies were carried out on the sample material of the virgin and aged one by energy dispersion X-ray and X-ray diffraction.

**HYDROPHOBICITY TEST**

Hydrophobicity of the composite insulator material is very much important for the long term performance of the insulator under service conditions. In order to check the hydrophobicity of the material, the virgin and aged insulator were subjected to

hydrophobicity test. The method used for the test is STRI method [17].



Fig. 5. Arrangement of test specimens for multi stress ageing

**ENERGY DISPERSION X - RAY (EDX ) ANALYSIS**

This technique indicates the filler concentration as the ratio between aluminium and silicon. It should be noted that even EPDM insulators contain silicon in the form of silanised filler material. To understand the physical processes involved in the failure of the insulator, fundamental studies were carried out using EDX analysis at critical locations of the insulator. The virgin and the aged samples were cut and subjected to EDX analysis to study the processes, which have degraded the material. EDX analysis was carried out using Scanning electron micro-scope LISA make with EDAX facility. This technique is used to demonstrate the depletion of low molecular weight polymers on the surface of the aged material. Samples of silicone rubber and EPDM 1 cm x 1cm cut from the virgin and the aged composite insulator material were subjected to EDX analysis.

The X-Ray mapping is a method by which the characteristic X-Rays collected from EDX measurement is correspondingly mapped on to a computer screen based on the secondary electron image. Because the mapping technique uses signals obtained from X-Ray collection, it is therefore operates only when distinct elemental peaks are detected by EDX. Each element receives a color code, and thus this technique provides the elemental distribution on the surface being analyzed. X- rays in silicone rubber are obtained from the silica in the polymer and reinforcing filler, and aluminum from the ATH filler. The depth of the surface analyzed depends on the accelerating voltage of the electron beam, and is calculated using the following formula:

$$R = 0.033 (E^{1.7} - E_c^{1.7}) A / \rho z$$

where E = electron beam energy, keV,



$E_c$  = critical energy required to excite the X-ray line of interest,

A, Z and  $\rho$  = atomic weight, atomic number and density of the material respectively and

R= depth of penetration. The count of X-rays per minute is dependent on the concentration of the particular element.

### E X-RAY DIFFRACTION ANALYSIS (XRD)

This technique was used to demonstrate that there is a change in the physical structure of the polymer with ageing; In addition the clustering of the filler particles on the surface with aging was determined by this technique. The instrument used was of PHILIPS make. A copper anode sealed X-Ray tube operated at 30 kV /30 mA provided the X-ray source and a scintillation counter was used for the detection. The diffraction data on each polymer sample was obtained from 5 to 100 degree 2-theta, with a sampling interval of 0.02 degrees and a scan rate of 2 degree per minute. Data reduction was done using the software provided by the manufacturer. This includes removal of k-alpha component of the copper radiation prior to peak identification. The samples were of 1cm x 2 cm. the diffraction pattern obtained is a plot of the intensity vs. Theta angle. The estimated sample depth of 10,000 to 60,000 Angstroms, the depth increasing with 2 - theta angle. The degree of crystallinity can be determined if the crystalline and amorphous scattering in the diffraction pattern can be separated from each other. The degree of crystallinity is equal to the ratio of the integrated crystalline scattering to the total scattering, both crystalline and amorphous, and is given by

$$x_c = \frac{\int s^2 I_e(s) ds}{\int s^2 I(s) ds},$$

Where  $s$  is the magnitude of the reciprocal-lattice vector and is given by

$$s = (2 \sin \theta) / \lambda$$

$\theta$  is the one-half the angle of deviation of the diffracted rays from the incident X-rays

$\lambda$  is the X-ray wavelength,

$I(s)$  is the intensity of coherent X-ray scatter from a specimen (both crystalline and amorphous),

$I_c$  is the intensity of coherent X-ray scatter from the crystalline region.

The degree of crystallinity calculated from the above equation tends to be smaller than the true crystalline fraction, because part of the X-ray intensity that is scattered by the crystalline regions is lost from the peaks and appears as diffuse scatter in the background as a result of atomic thermal vibrations and lattice imperfections.

## III. RESULTS AND DISCUSSION

The following passages discuss our results.

### A. RESULTS OF THE AGEING TEST

1000 hours tracking and erosion tests performed on various insulators showed no tracking and erosion of the insulator material. All the samples withstood the test without tracking and erosion. In order to check the performance of these insulators, ageing tests was further continued on the samples and found that the EVA based insulators failed in the tests after 1400 hours of ageing with severe tracking and erosion of the material. Based on the test results it was possible to conclude that the 1000 hours tracking and erosion tests on insulators is not sufficient to check the long term performance of insulators, but can be used as the minimum requirement for the material evaluation. In order to evaluate the long term performance of the polymeric insulators, it was decided to conduct the long term ageing test on the insulators in order to assess the life of insulators.

### B. HYDROPHOBICITY TEST

The hydrophobicity of the composite insulator material is the main characteristics of the performance of the insulator under polluted conditions. Loss of hydrophobicity is due to continuous dry band arcing. Hydrophobicity test was performed on the virgin and aged samples by ABB method. The contact angle of the droplets is visually observed. The silicone rubber and EVA insulators, which were aged at low conductivity fog, showed hydrophilic surface especially the EVA insulator.

TABLE 1  
Results of hydrophobicity test

Insulator	SR-0	SR-1	SR-2	EVA-1
Before Ageing	HC-1	HC-1	HC-1	HC-1
After Ageing	HC-4	HC-4	HC-5	HC-7

### C. RESULTS OF MULTI STRESS AGEING TEST

Initially three SR and one EVA insulators were subjected to ageing test. Among these, EVA insulator was eroded near HV electrode after 74 hours of ageing (after immediate completion of rain simulation). A new insulator of same material and design was replaced.

The new insulator, which was replaced, performed well as compared to previous one. Two pinholes were observed on the sheath near to HV electrode after nearly 200 hours of aging. Due to these pinholes it was drawing more current. Therefore, measurement of current was not carried out for this insulator. After 600 hours of aging, two black spots were observed on the weather sheds of the EVA insulator, and it became hydrophilic after 750 hours of aging. It could not regain hydrophobicity. The erosion of the surface was continued with aging. But after 1400 hours of aging this insulator was removed from test, because it was conducting

through the FRP rod through the pinholes, under rain conditions.

SR insulators were continuously losing their hydrophobicity with respect to time, but these insulators regained their hydrophobic characteristics after some time. In this aging test all silicone insulators recovered their hydrophobicity after 790 hours of testing, and they exhibited HC-2 hydrophobicity. The metal end fittings of insulators SR-0 & SR-1 were corroded. But this corrosion was not affecting the performance of insulators. On one of the weather sheds of SR-2 insulator light black coating was observed after completion of 2600 hours of ageing.

EVA insulator was removed at first from the test with in 100 hours of aging and the second insulator was removed after about 1400 hours of aging. In the case of silicone rubber insulators even though the recovery of hydrophobicity was taking place with in 1000 hours, after about 2700 hours of aging tracking had initiated. From this it can be seen that the 1000 hours test duration is not sufficient for the long run. Some insulators, which may pass 1000 hours salt-fog aging, may fail on prolonging test period. Therefore, 5000 hours of ageing test with different ambient conditions of humidification, heating at 50°C, rain, salt fog and UV radiation is necessary to ascertain the quality of polymeric insulators. The loss of hydrophobicity of polymers is due to the formation of hydroxyl and carbonates layer on the surface of material. As per the observations, the current was very high at the time of rain and salt-fog conditions, but it was low when heating conditions are simulated. At the end of 5000 hours of ageing the SR insulators lost their hydrophobic properties but electrically there was no deterioration of the insulator property. Traces of iron oxide on the surface of the insulator material were predominantly seen which had no effects on the performance of the insulator.

#### D. RESULTS OF X-RAY DIFFRACTION

Fig 6 shows a typical wide angle scan. The following conclusions were arrived after studying the other wide angle scan. The very broad low intensity hump between 10 and 17 degrees proves that the silicone polymer is mostly amorphous. The other peaks observed are due to ATH filler in the polymer. It was seen from the pattern that the low broad intensity hump has sharpening of the amorphous hump indicating that the polymer has become more crystalline. Aged sample aged during accelerated aging test also showed similar results. Scan of samples subjected to tracking and erosion test and multi stress ageing showed similar results indicating polymer do degraded at low severity of pollution.

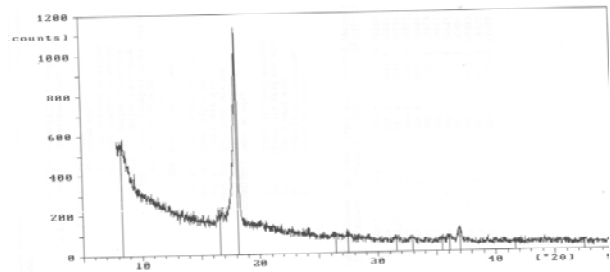


Fig 6. wide angle scan of silicone rubber insulator

#### E. RESULTS OF EDX ANALYSIS

Table 2 shows that EDX analysis of both EVA and SR materials before and after aging studies. The typical EDX spectrum is as shown in fig 7. The elemental analysis of the material shows a reduction in silicon aluminum contents of the material in most cases. This proves that the surface of the material is aging. Since the surface is made up of low molecular weight polymer chains due to its low surface energy there is a depletion of large amount of low molecular weight polymer chains on the top surface of the layers, which is the proof of the aging of the material. The increase in sodium and chlorine contents showed that the aging of material due to the deposition of these would enhance the degradation of the material.

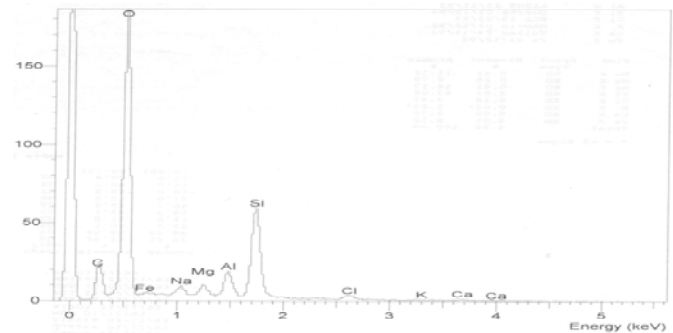


Fig 7. EDX analysis of virgin Silicone rubber insulator

TABLE 2  
ELEMENTAL COMPARISONS BY CONDUCTING THE EDX TEST ON  
THE VIRGIN AND AGED SAMPLES.

Samples		Aluminum	Silicon	Sodium	Chlorine
SR-0	Virgin	13.46	64.33	9.57	4.22
	Aged	8.51	70.17	9.19	5.85
SR-1	Virgin	14.45	71.85	7.42	2.14
	Aged	12.09	63.14	12.38	2.14
SR-2	Virgin	13.87	70.73	8.89	1.8
	Aged	9.64	59.1	12.08	5.91
EVA	Virgin	27.08	33.43	20.77	6.26
	Aged	26.11	36.88	13.95	7.22

## F. EXTERNAL DAMAGES

The damages to the external housing found after the ageing tests are summarized in Table 3. Scaling formations were seen at the end of ageing on most of the insulators. The insulators made of silicone rubber showed superior performance till the end of ageing test. Corrosion of the metal end fittings and the distribution of iron oxide on the material were seen.

TABLE 3.  
DAMAGES ON DIFFERENT TYPES OF INSULATORS

Insulator	Total ageing hours	Description of the damage	Severity of Damage
SR-0	5000		Negligible
SR-1	5000	Iron oxide on ground end insulator surface	Negligible.
SR-2	2600		Negligible
EVA-1	100	Severe erosions and treeing on the surface	Severe
EVA -2	1400	Pin holes damaging the FRP core	Severe

## G. RAPID FLASHOVER TEST BEFORE AND AFTER AGEING TEST

First the insulators were cleaned with trisodium phosphate and thoroughly rinsed. The salt solution is pumped through the vertical nozzle and the compressed air at a pressure of 7 kg/m<sup>2</sup> was let through the horizontal nozzle. The salinity used was 10 kg/m<sup>3</sup> and the salt fog was sprayed directly towards the object. The insulator was initially energized at a voltage of 40kV for 20 minutes. The voltage was increased in steps of 10 % every 5 minutes until flashover. The voltage to be applied after a flashover was equal to 90 % of the previous flashover voltage. The value was then increased in steps of 5% of the previous flashover voltage every 5 minutes until flashover. This procedure is repeated until 8 flashover voltages were obtained. Fig. 8 & 9 show the trend of average flash over voltage of SR-0 and SR-1 insulators.

It is seen that as the pressure of the fog increases, the flashover voltage of the test specimen decreases. This is due to the fact that as the air pressure increases, the smaller sized particles, which were generated, will wet the surface of the insulator thoroughly to form a conductive surface. This conductive surface provides a path for the leakage current and hence for the arc to develop. The arc will travel on the surface of the electrolytic layer leading to flashover at lower voltages.

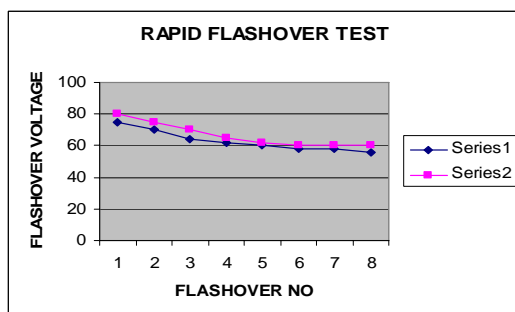


Fig. 8. Rapid flashover test on SR-0 insulator

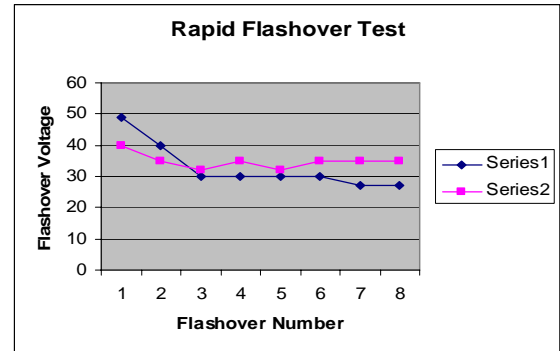


Fig. 9. Rapid flashover test on SR-1 insulator

TABLE 4.  
FLASHOVERS DURING AGEING TEST

## IV. CONCLUSION

Based on the tests conducted on the polymeric insulators, the following conclusions were drawn.

1. Tracking and erosion tests performed on insulators of different materials showed no degradation of insulator material.

Insulator	Number of flashovers	Hours of ageing	Environmental condition during flashover
SR-0	-	5000	-
SR-1	-	5000	-
SR-2	-	2600	-
EVA-1	3	100	Salt fog
EVA -2	3	1400	Salt fog

2. Some of the insulators especially EVA based material showed degradation of the material after 1000 hours of ageing.
3. In the multi stress ageing test, the performance of SR insulator was better than that of the EVA insulator. The ageing performance of SR insulator was good due to its hydrophobicity recovery mechanism. Even after 3000 hours of aging, these insulators were still hydrophobic. No tracking and erosion was observed on SR insulators.
4. SR insulators showed hydrophilic surface at the end of 5000 hours of ageing.
5. From the observations of ageing tests, to evaluate the long term performance of polymeric insulators, it is suggested that 1000 hours of ageing is not sufficient, because the insulator which passes the 1000 hours ageing test failed under long term ageing.
6. From the EDX and XRD analysis, the surfaces of the aged samples are more crystalline in nature as compared to the respective virgin samples. EDX analysis on the surface of aged samples showed decrease in their atomic

counts of the elements such as Silicone and Aluminum, increase in the counts of Calcium, Sodium and chlorine.

7. An accelerated ageing procedure for the evaluation of polymeric insulator was evolved taking into the considerations of typical Indian environmental conditions.
8. While manufacturing polymer insulators proper filler and polymer percentages are to be chosen for better service life in practical conditions.

In conclusion : Life expectancy of a polymeric insulator is based on the type of material used for the insulator. Tracking and erosion test prescribed as per IEC 61109 (1000 hours) is not sufficient to assess the long term performance of the insulator. This test is to be taken as the minimum requirement of the base material performance. Multi stress ageing test (5000hours) showed that the material which performed well in 1000 hours test failed during the multi stress test. It was possible to conclude from the test result that the life expectancy of a polymer insulator can be evaluated only with multi stress ageing tests (5000hours) which is of relevance to our country's tropical environment. Therefore, multi stress ageing tests (5000hours) can be made mandatory to evaluate the polymeric insulator for application in our country.

#### ACKNOWLEDGEMENT

The authors are thankful to the authorities of Central Power Research Institute for according permission to publish this work, and all the staff of High Voltage Division of CPRI for their constant support during this work.

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#### BIOGRAPHIES

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# Performance of SR Insulator Under Polluted Conditions – an experimental study

D.Sathyanarayana, Dr. V. Krishnan & Pradipkumar Dixit

**Abstract:** To ensure high reliability in EHV/UHV System, it is very much essential to design external insulation considering pollution with stand level. In the quest of a remedy for pollution-triggered flashovers, polymeric insulators have come into focus. Silicone Rubber (SR) is one of the best-known polymeric insulation materials and is widely used for modern outdoor insulator applications. Under polluted conditions leakage current flows on the surface of the Silicon Rubber insulator. In many cases it is desirable to measure leakage current, flashover voltage, dry band energy of Silicon Rubber insulator under polluted conditions. Leakage Current causes the degradation of the Silicon Rubber insulator. An attempt has been made to calculate the Dry Band Energy for the SR Insulator for different SDD values.

**Index Terms—** leakage current, Hydrophobicity, Insulator, Dry Band Energy and Pollution.

## I. INTRODUCTION

Silicone rubber insulators for transmission line have significant advantages over porcelain and glass insulators. Their advantages are lightweight, vandalism resistant and hydrophobicity. SR insulators are relatively new and their expected life is still unknown. The leakage current measurement test of SR Insulator are mainly carried out as per IEC 507 Specifications [1]. When polluted and wetted, Silicon Rubber insulators are able to withstand higher voltages than their Ceramic equivalent [2]. This superior Performance is attributed to the hydrophobicity of the SR Insulators [3].

For the same environmental conditions and average surface stress, the leakage current across hydrophobic insulating materials is generally much lower than that across hydrophilic ones [4]. This is because free surface energy is less for the former than it is for the later [5]. Although it is often stated that Silicone Rubber transfers hydrophobicity to the pollutants, some flashovers of SR insulators have occurred [6]. Therefore, there is some concern about the extent to which the leakage current increases during this transition period.

To provide information about the rate at which the surface of pollution on SR changes from being hydrophilic to hydrophobic, experiments have been conducted at set times from the application of pollution layer. The highest value of peak current was measured during an 810 secs test. These tests have been performed using commercially available SR insulator.

TEQIP, UBDTCE, Davangere, Karnataka, India supports this project.

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## II. EXPERIMENTAL DETAILS

Pollution chamber used of the dimensions 9\*9\*9 cubic feet, covered with high temperature resistance polythene cover with proper arrangement to hang the insulator. 11 kV SR insulator used in the experiment. Leakage current, and flashover voltage of the insulator were measured. Insulators were polluted using suitable amount of Sodium Chloride solution with 40g of Kaolin in one litre of distilled water as per IEC 507 Standards 1991.

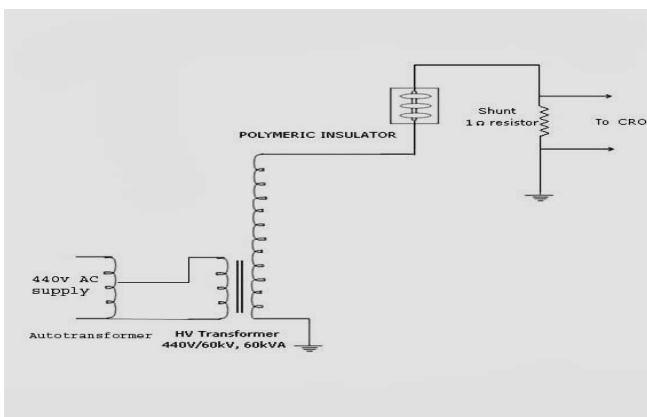
Table.1 shows the technical detail and Fig.1 shows the SR insulator used in the present work. The 11 kV SR insulator is dipped in pollution slurry and then allowed to dry. For the purpose of wetting insulator, steam was produced by boiling the water. Since the chamber totally covered, steam remains inside the chamber till the end of experiment. High Voltage is applied to SR insulator using 60 kVA, 50 HZ, 440V/60kV testing transformer. A maximum of 11kV was applied to 11kV SR insulator. Leakage current measurements were made continuously during the experiments. The detail of the circuit used in the experiment is shown in Fig.2.



Fig.1. 11kV SR insulator

**Table.1** Technical details of SR insulator under test

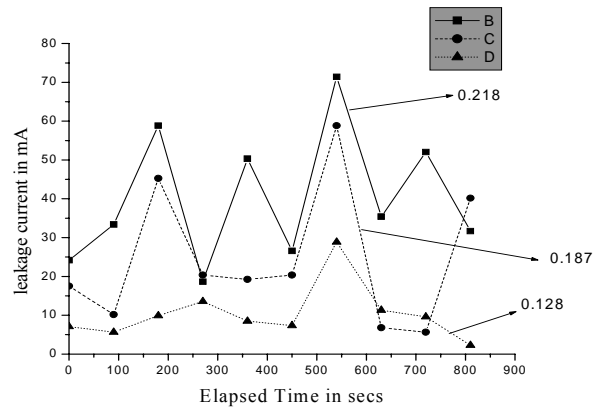
CHARACTERISTICS	VALUES
Length	274mm
Mechanical strength	45 kN (minimum)
Minimum creep age distance	307 mm
Weight	0.90 kg
Number of sheds	3
Dry power frequency with stand voltage	55 kV (rms)
Dry power frequency maximum with stand voltage	70 kV (rms)
Wet power frequency withstand voltage	35kV(rms)
Wet power frequency maximum with stand voltage	40kV(rms)
Dry Lighting Impulse with stand voltage-Maximum	
a) Positive polarity	119 kV(peak)
b) Negative polarity	121 kV(peak)
Shed Diameter	89 mm
Maximum RIV @ 1MHz/10 kv(rms)	Less than 50 micro volt



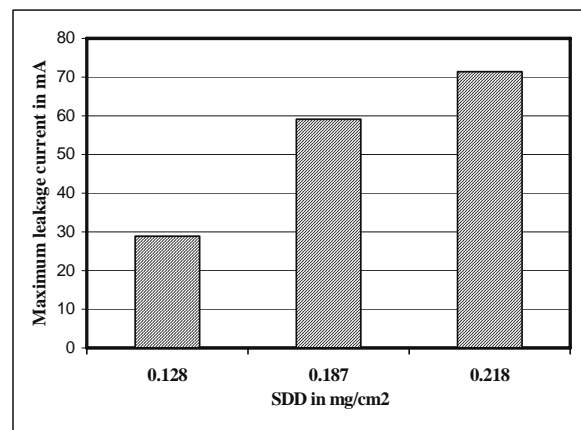
**Fig.2.**Experimental Set-up

### III. RESULTS AND DISCUSSIONS

This is an improvement on the standard pollution tests for which large variability has been observed by earlier researchers. Fig.3 gives the leakage current vs time for different SDD values. From fig.3 it is seen that with increase in SDD, leakage current also increases. More ever in most of the cases exactly at 540 secs there is a peak in leakage current for all SDD values(0.128,0.187and 0.218). For better understanding the variation of maximum leakage current is drawn for different SDD values and is shown in Fig.4.

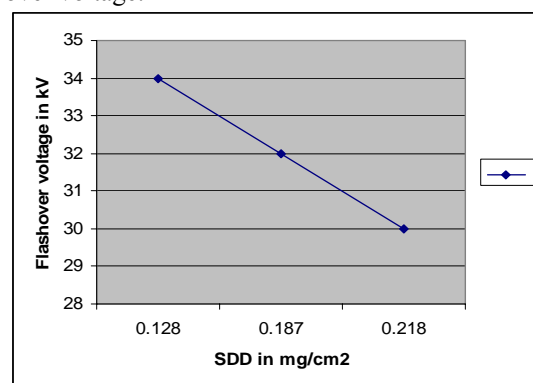


**Fig.3.**Variation of Leakage current vs Elapsed time



**Fig.4.** Bar Chart showing the maximum leakage current as a function of SDD

Fig.5 gives the values flashover voltages for 11kV SR insulators for different SDD values. It is evident that flashover voltage decreases as SDD increases. This is because as SDD increases conductivity of the insulator also increases and therefore there is a substantial decrease in flashover voltage.



**Fig.5** Variation of flashover voltage vs. SDD

Energy required to form the Dry Band is calculated using the equation  $V \int i(t) dt \Delta t$ . where  $\Delta t$  is a time interval of the applied voltage,  $V$  is the applied voltage and  $i(t) dt$  is the leakage current at different instants. The above equation was solved using Numerical Integration Technique [Trapezoidal Rule]. The solution of above equation is nothing but the area under the curve.

Table.2 shows the Dry Band Energy for 11kV SR insulator under different SDD.

**Table2.** Values of Dry Band Energy for different SDD values

Type of insulator	SDD in mg/cm <sup>2</sup>	Dry Band Energy in kW-Sec
11 kV SR Insulator	0.128	96.534
	0.187	366.789
	0.218	685.97

From Table.2 it can be observed that the dry band energy increases as SDD increases.

#### IV CONCLUSIONS

Leakage current depends on SDD and it varies in zigzag way with time for a given SDD. As SDD increases leakage current also increases. The experiments show that the use of Leakage current measurements provides valuable information about the onset of dry band arcing and consequently the loss of hydrophobicity on SR insulators. The Leakage current level is increased significantly when SDD increases. At the same time insulator become purely resistive when the insulator surface was polluted giving rise to the formation of dry bands and high magnitude discharges. As SDD increases, surface conductivity of SR insulator increases so causing a corresponding decrease in flashover voltage. On the other hand dry band energy increases as SDD increases. A more extensive analysis of Leakage current characteristics is in progress.

#### ACKNOWLEDGMENT

Authors wish to thank the authorities of UBDTCE, Davangere , Karnataka , India for sponsoring this project under TEQIP, World Bank scheme.

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# Partnering the Traditional Societies for Sustainable Development of Human Society: The Case of Ghana

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## EXECUTIVE SUMMARY

Managing societies demand a conceptual collaboration between and including traditional authorities and societies, local and national leaderships. The millennium Development Goals (MDGs) constituted an unprecedented promise by world leaders to address, as a single package, peace, security, development, human rights and fundamental freedoms to which traditional societies have very key roles. Most countries have committed themselves to the principles of sustainable development. But this has not resulted in sufficient progress to reverse the loss of the world's environmental resources. The links between governance and sustainable development are multiple, complex and important. The effects on the environment and development, in fact, depend on the extent to which environment and political goals can be made complementary and mutually supportive. A positive outcome requires appropriate supporting political, economic and environmental policies at the national and international levels.

The paper examines the complexities between traditional and political leadership and sustainable development in the context of developing countries. Particular resource information was drawn from Ghana's experience. Available literature was also reviewed. It was identified that both traditional and national politics have marginal roles to play in ensuring sustainable development. Chiefs, Queen mothers and elders of Ghana's traditional societies are actively contributing to sustainable development through best practices, education and drives towards a safe and productive environment and its resources. Adopting a closer bottom-to-top approach to development was identified as a pragmatic step to ensuring an environmentally safe and productive development to both the present and future generations. It was therefore recommended that achieving sustainable development should see political leadership adopting an all inclusive governance system that intergrades all including but not limited to traditional leadership and societies, civil societies and development partners. More so, development should take into account recommendations and demands of local authorities. This obviously would lead to development by, for and with the people. In view of the complexities of environmental issues, wider experience should be shared globally to tap richer experience from far and wide since they are dynamic and cross-cutting issues that cannot be handled by individual countries.

This is a review full paper that appeared in the Proc. of ICAST, 10-12 Dec., Accra Ghana GhC-P101 ©2007 ICAST

## I. INTRODUCTION

Different societies have their distinctive view of nature, society, human and history. While sustainability is a global issue requiring bilateral and multilateral cooperation, the basic framework of sustainable development must embrace the distinctive social and cultural setting, with special attention to the local economic and social conditions (for example, poverty, inequality and inefficient use of resources). The issue of governance and sustainable development therefore demands a multiple, complex and important interface.

The United Nations (2005) Millennium Development Goal (MDG) 8 prescribes the need for nations to develop a global partnership for development. The United Nations Millennium Declaration represents a global social compact which state among others that: developing countries will do more to ensure their own development, and developed countries will support them through aid, debt relief and better opportunities for trade.

Indigenous knowledge, leadership and biodiversity are complementary phenomena which are essential to human development. Global awareness of the crisis concerning the conservation of biodiversity was assured following the United Nations Conference on Environment and Development held in June 1992 in Rio de Janeiro. Of equal concern to many world citizens is the uncertain status of the indigenous knowledge that reflects many generations of experience and problem-solving by thousands of ethnic groups across the globe. Very little of this knowledge is being acknowledged and recorded, yet it represents an immensely valuable data base that provides humankind with insights on how numerous communities have interacted with their changing environment including its floral and faunal resources.

Sustainable development as captured by 'Our Common Future' emphasizes the idea of 'development that meets the needs of the present without compromising the ability of future generations to satisfy their needs' (WCED, 1987).

Environment, governance and development are not separate challenges to sustainable development. Development cannot subsist on a deteriorating environmental resource base; the environment cannot be protected when growth leaves out the costs of environmental destruction; environment and development cannot also thrive under inappropriate governance. These problems cannot be treated separately by fragmented institutions and policies. They are linked in a complex system of cause and effect.

Wherever sustainable development decisions are taken, im-

pacts on economic well-being, quality of life, governance and the natural environment depend on good decision support. Wrong decisions, or decisions which are blocked because of lack of public acceptability and effective collaboration with institutions including traditional societies, can have major impacts on the achievement of development goals. Sustainable development decision-making raises a wide range of environmental, social, political and economic issues apart from holding implications for the goals, objectives and development of the society concerned. Poor decisions which lack public acceptability or are not based on proper analysis can have serious impacts on the environment as well as economic and social well-being. Decision support is therefore absolutely critical.

Partnering traditional societies for effective governance and sustainable development is an emerging concept. Apart from the claim that traditional societies have intended purposes of promoting development, it performs to ensure the conservation and preservation of the environment for both present and future uses. In some of Africa's most ecologically fragile and marginalized regions, knowledge of the local ecosystem simply means survival. As so much is at stake in changing traditional natural resource management practices, any proposed change is usually based on an informal evaluation and consultation process among key community members (usually a peer group involving elders). By sharing and comparing knowledge of key indicators that describe ecological responses to change or the prediction of environmental trends, the community can weigh the long and short-term costs and benefits of change related to any new innovation or application of local ecological management systems (Lalonde, 2006). Ghana has taken remarkable strides towards consolidating democratic development in recent years, with successive and successful national elections. This spans across nearly 50 years of democratic and military periods of state governance. However, the country faces a significant challenge. The rapid pace of development has led to numerous local tensions over land, resources, and chieftaincy succession, especially where traditional groups and communities have grappled with modern politics and jurisprudence. While the chieftaincy system has served as a mainstay for social cohesion in Ghana even in modern times, the politicization of some aspects of the system has contributed to these tensions. In the recent past, an absence of new mechanisms to complement traditional means for managing these tensions has led to violent conflict.

The nation practices a dual system of governance. The first is the modern state system with its institutions. The second is the traditional systems that date back to pre-colonial times. The evolution of the modern system is traceable to British colonial rule that started in the early nineteenth century through gradual and subtle methods of encroachment on the sovereignty that was vested in the indigenous people led by their local rulers (Donkor W.J., 2006).

Among the methods used were the gradual introduction of principles of English Common Law in deciding cases and the introduction of tax systems aimed at raising revenue to cover the cost of administration. As the new system evolved, it did not obliterate the earlier indigenous systems by which the

people had governed themselves. However, colonial rule halted the evolutionary processes of the traditional administrative structures and undermined the basis of traditional rule that was rooted in moral authority and consultation by making organized physical force the primary locus of authority. On another level, traditional rulers took another revolution as a new basis for their existence, sometimes referred to as natural rulers. In Botswana for example, chiefs play a central role in the legal system. Around 70 - 80

Indigenous leadership and knowledge, though sometimes undermined, has led to various proactive ways of environmental practice. The strategy implies the science and art of employing traditional know-how through effective leadership to creating and adopting local technology that positively imparts on the environment.

Some positive practices of indigenous traditional knowledge are based on symbolism, and involve spiritual rituals, religious practices, social taboos, and sacred animal totems. Other positive practices are based on the experiential, involving travel in order to learn from the experiences of other farmers, hunters, gatherers, fishermen, herbal medicine healers, and artisans. The traditional keepers and users of local ecological knowledge and wisdom are typically the key elders from rural African communities.

In 1991 the Natural Resources Institute of Britain's Overseas Development Administration (NRI) provided a forum for African farmers to exchange views on ways of reducing crop losses due to pests. The NRI, working on the Mali Millet Project, described how indigenous farmers in north-western Mali placed leaves of the neem tree under the millet heads when they lay them on the ground to dry. This practice discourages insect infestation. This obviously could be a better alternative to the use of harmful chemicals as insecticides and pesticides that tend to destroy the environment.

Ghana is no exception in the use of traditionally influenced local technology. The use of the leaves of neem tree prevents insect infestation of many plants. Such attempts are environmentally friendly since the mode itself replenishes the nutrient content of the soil. Though, fertilizer application is very useful, it tends to degrade the soil in the long run hence the appropriateness of the neem solution technologies. The use of traditional modes of addressing disputes is also very high in most societies of Ghana.

## II. STATEMENT OF THE PROBLEM

Achieving sustainable development (S.D) is still being addressed worldwide as well as in Ghana. Many attempts have been made at promoting development, with the aim of satisfying the needs of the present, without compromising the ability of future generations to satisfy their own needs. Institutions including the Environmental Protection Agency (EPA), Forestry Commission, and The Ghana Chamber of Mines have been tasked to ensuring sustainable development in their areas of focus but with minimal success.

Institutional support for sustainable development has been inadequate. Government policies have also achieved minimal success. The sole role of government in governance therefore

has called for a re-evaluation of the policy hence the need for the study. Traditional authorities can and have valuable contributions they to offer in ensuring sustainable development and it is in the bane of such that the study was carried out to identify how best they could be partnered in the quest at ensuring sustainable development.

Ghana continues to lose large tracts of forest cover to environmental degradation. Domestic and industrial waste continues to pose problems to biodiversity and human health. Refuse continue to pile up in major cities in Ghana such as Sekondi-Takoradi, Accra, Tema and Tamale. The issue arising is whether there aren't any effective policies towards waste management and conservation of natural resources or whether government directives and guidelines are not in consonance with traditional objectives and core values.

The study therefore attempts to answer the following questions:

- Are there any effective government policies towards Sustainable Development (S.D)?
- To what extent is traditional leadership actively involved in the quest for S.D?
- What are the roles of traditional leadership in state governance?
- Can government alone champion the course of S.D.?
- How best can government collaborate with traditional authorities in ensuring S.D.?

#### A. Objectives of the Study

Specific objectives are to:

- Evaluate the level and effectiveness of collaboration between State and Traditional leadership in the governance of Ghana.
- Provide effective tools for collaboration between state and traditional authorities to ensuring development that provides for the needs of both the present and future generations.
- Identify effective tools for collaboration between traditional leadership in promoting sustainable development in Ghana.
- Provide suggestions and recommendations.

#### B. Significance of the Study

The study will help to identify various strengths and weaknesses of development that integrates the contributions of all including traditional leadership. It would provide first hand insight into some of the problems faced by the government in its quest at ensuring sustainable development. This would determine and provide effective tools as well as guidelines to making Ghana have an appreciable social and economic development that satisfies the needs of all including the present and future generations. It would also assist in creating an effective interface between development that integrates traditional leadership and sustainable development of human societies.

### III. COMPLEXITIES OF TRADITIONAL SOCIETIES IN GHANA

The traditional rule in Ghana finds expression in forms such as religious leadership, lineage headship, leadership in

extended families, and chieftaincy. Chieftaincy is, however, the fullest expression of traditional rule in its institutionalized form. It embodies: the cardinal characteristics of prescribed kinship and lineage succession to office; awe and sacredness of office and office holders; specific forms of contractual relationships between chiefs and their subjects; and institutionalized procedures for decision-taking and implementation at the levels of local community and local participation.

Ghana's traditional leadership structure is a hierarchy. At the base is the clan head (Abusuapannin). Next and above the clan head is the village or town chief, also known in some of the Akan dialects as the "Odikuro", literally the head of the village or the town. The next in the hierarchy is the "Omanhene" or the paramount chief, usually the traditional leader at the district level. At the apex is the head of a tribal group such as the King of Asantes or the Ga Mantse of the Gas.

Social anthropologists who have studied the governmental structure of traditional communities have usually divided the pattern of such governments into centralized societies and stateless or segmentary lineage societies. In centralized societies, there is an administrative organization which serves as the framework of the political structure and its functioning. Such a centralized administration or organization is lacking in societies that are identified as having minimal government. Centralized societies are properly called "states" and are characterized by following a clearly demarcated authority, administrative machinery and judicial institutions. These go to indicate the existence and working of a government. Here we do find cleavages of wealth, privileges, and social and political statuses corresponding to the distribution of wealth and authority (Radcliffe-Brown, 1961).

Stateless societies do not have the above mentioned structures in any sharply demarcated forms, but this does not imply the absence of mechanisms that ensure order and stability and regulate relations amongst individuals and social groups. Nonetheless, the extremely minimal nature of power; and the diffusion of such power among several virtually autonomous segments of the entire community - has led to the characterization of stateless societies. These "tribes without rulers" include the iKung Bushmen of the Kalahari desert in Namibia, the Tiv of mid-southern Nigeria, and the Tallensi and Kokomba of Ghana. This characterization, however, initially appears misconceived; it creates the impression of the existence of anarchy and chaos in such communities (Radcliffe-Brown, 1961).

The Asante dynasty is one of the well constituted traditional bodies in Ghana. Apart from the rather unique role of the Asantehene, and of the Golden Stool in welding virtually autonomous traditional states and amanhene together, there is very little in which the Ashanti differ from other Akans in their political set-up. Such roles are also performed by the Akyem and Ga dynasties in Ghana. More so the Asante dynastic have clearly demarcated hierarchy of authority that transcends from the head of the clans to the Abusapanin thus supporting the claims of Radcliffe-Brown, 1961.



#### IV. QUALITIES AND FEATURES OF TRADITIONAL LEADERSHIP

"The kingly office springs from a period in native history when there was continual warfare among the different tribes inhabiting the country. The choice of a king was most probably determined by the personal valour, intelligence and capability of the individual to lead the forces of the community in times of war. Such an individual was undoubtedly the best man the community could produce." For example, under the kingship of his royal majesty Nana Wiafe Akenten III, the Offinso traditional council has been working to prove the quality traditional leadership offers, restoring the pride once lost and reforming into its true status. It is therefore apparent that traditional leaders are people imbued with good virtues as supported by many scholars.

Contributing to the debate, Casely Hayford had noted that: "At the head of the native state stands prominently the chief (king) who is the chief magistrate and the chief military leader of the state. He is first in the councils of the country, and the first executive officer. His influence is only measured by the strength of his character." A second feature is that in the political system of the traditional order, recruitment to office has been by ascription. The process of recruitment has been on the basis or pattern of clan and lineage relationship. Nevertheless, even among the matrilineal Akan, for instance, we have examples of stools that are succeeded to patrilineally. These are known as Maama Dwa, and are occupied only by sons and grandsons of the stool. Examples are the stools of Ashanti Akropong (near Kumasi), and Adum (Kumasi). Such stools would have histories peculiar to them.

The third feature of traditional rule is the sacredness of the office of the chief, and for that matter, the person of office bearers. Thus offices (and personages) are set apart from ordinary mundane phenomena. A fourth feature is that the behaviour pattern of any such chief was hemmed throughout in tradition, myths and taboos. These in turn served to validate that the exercise of his authority was mainly through myths and tradition; and owing to the religious-secular nature of political office, the incumbent was seen as more than human. In Ghana, this was particularly so in the cases of the Awoamefia of Anlo, and the Yagbonwura of the Gonja state. A fifth characteristic of traditional political rule was the significance of age which was regarded as being related to the level of wisdom that had been attained by an individual. Finally, while incumbents of office could be questioned about the way the system was manipulated, rarely did people question the structure of the society and its institutions as such. In other words, one experienced enough rebellion but scarcely revolutions. The foregoing features have been enumerated because they have a bearing on the democratic nature of traditional rule, as we shall examine later in this paper (Casely-Hayford J.E., 1903).

The traditional governance system, on the other hand is the age-old method by which the indigenous people administered their affairs prior to and after the advent of Europeans into the region of modern Ghana around 1471. Traditional governance systems varied considerably among the different peoples that

occupied the region of modern Ghana. While some groups developed very complex hierarchical structures, others had simple kin-based types. The matrilineal Akan-speaking people, for example, seemed to have evolved once of the highest forms of the complex system of governance. The Akan political system ensured socially acceptable conduct backed by general good-will that in turn ensured social cohesion. Other groups like their Guan-speaking neighbors and the Ga-Adangme groups who originally practiced a religion-based system of government seem to have adopted and adapted the Akan model as could be inferred from the titles used for their political leaders. In the northern regions, although there are such centralized states as Mamprussi, Dagbon, Gonja and Wa that have hierarchical structures with clearly defined rules of succession and titles for their officeholders, there are many others like the Tallensi, Konkomba and Gurunsi who until fairly recently did not have such systems. It is important to note that the history of the chieftaincy institution differs among the different ethnic groups and even in the various administrative regions into which the country is divided.

#### V. THE ROLE OF TRADITIONAL SOCIETIES IN STATE GOVERNANCE

Good governance and sound public management are pre-conditions for the implementation of sustainable development policies. These preconditions include efforts to ensure an ethical and more transparent government process, as well as decision-making practices sufficiently open to citizens. Good governance therefore seeks to satisfy economic, political and administrative demands of a society.

Traditional leaders play both statutory and non-Statutory Functions. They are seen contributing effectively to state governance through effective economic, political and administrative policies.

The statutory functions among other things are:

- Collection, refinement, codification and the unification of customary laws,
- Adjudication in chieftaincy disputes,
- Compilation of lines of succession to offices in the various traditional areas,
- Appointment of representations to various government statutory bodies including the Council of State, Prisons Council, National and Regional Lands Commissions and Regional Co-ordination Councils and constitutionally too, traditional rulers are barred from active partisan politics.

The non-statutory functions of traditional rulers are derived from their positions as moral/natural leaders of their respective communities. As influential members of their communities, they undertake the under-listed functions:

- Settlement of disputes through arbitration, Mobilization of their people for development purposes.
- They act as linkages between their communities and development agencies including central government departments, local government organs, NGOs, diplomatic missions, religious bodies and welfare associations and use of the agency of annual festivals when traditional rulers mobilize their people for the purpose of planning

and seeking avenues and opportunities for executing development projects.

On close examination of the historical development of local government in the country, one can discern two basic orientations. From 1951 to 1959, local government was conceived largely in terms of the democratic right of the local people to run their own affairs. This right consisted in the people's ability to select their own representatives who then became the policy-makers or law-givers as far as the affairs of the local areas were concerned. The right also consisted in the people's capacity to determine what services to provide, what taxes to impose, and how the proceeds of these taxes should be used. The type of local government that obtained then was akin to the British local government system with its emphasis on the principles of democracy, representation, devolution and responsibility. This was not surprising since it was from the British that Ghanaians took their cue for most of the country's political and constitutional development.

Although the traditional manners of government look awesome and fearful when seen from outside, and although the pomp and pageantry around the leaders make them look impregnable, a closer study reveals otherwise. Indeed, in many regards traditional rulers appear as loving slaves to their office. There is no movement of theirs which is not controlled by custom, tradition and taboo. In palace deliberations, for instance, the chief talks last - and what he says is usually a summary of what has been said by other elders and counselors. Besides, the traditional leader only speaks through a linguist, a titled palace official versed in customary usages and oratory. In such regards, any tendency to depart from consensus decisions will be straightened out by the linguist in the course of his presentations.

Creating the enabling functional environment for traditional leadership would result in an effective collaboration between the state and the local societies. The outflow is a society that enjoys peace, economic growth and human development. The negative impact of defective governance on economic and social development, as well as on the environment, is clear. In addition to these basic preconditions, the importance for sustainable development of key management tools such as performance measurement, mechanisms for citizen engagement, specific policy and implementation processes, and continuous strategic assessment is crucial. This obviously is inclusive of traditional leadership.

## VI. CONFLICTING ROLES OF TRADITIONAL LEADERSHIP AND LOCAL GOVERNMENT

Notwithstanding the functional roles of traditional leadership in state governance, it should also be noted that, in executing such duties many conflicts have resulted between them and state machinery.

Decalo S. (1989) argues that in hoping to "modernize" their usual mono-economies, the new African leaders often espoused an "African Socialism" where the state controlled the economy. Insisting upon the need for "national integration," in the face of a plethora of ethnic collectivities, African leaders imposed a single party system, claiming that this was close to the African "palaver."

Kwame Nkrumah had a bitter conflict with the Asantehene and other traditional leaders in Ghana who objected to being excluded from government. In Ouagadougou, a frustrated traditional emperor, the Mogho Naba of the Mossi people, attempted to use his traditional army in a quixotic attempt to dissolve an embattled Territorial Assembly. Sir Edward Mutesa II of the Baganda quarreled with Sir Andrew Cohen, Britain's last colonial governor, about the future government of Uganda and was exiled to England where he died in poverty.

Democratic governance has also not succeeded in eroding such tendencies for tension between state and traditional administration. 1992 saw the swearing in into office in Ghana of an elected government. This brought into its wake the District Assemblies (DA) concept. DAs are accorded wide-ranging powers by the 1992 Constitution and the Local Government Act of 1993. Within its designated geographical area each District Assembly is the: highest political and administrative authority; planning authority; development authority; budgeting authority; and rating authority (Ayee, 2003). The District Assembly also has an overall responsibility to "co-ordinate, integrate and harmonize" the activities of all development agencies in the District inclusive of central government ministries, departments and agencies (MDAs) and non-government organisations [Article 10 (5)].

Ensuing an effective DA and traditional leadership therefore create an interface that sometimes result in duplication of functions as well as undesirable frictions. Such complexities do mainly result from the intersecting roles and boundaries of operation, including managing waste and executing executive functions, for both state and traditional machinery of leadership. In April 2000, religious and traditional leaders agreed to modify the ban in drumming and noise-making, an annual event prior to celebrating "Homowo" a festival of a large section of traditional enclave in the Greater Accra region (Capital of Ghana) of Ghana. The agreement was for drumming to be subdued and confined to the churches. On May 7, 2001, the first day of the 2001 ban, the Ga Traditional Council (GTC) announced that the agreement it had previously reached with local churches in 2000, which dealt on moderate and permissible noise making levels, was not applicable for 2001 and that the ban would apply to all drumming and noise-making. Christian churches claimed then that the ban was unconstitutional and that they would not observe it. Several incidents of violence were reported during the ensuing 2001 ban on drumming. Meanwhile, political leadership stayed a further 'distance' away from the issue whilst those unfortunate developments occurred. The resultant conflict that ensued between the traditional leadership and religious groups led to massive destruction to property worth hundreds of millions of Ghanaian cedis. Clearly if there was a meaningful collaboration between these traditional societies and state governance the stalemate would not had manifested itself. However, coherence and effective mobilization of such human resource, in terms of empowering traditional leadership, had led to many strides in effective governance, hence sustainable development. Traditional Societies are actively represented in the general assembly of the District Assemblies (D.As). Policy decisions are taken with the keen input and

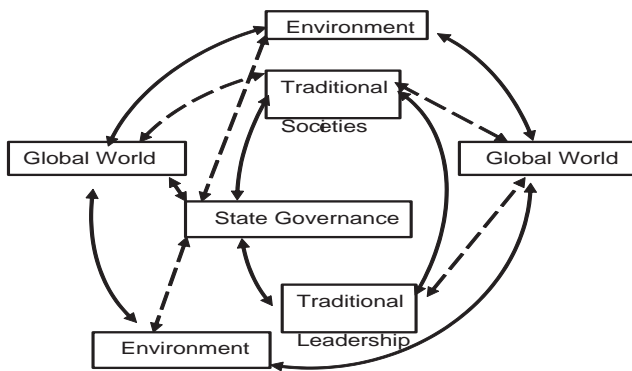


Fig. 1. Conceptual framework for partnering traditional leadership in state governance for sustainable development of human societies

contributions of local authorities.

Creating an enabling interface between traditional and state leadership has not been without challenges. Leadership styles and ideologies do and have in many instances created friction in governance at both national and local levels. What confounded many western theorists on the issue were whether African leaders espoused Marxism-Leninism, African and non-African socialism, capitalism or mixed capitalism and so on, their efforts failed. A critical scenario was the situation when Dr Kwame Nkrumah rejected compromises and ignored the advice of Sir Arthur Lewis to him, that the political-economy of the new African states should use agriculture to build their economies and should employ ethnic-based coalitions for government (Lewis, 1967). The result was that confusion reigned about how African leaders could and should deal with their economies and regimes.

Those anthropologists who kept abreast of conditions in Africa were not surprised by the chaos. Surprised when asked by some political scientist to deal with traditional leaders in a book dealing with political parties and national integration, Peter C. Lloyd, a specialist on the Yoruba kingdom, observed that while "the chiefs have not been in the van of the national movement, at least in recent decades ... the picture so often painted of a straight fight between elderly illiterate chiefs, living in the past, and modern Western-educated politicians is not in accord with the facts" (Lloyd et al, 1970).

## VII. PARTNERING TRADITIONAL LEADERSHIP FOR SUSTAINABLE DEVELOPMENT IN GHANA

### A. The Concept of Partnership for Sustainable Development

Partnering the traditional leadership in state governance is a vital and necessary tool for sustainable development. Traditional leadership, state governance and traditional societies have functional inter- and intra-relationships that impact on both local and global environmental variables. This is illustrated pictorially in Fig. VII-A.

The state, traditional leadership and societies exist in a globalized world to which there exists a close knitted collaboration. It is therefore necessary that all parties to sustainable development of human societies are integrated towards growth

and development that satisfies all (Fig. VII-A). Governance, though complex becomes easy to coordinate if considered in an integrative manner. Rooting indigenous knowledge in state governance is therefore a necessary impetus for growth and development.

Achieving sustainable development therefore requires an effective use of both traditional leadership and state governance since communities are mostly controlled by elders and clan heads who are answerable to chiefs and kings that pay allegiance to state authority.

Chiefs and Kings are accorded extreme respect due to the power and authority they wield. In recent past their authority was considered way above that of colonial administrative power as well as contemporary state authority. Using Chiefs for development therefore, is an active ingredient for achieving one's objective of sustainable development. Since the Chief resides with his subjects in the community, he is able to monitor and ensure that his decisions are carried out since such directives are not different from decrees. Using them therefore, to make and monitor laws of the environment, would ensure maximum co-operation and observance of such directives.

In many traditional societies, large areas of land are reserved as sacred grooves or abodes of the gods. Observance of such directives is non-negotiable, and this ensures that the land with its resources is conserved. The belief behind the scenario is that, if such laws are not respected, one would incur the displeasure of the gods, which is mainly fatality. Death is much feared by people than the punishments associated with the laws of the state. Laws are sometimes flouted with impunity, since they are not punitive.

Totems, use of objects as symbols of worship and reverence, are prevalent in many communities in Ghana. Animals including but not limited to the crow, deer (aboakyer festivals) are considered sacred in certain communities. Failing to protect such animals becomes a crime against the gods. Such a practice has led to the increase in the population of such animals in many communities. An interface of such idea and practice would ensure the protection of the environment and its resources.

Currently Ghana practices a Presidential system of government that seeks to execute power from a central point with representatives in both the regional and district administrative zones. State authority, which is mainly centrally based, makes it difficult for effective monitoring and coordination of national agenda. Making Chiefs responsive in state governance would ensure that government policies are easily accepted and observed by the various communities in Ghana. In such dimensions, an effective scenario that seeks to promote good governance and development would be created. Communities would also gladly accept government policies whilst working hard to ensure that they are achieved. The success story of government's massive cocoa spraying exercise for the past 4 years had been mainly due to the active and effective participation of traditional leadership and societies.

A bottom-to-up governance strategy involving local authority and central government would also encourage communities to own policies developed since they would be part of the planning and implementation of such projects. Studies have



shown that community projects that infuse the suggestions and contributions of indigenes have culminated into the success of these developments. Chiefs in Ghana, though not to engage in active politics, can help better explain policies of the government whilst mobilising resources for its completion. In doing so, such Chief would earn the trust and support of his people which will further enhance and promote the needed governmental support for their communities. The introduction of a Kumasi Ventilated Improved Pit (KVIP) facility in most coastal communities met little support from such communities. The underlining cause was identified to be the non-involvement of such communities in the planning and execution of such project. The people therefore avoided using such facilities. Through a collaborative agreement between such communities and government the people have returned to the use of these toilets since it has now been constructed at sites and in conditions accepted and approved by the communities. Sanitation and health has consequently improved in such communities. This obviously is the success story of involving state and traditional leadership in governance.

Traditional societies in Ghana, like many African societies, practice the extended family system. This practice ensures that the society is close knitted since each is the other brother's 'keeper'. Such a society, therefore, promote group living, discipline since anyone can punish as offender notwithstanding whether they are closely related. The future generation is also very critical to their present state and ability to see and survive the future. This invariably is a good impetus for grow and development of human societies.

### *B. The Way Forward*

International and national development agencies have recognized the value of participatory approaches to decision-making for sustainable approaches to development. During the past decade a rapidly growing set of evidence indicates a strong relationship between indigenous knowledge and sustainable development (Posey, 1985). Meeting the challenges of governance in contemporary Africa is to recognize and satisfy the goals and aspirations of different groups and their leaders. Different African societies necessitated types of governance based on compromises between types of groups and individuals. It is therefore in the right perspective for state governance to actively pursue all inclusive state governance that recognizes traditional leaders, societies and their contributions.

One of the longest-lasting violent conflicts in Ghana has afflicted the Dagbon traditional area of the Northern region, where each of the two major clans claims affiliation to different and opposing national political parties that is, New Patriotic Party (NPP) and the National Democratic congress (NDC). In 2003, the traditional ruler of Dagbon and a number of his followers numbering about 40 were killed in a chieftaincy dispute. Law enforcement agencies provided only a tepid response. Perceptions by the aggrieved clan of national authorities' ineptitude or compliance significantly ratcheted political tensions at the national level. This threatened to create instability and violence during national elections in December 2004. The scenario is an inducement for an effective

collaboration between state and traditional leadership since its omission will mean a possible chaos. The state should recognize traditional leadership whilst providing for such their legitimate state support.

Traditional leadership should not meddle in politics but rather in effective governance of their communities and the state. Chiefs and their council of elders should not be seen in party paraphernalia as well as partaking in party political campaigns. By respecting their boundaries in politics would prevent situations where they fall into the dark side of parties in power. Meddling in state politics may result in some of the unfortunate events that led to the Dagbon crisis that occurred in Ghana. The Chief's authority is primarily vested in his people and he should therefore be primarily responsive to the needs of his subjects. When such a desirable interface between traditional leadership and state machinery is created, it would further enhance strides for cooperation, growth and development of human societies.

Sustainable development that seeks to provide the need of the present generation without compromising that of the future generations should be an integral component of the aspirations of societies at the community level. Chiefs, Queen mothers, though actively working towards community development, can be made more effective if given the necessary legal backing as well as state support.

### *C. Recommendations*

Achieving sustainable development should see political leadership adopting an all inclusive governance system that intergrades all including and not limited to traditional leadership and societies, civil societies and development partners.

Government should strengthen traditional leadership through the regional and national houses of chiefs to ensure the promotion of peace and settlement of chieftaincy disputes. The judiciary can also be tasked to deal effectively and quickly with chieftaincy disputes in order to safeguard the chieftaincy institution. This would facilitate the existence and effectiveness of the institution. The Asantehene has instituted a policy that ensures that most chieftaincy disputes in the Ashanti kingdom are settled out of court. The current Asantehene has also requested and personally requested and ensured the withdrawal out of court of such disputes that relate to his kingdom and his sub-chiefs. This is a clear manifestation of the quest to ensure the effective participation and function of his chiefs to promote effective governance and development.

Further, development should take into account recommendations and demands of local authorities. The inputs of traditional societies should be sought before development projects are institutionalized as this would ensure a fuller corporation of the communities. This obviously would lead to development by, for and with the people.

Effective growth and development should also seek to include the empowerment of organizations that work at the local level. Non Governmental Organizations (NGOs), Civic groups and Community Based Organizations (CBOs) should be given adequate support to ensure their effective participation in community development. As these groups are supported, they can

effectively collaborate financially with traditional leadership to execute community project that include the conservation and protection of the environment.

Governments should create the environment for unity and not align themselves with particular chieftain or people, in the societies which leads to suspicion and division. This would ensure that successive governments continue to work effectively with all communities.

### VIII. CONCLUSION

Through the 50 years of Ghana's independence, the nation has transcended through a mirage of leadership ideologies both at local and national levels. This has passed through stages of colonial leadership that exploited traditional leadership to the present where the District Assembly concept has co-habited traditional leadership and state governance. In all such developments, the benefactors or losers have been the societies and the environment. Given the evolution of both traditional and state governance available to the societies, new strategies are needed to extend sustainable development to all societies.

State support and indigenous knowledge is recognized as a basic right that is vital to the society. Yet, governments have not been able to promote effective bottom-to-up governance that integrates the contributions of traditional leadership. With a high level of forest resource depletion, pollution of water bodies and low level of consciousness to environmental issues, it is proper relevant that Chiefs, Queenmothers and local opinion leaders are recognized and integrated into state governance. This obviously would lead to appropriate modes of conserving and preserving the environment, hence improved wellbeing.

It must be noted that it is absolutely impossible to promote sustainable development of human societies without ensuring a partnership that seeks to draw traditional leadership into state governance, hence sustainable development.

The study also revealed that, Ghana has laudable policies towards dealing with environmental conservation and preservation. Such policies deal with issues including forest stock depletion, pollution and best practices. Such policies though effectively coordinated, has left much to be desired. The Ghana Standards Board (GSB), Environmental Protection Agency (EPA), Chamber of Mines have been active in the front to comprehensive and effective environmental protection and consciousness. However, their functions and policies are not effectively coordinated due to the little involvement of traditional leadership and indigenous knowledge.

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(MDG) prescribes the need for nations to develop a global partnership for development. The United Nations Millennium Declaration represents a global social compact: developing countries will do more to ensure their own development, and developed countries will support them through aid,

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# Inland Habitat Environmental Sensitivity Index Mapping And Modeling Using Geographic Information Systems And Remote Sensing Technology

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## Abstract

**This study applies the Inland ESI mapping model developed by ERML and ESRI for the Niger Delta to the southeastern coastal region of Nigeria. Traditionally ESI mapping had been applied to shoreline areas and the maps typically contain three types of information: shoreline classification in terms of sensitivity to oiling, human-use resources, and biological resources. The ESI shoreline classification scheme is a numeric characterization of the sensitivity of coastal environments and wildlife to spilled oil. ESI was developed to reduce the environmental consequences of a spill and help prioritize the placement and allocation of resources during cleanup efforts. An improvement to the traditional ESI atlas has further been added through the development of ESI for inland/interior areas. This is particularly significant in the Nigeria context where many oil and gas facilities are located in the inland/interior habitats. This study shows that the model developed for the Niger delta is equally applicable to southeast coastal environment. The modeling is done using satellite imagery followed by rigorous field data collection and modeling within Arcview GIS environment. The GIS approach is quite ideal for ESI modeling because of its capability to sequentially overlay different data layers for various kinds of spatial statistical analysis and spatial modeling. The most critical element is the construction of the database: the relational database structure adopted greatly facilitates data search and analytical operations.**

*Keywords:* Environmental Sensitivity Index, geographic information systems, remote sensing

## Introduction

The Environmental Sensitivity Index (ESI) mapping concept was developed in 1976 and has since become an integral component of oil-spill contingency planning and response as well as coastal resource management in the USA and other countries worldwide [1]. The first ESI maps were prepared days prior to the arrival of the oil slicks from the IXTOC 1 well blowout in the Gulf of Mexico [2]. Since then ESI atlases and databases have been prepared for most of the U.S. shoreline, including Alaska and the Great Lakes. ESI Atlases are used in oil spill evaluation, prevention, and clean up processes. It must be noted that prior to 1989, ESI atlases were often prepared manually using traditional cartographic methods. However, since then, ESI Atlases have been generated using Geographic

Information Systems (GIS) techniques. The use of GIS and remote sensing techniques in the development of ESI Atlases is made possible because of the rapid development in computing and other allied information technology fields [3][4].

Traditionally ESI mapping has been applied to shoreline areas and the maps typically contain three types of information: shoreline classification in terms of sensitivity to oiling, human-use resources, and biological resources [5], [6]. Managers can look at an ESI map of an area threatened by a spill to quickly identify the most sensitive locations. Generally ESI maps have become a vital decision support tool used by government and industry to improve oil spill response and enhance the protection of the most sensitive habitats and localities.

ESI mapping can be described as the cartographic presentation of selected environmental attributes of a given area. The attributes are classified and ranked in terms of sensitivity to a stress factor (e.g., oil) and colour coded to distinguish environment type/class. In reality, it is a measure of the sensitivity of coastal zone natural resources to a stress factor (in this case oil /chemical spill), which is then depicted in form of maps and atlases [7].

The ESI shoreline classification scheme is a numeric characterization of the sensitivity of coastal environments and wildlife to spilled oil. Shorelines are colour-coded differently to indicate their sensitivity to oiling. To code them differently, a form of objective assessment and ranking of the shoreline attributes in terms of their perceived value in the ecosystem plays a significant role. The shoreline ranking concepts described by [8], and others, provide a scale of one to ten (ten is most sensitive) to indicate shoreline sensitivity and the use of symbols and patterns to indicate point or polygon (area) locations that are ecologically and/or socio-economically important. Within each numeric division, there are several alphabetic sub-classifications that further clarify the type of coastal environment and its sensitivity to spilled oil.

On ESI maps, warm colours like red and orange denote the shorelines that are most sensitive to oiling, such as tidal flats, swamps, and marshes. Cool colours like blue and purple indicate the least sensitive shorelines, such as rocky headlands and sand and gravel beaches. Shades of green denote shorelines of moderate sensitivity [9]. Large habitat areas, such as tidal flats used by shellfish and wetlands used by shorebirds or waterfowl, are shown as colored polygons. Wildlife of all types is mapped based upon known habitats, locations, and seasonality. This information is cross-referenced for each map in the atlas and is scientifically based and documented thoroughly. Each atlas comes with a detailed documentation, legends, and metadata to provide scientific support for oil spill responders. Other information of great importance on ESI maps include sensitive biological resources such as seabird colonies and marine mammal hauling grounds which are depicted by special symbols on the maps. In addition, important human-use resources such as water intakes, marinas, and swimming beaches are depicted with appropriate symbols on the maps [10].

Reference [11], noted that ESI was developed to reduce the environmental consequences of a spill and help prioritize the placement and allocation of resources during cleanup efforts. The successful use of analog and digital geographic information system versions of the ESI concept during the past ten years has led to improvements and refinements, including (1) the development of tidal inlet protection strategy maps produced before a spill that specify the type of response (e.g., boom, skimmer) and where and how to place it, (2) new large format seasonal summary maps, (3) geographic expansion of the ESI concept inland to classify the sensitivity of rivers using a River Reach Sensitivity Index (RSI), (4) regional watershed analysis to identify hazards and potential spill consequences, and (5) the identification of unusually sensitive areas to environmental damage if there is a hazardous liquid pipeline accident. Despite all these, the basics of ESI mapping have remained constant throughout almost all projects, which serve to support the validity of its original conceptual design and format [12]. An improvement to the traditional ESI atlas has further been added through the development of ESI for inland/interior areas. This is particularly significant in the Nigeria context where a lot of oil and gas facilities are located in the inland/interior habitats. Environmental Resources Managers Limited (ERML, Nigeria) in association with Environmental Systems Research Institute (ESRI, California) developed an ESI habitat modeling approach for the inland areas of the Niger Delta oil producing region. This paper is concerned with the application of this model in an oil producing region in Nigeria's southeastern coastal area.

#### Objectives

The aim of this study is to demonstrate the utility of the inland ESI habitat modeling approach developed by ERML, Nigeria and ESRI, California for the Oil Producers Trade Section (OPTS) of the Nigeria Chamber of Commerce and Industries in the

evaluation of the sensitivity of an area in Akwa Ibom State, Southeastern Nigeria that has a large number of oil and gas facilities. In order to achieve this, the following objectives and stages provided the required direction to the study:

- i. To collect all relevant primary and secondary data and information relating to oil and gas activities as well as the locations of communities and other biological resources in the delineated study area
- ii. Using appropriate software, to develop the initial habitat classes using unsupervised classification algorithm (Level 1 ESI map)
- iii. Based on (ii) above, design appropriate sampling plan for the field data collection and verification of the initial habitat classes (Level 1 ESI map)
- iv. To collect georeferenced habitat based data on soil, vegetation, wildlife, socio-economics, and beach geomorphology
- v. To determine the sensitivity of the terrestrial and socio-economic resources within and around the area of study to oil/chemical spill damage so as to enhance development of a more effective and coherent strategy for pollution response and prevention
- vi. On the basis of the above, to model the sensitivity of each inland and outer coastline habitat within the delineated area.
- vii. to identify and inventory environmental resources within the delineated area.
- viii. to characterize, classify and rank identified resources based on sensitivity to oil; and
- ix. to develop and produce cartographic representations of the environmental attributes of the areas for the purpose of oil spill response

#### Area of Study

Administratively, the study area is located in the Mbo Local Government Area (LGA) of Akwa Ibom State, Nigeria. Geographically it is located within Latitudes  $8^{\circ} 12'$  and  $8^{\circ} 18'N$  and Longitudes  $4^{\circ} 32'$  and  $4^{\circ} 36'E$ . The area is located adjacent to the Cross river estuary which is one of the most important river estuaries in Nigeria. The study area is about 35km from the Calabar Town Export Free Zone and about 18km. east of Qua Iboe terminal and 244km. east of the Brass River LNG development project. This study area comprises of a number of oil and gas facilities both onshore and offshore. The onshore area consists of dry, flat, fresh water rainforest and mangrove swamps and beaches, while the offshore component is largely made up of ocean water.

#### Methodology

The methodology used in this study is contained in the 'ESI Mapping Standard and Protocols' [13], developed for the OPTS. For the purpose of ESI classification, a distinction is made between the inland/interior and the coastal/shoreline habitats [14]. Coastal habitats are defined as those areas affected by marine, brackish, or riverine processes. Inland habitats do not experience marine processes being typically at least 1.5m above sea level in elevation.

The vegetation is essentially rain fed, although heavy rains may cause flooding in some parts. The inland /interior habitats in the oil and gas producing areas do not have the same history of sensitivity analysis as the shoreline and coastal environments, primarily because spills that occur on land are commonly locally controlled, cleaned up, and replanted so that the effects are relatively short-lived [15].

Figure 1 shows the cartographic model that was employed in the study. The data used in the ESI modeling for the inland habitat and the outer coastline sensitivity were derived from both primary and secondary sources. The secondary data were derived from relevant bibliographic and spatial data from the oil and gas companies operating in the area of study.

These materials were reviewed in terms of their suitability for integration into the ESI database that was ultimately used in modeling the interior inland habitats. The primary data collection involved the direct collection of the required data from the study area on vegetation, soil and geomorphologic characteristics. In collecting the primary data, Landsat satellite imagery covering the study area provided a significant direction on how the field sampling was carried out.

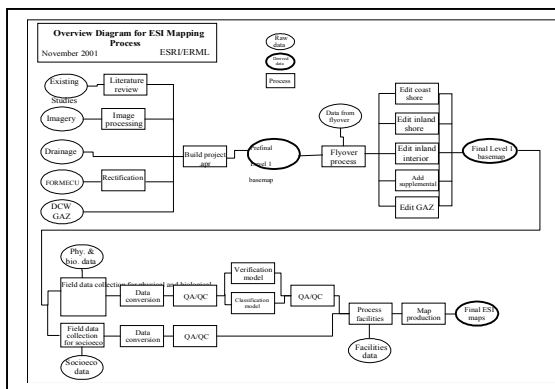


Figure 1: Cartographic Model for the ESI Mapping

#### Image Processing

The second most important activity involved the development of the Pre-Final Level 1 ESI map used in the field data collection. A Landsat ETM imagery which was acquired in January 2006 was used in the development of the ESI Map. The image was georeferenced and enhanced in order to visually differentiate possible inland habitats in the study area [16]. The satellite imagery was classified using an unsupervised classification algorithm technique to derive initial habitat classes. The unsupervised classification algorithm yielded four different habitats: two inland and two shoreline types. The four habitat types identified on the image provided the basis for planning the field investigation especially the selection of sampling sites. However, prior to the field sampling, a contingency plan was made to sample additional habitats that may not have been captured on the image but which are visible on ground. This is one problem that a helicopter over flight would have solved easily, but because of logistic problems, the fly over could not be done. The

implication of skipping the flyover component was that more effort was expended in the field sampling.

#### Field Sampling Design

A random site selection process was used to identify inland and coastal sampling sites to facilitate the extrapolation of the data collected at those sites to other places in the study area. This methodology uses the word "site" to describe a location where samples are collected. But for the inland/interior habitats a site is made up of six "stations" from which specific measurements and observations were made. Data on the six stations were subsequently combined to represent a set of single site indexes that enabled comparisons among sites and polygon types [17]. Site coordinates generated by the GIS were located in the field using a global positioning system (GPS) receiver. The application of the random site selection algorithm involved the placement of 400m x 400m tessellations on the pre-final level 1 ESI Map. The grids were created using ArcView 3.3 Avenue script. Another Avenue script was used to randomly select fifteen (15) cells (sites) from the grids covering each habitat. The selected sites must however be completely within the habitat and not located at the boundary of the habitat and other habitats.

In all, thirty (30) sampling sites were thus randomly selected for the five identified habitats. The centroid location for each grid then became the sampling origin for data collection during the field survey. The coordinates of the centroid points were extracted using ArcView GIS Software. Once all 30 alternate sites had been selected, transect bearings were established for each site. The design was such that transect station 5 would always begin at the direct center of the square (See Figure 2)

In terms of the shoreline sampling design, at least three sampling sites were established on each type of shoreline encountered during the field survey. A series of station points were located at 400-meter intervals along the shoreline and each station point was numbered sequentially. A random selection procedure was equally employed to identify the shoreline segments from which samples would be subsequently collected during the field sample. For each instance of shoreline type, three station points were randomly selected from the total number of the 400m segments. The selected coastal /shoreline segments were sampled adequately for ESI related data collection

#### Establishing the Transect

Once all the sites were identified, the next activity involved the determination of the transect direction in each of the sites. The first step in determining transect bearing was to identify the latitude and longitude point of the exact center of the square. From that point the transect radiated outward for 100 meters. A random process was used to determine what bearing from north the transect would follow. At least one backup bearing was generated for each site [18]. The second 100-meter transect always fell 90° clockwise from the original transect. To establish a bearing, the magnetic north was determined using a hand-held

compass. Next, the bearing was determined by randomly selecting a direction using a pie chart.

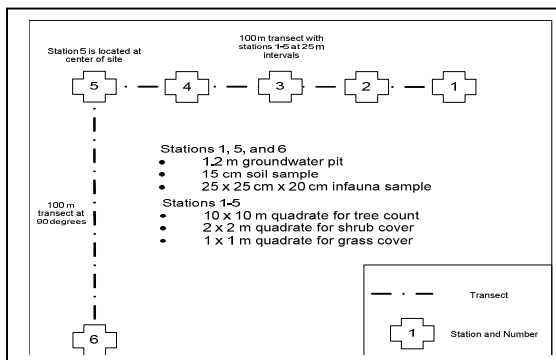


Figure 2: Field Sampling Design: Inland Habitat Type (OPTS 2001)

#### Field Data Collection Activities: Inland Habitat Data Collection

Four parameters related to spill persistence and cleanup difficulties which were measured in the field include (a) type of substrate (b) presence of near surface groundwater (c) presence of inhibiting penetrating layer and (d) presence of surface debris [19]. Figure 2 shows the field sampling design for the inland/interior ESI habitats mapping for the study area. For each of the five (5) sites, six stations each were established in line with the above diagram. Furthermore, field templates contained in the ESI Mapping Standards and Protocols [20], were used in recording the collected data in-situ. A brief description of the types of data collected with the templates is provided below. Further detailed description of this methodology is contained in the ESI Mapping Standards and Protocols.

The following data were collected for the inland/interior habitat locations during the field data collection exercise:

1. Environmental data on each station including the geomorphology, sediment type, flora and fauna, health of vegetation, locations of small water bodies and groundwater were collected. All the sites were visually inspected for the amount of surface debris covering the site including leaf litter, dead trees, and broken branches. A visual aid contained in the ESI Mapping Standards and Protocols was used to estimate the percentage of debris cover at each of the site visited. The surface debris values were recorded in the appropriate field template form.
2. Three soil samples for grain size and total organic carbon analysis were taken of the top 15 cm of sediment. The sediments were taken at a distance of 0m, 100m and another 100m at a right angle to the origin of the transect [21]. These locations correspond with stations 1, 5, and 6 in Figure 2.
3. Vegetation samples were taken at a distance of 0m, 25m, 50m, 75m and 100m from the transect origin. The number of each vegetation species at each site, their condition and status were recorded into the appropriate field template forms.
4. In areas where no surface water is visible, 1.2 m pits were dug at three locations corresponding to stations 1, 5, and 6 in figure 2 to determine the presence of near surface water which can easily be polluted in the event of an oil spill. Inhibiting layer

(Top 50 cm) is a layer of clay that can inhibit the downward movement of spilled oil. Such layers are particularly important especially in areas of heavy clay. The extent of inhibiting layers present in any site was calculated from the percent of silt + clay found in the soil sample after the laboratory analysis. A 45% or greater silt + clay content defined an inhibiting layer.

5. Animal species associated with each site were observed and recorded in the appropriate field template forms. Additional information about the animal species in the locality was also obtained from local hunters in the nearest community to the sample location. The information provided by the hunters was regularly cross-checked against a field guide and sometime a picture of the animal that hunters claimed to have been sighted was shown to them to ensure consistency. Information with regards to animals was also sourced from existing literature on the area of study. Important protected and endangered species were noted. This information was assembled in order to have a comprehensive understanding of the animal species present in the area of study. Bird and reptile species associated with each station were also observed. Previous records of bird and reptile species from the locality were also obtained from reliable literature sources and from local knowledge. Again, important protected, and endangered species present in the area were noted.

6. The population density of trees was determined using the quadrat method. The size of the quadrat used was 10 m x 10 m. Trees were defined as having trunk diameters of 10 cm or greater at breast height. Tree density was measured by counting the number of individuals of the study species rooted within the quadrat and recorded on the appropriate form. The procedure was carried out five times along the 100 m transect (Figure 2). The height of the trees was determined using a clinometer.

7. Coverage by shrubs and grasses in the understorey: Percent cover of grasses and of shrubs in the understorey were estimated using the line intercept method. A 100m tape measuring rule was stretched along transect. The transect direction was selected from the center of the site along a randomly pre-determined compass direction (see Figure 2). Percent coverage by shrubs and by grasses at five stations (25 m intervals) were recorded on the appropriate ESI field form. For shrubs, the diameter within which coverage was measured was 2m. For grasses and low-lying plants, a 1 m<sup>2</sup> -point quadrat was used at each of the 25m interval. The point quadrat frame has 10 holes. Each point quadrat was lowered vertically through the vegetation. The measure recorded was the percentage cover. The pins were lowered one at a time, and the species touched by each pin was recorded. The final number of "hits" from a number of sample "frames" was then expressed as a percentage of the total number of pins. The summary of all hits on a species provided a measure of the "total cover" of a species, a measure which reflects the size of plants or a species as well as its abundance in the vegetation. Any species in notable abundance (>5% cover) that could not be identified in the field were collected for later

identification. Important, medicinal, protected, and endangered plants were also noted.

During the field data collection, each plant species was also visually inspected to detect notable levels of fungal or bacterial infestation and defoliation due to disease. Where infestations were noted, these were recorded as percent "stressed" or "normal" in the appropriate ESI field template form. The total percentages of "stressed" and "normal" were calculated from the individual data for all measured species.

8. Sediments for Infauna were taken with a hand held garden spade at stations 1, 5, and 6 adjacent to the other sediment sample locations. Sample size taken was a 30cm x 30 cm x 5cm deep sediment. The samples were stored in polythene bags and preserved with 70% alcohol solution. Infauna population at the shoreline was equally examined. Samples collected especially at the sand beaches were washed and preserved for further identification of the contents.

#### Coastal/Shoreline Habitat Data Collection

1. The descriptions focused on the primary biological and physical characteristics of the shoreline site. In addition, the following conditions were documented with respect to each shoreline segment: sediment type, exposure to waves, flora, and fauna. Exposure to waves was described as high (open ocean), moderate (embayment or large rivers), or low (sheltered or riverine areas). The field sketch of the shoreline from oblique perspective was drawn on the field template. The drawing highlights the beach width and slope, sediment type, wave height and direction, vegetation, the backshore area, and any other distinguishing characteristics. It also indicates the location of samples taken for infauna and grain size.

2. A single soil sediment sample was taken from the upper 15 cm of the middle beach face using shovel. The collected samples were analyzed for grain size (using the USA Standard Sieve Mesh) and total organic carbon (TOC) (using Walkeley-Black method). The average slope in degrees of the active middle beach face was determined. An average of three measurements was taken in order to determine shore slope. Visual estimation of slope was employed especially when physical access was not possible due to inaccessibility (overabundant vegetation, unstable footing, or deep mud). Wave height in meters was also estimated during the field survey. Current direction was estimated based on a 360-degree compass bearing. This was done by tossing a buoyant object into the surf and observing its direction of movement [22].

3. Sediments for infauna analysis were taken with a hand held garden spade at three locations at the mid-beach face, adjacent to the site used for grain size analysis during the field data collection exercise. Samples of 30cm x 30cm x 5cm deep of sediment were collected at each of three locations. The samples were mixed into a single polythene bag and preserved with 70% alcohol solution. The number of crab burrows along the upper swash zone within five of 1-

meter squares randomly placed along the upper swash zone was also counted and recorded.

4. A vegetation survey to determine relative coverage of species was undertaken along a 100 meter transect within the area of study (See Figure 3). The transect was located at the center of the site corresponding to the beach profile sketch. Transect was laid out perpendicular to the shoreline beginning at the high water mark and proceeding inland. Observations were made on the percentage coverages of individual species along the transect. The values obtained were recorded in the appropriate field template form.

#### Database Creation

Following the successful completion of the field data collection activities, all the collected data were compiled into a database within a GIS environment.

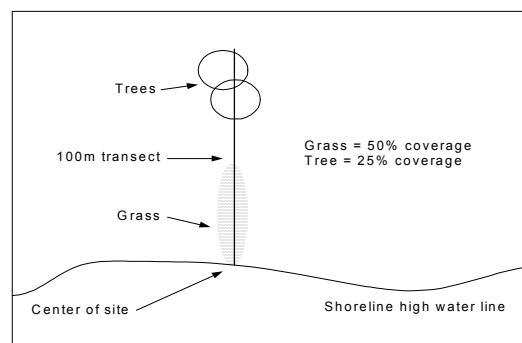


Figure 3: Shoreline Vegetation Observation (OPTS, 2001)

This was done in order to be able to model the field data in line with the requirement of the Protocols. In order to ensure consistency and accuracy of data, a rigorous data inspection and quality control exercise was carried out prior to the modeling phase.

#### Results and Discussion

The results of the field survey and laboratory analysis show that there are five distinct shoreline/coastal habitats and two inland habitats in the area of study. Table I shows these different inland and shoreline habitats. Data were collected for each of the habitats and managed in a relational database using Microsoft Access. The data were first entered into their corresponding thematic tables using a unique identification code (ID). Site coordinates were chosen as the unique identification code for each survey site. As an example, data such as depth to ground water, percent clay, and wave height were entered into the geo-characteristics table, while data on vegetation diversity index, percent grass, and tree and shrub coverage were managed under the vegetation table. The animals table contains all data and information on fauna and infauna species.

Table I: ESI Classes in the Study Area

	Coastal/Shoreline Habitats	ESI	Inland / Interior Habitats
1	Fine Sand Beach		Bush Fallow
2	Mangrove/Nypa shoreline	palm	Farmland
3	Exposed Manmade structure		

4	Freshwater swamp forest	
5	Huts over shoreline	

In analyzing data the six-station data would first be aggregated into site data and then the five sites data were aggregated into habitat data. The data collected for shorelines were validated using the procedure contained in the ESI Mapping Standard and Protocols. The verification involved averaging the grain sizes for each shoreline type into an average grain size range for that class. The average grain size range for each shore line type was compared to the existing standard grain size range for that shoreline type. Wherever the grain size determined from the field data collected was outside the existing standard range, then the habitat delineation would be changed to reflect another habitat type (see Table II).

The variables used in the validation were dominant grain size, slope, and wave exposure. The dominant grain size is determined by averaging the percent grain sizes for the three sample locations on a given shoreline to give an indicator of that shoreline's grain size. The grain size with the highest percent average is the dominant grain size. The average slope in degrees and the average exposure of the beach to wave energy were compared with the standards for each shoreline type (see Table III)

Based on the results contained in Table III, the five distinct shoreline types observed in the area of study have the three dominant indicators used in assessing them within the established range for those shoreline types. The 'man-made structure' and the 'huts over shoreline' type of coastal habitats did not have any readings for grain size because they are mainly concrete structures. The huts over shoreline are actually huts directly placed over the coastline with water running under them.

In terms of sensitivity to spill, the most sensitive is the huts over shoreline area. Indeed these areas are very critical in view of the fact that if there is any spill, it is likely to affect humans directly. This is followed by the freshwater swamp forest, which according to [23] has the highest biological diversity

Table III: Shoreline Sensitivity Assessment.

Shoreline/Habitat Type	Dominant Grain size (mm)	Standard Grain Size (mm)	Slope Angle (Degrees)	Standard Slope Angle (Degrees)	Wave Exposure	Standard Wave Exposure	Average TOC Content (%)	ESI Class
Sandy Beach	0.14 (FS)	0.0625—0.25	2.47	< 5 <sup>0</sup>	High	Low-High	0.18	3A
Manmade Structure	ND	>64m but depends	29.32	Moderate - High	High	Moderate - High	ND	1B
Mangrove/Nypa	0.056 (SC)	Mud < 0.0625	0.01	< 3 <sup>0</sup>	Low	Low	1.56	10A

Palm								
Fresh water Swamp	0.056 (SC)	Mud < 0.0625	0.01	< 3 <sup>0</sup>	Low	Low	1.49	10B
Huts on Shoreline	ND	ND	ND	< 3 <sup>0</sup>	Low	Low	ND	9C

Notes: MS = Medium Sand, FS = Fine Sand, SC = Silt and Clay, ND = Not Determined, NA = Not Applicable, TOC = Total Organic Content

of all the habitats in the region. The least sensitive is the sand beach because although it can provide a good recreational facility, it has limited biological diversity. The chance of ecological damage occurring on the sandy beach is therefore comparatively minimal.

Modeling the sensitivity index for the inland habitat was more rigorous as it involved not only the averaging, but also the computation, of some new indices. Three levels of modeling are involved. First, 'parameter models' was used to model field measurements into parameter values for each habitat type, while 'valuation models' was used to model site parameters into biota and geomorphologic indexes. The ESI model models biota and geomorphologic indexes into ESI classes.

First all the measurements from all the five stations were averaged to site index. This average is stored in the site index table. The five site indexes were subsequently averaged to characterize the habitat types. The habitat type average was then compared to a parameter valuation table and entered into the corresponding parameter value in the habitat type table. For the detail of the weighting used see [24], [25]. While ESI valuation for the shoreline only required a look up table to compare ESI indices, the inland habitats were modeled to determine their relative ESI valuation and rank. Table V gives the final ESI valuation and the final ESI model result for the two inland habitats observed in the area of study.

In terms of sensitivity, the result shows that farmlands are relatively the more sensitive habitat compared to the bush fallow. This result is not surprising in view of the socio-economic importance of farms (Table IV).

Table IV Final ESI Valuation for the Interior/Inland Habitats

Habitat	Valuation Indices				ESI Rank
	ESI - geomorphic Characteristics	ESI - Vegetation Characteristics	ESI - Mammals	ESI - Total	
Bush Fallow	14.2	56	22	102.20	3
Farm	12.3	46	18	76.30	2



Farmlands are typically cleared forestlands that are put under cultivation. Commonly cultivated crops include yam, cassava, corn fluted pumpkin and other vegetables. Oil palm trees and other useful economic trees are protected within the farmlands. Biological production is low compared to some of the other inland habitats while organic content can be as high as 1.3%. The predominant surface grain size is within the medium range. In terms of its predicted oil impact, the geomorphic and biota characteristics of farmlands indicate a low sensitivity to oiling. They are not exposed to marine and tidal influences. If oiled, vegetation mortality may occur; this will have more of a socio economic impact. They become more vulnerable if located near pipeline routes. If oiled, surface oiling will be generally confined to a small area. However, depending on surface debris and presence of confining layers, oil may percolate into the subsurface. Oil that reaches the groundwater may be difficult to clean up and can potentially cause a health hazard due to the presence of shallow wells in these areas [26].

Bush fallow is an abandoned farmland or cleared area that is left to regenerate. The fallow period ranges between three and five years. Fallow lands are generally more densely vegetated habitats than farmlands. Weeds and relic crops that were left in the farm e.g. cassava, typically dominate this habitat. If the fallow period is long enough the area turns into a secondary forest. Medium grain sized sediments predominate on these sites and their organic content is as high as 1.02% [26]. With respect to the predicted oil impact, many more biological resources may be impacted by spilled oil than on the farmlands but, impacts are generally restricted and localized because fallow lands are land-based rather than water-based ecosystems. Oil persistence may be worsened if oil percolates into the subsurface. Oil that reaches the groundwater may be difficult to clean up and can potentially cause a health hazard due to the presence of shallow wells in these areas. Recovery is dependent on the degree of oiling and penetration into the substrate, but with proper cleanup, restoration can be relatively rapid.

#### Conclusion

This study set out to demonstrate the applicability of the ESI mapping model for inland or hinterland areas developed by ERML and ESRI for the Niger Delta environment in a comparable portion of the southeastern Nigeria coastal region. The procedures adopted closely followed those prescribed in the model and the model standards for environmental indexes were relatively easy to apply to the study area. The findings of this study demonstrate that ESI modeling is more or less equally applicable to the shoreline and the hinterland of oil producing coastal regions. The ESI modeling also shows the integration of biodiversity variables into sensitivity index mapping. The terrain in the hinterland areas is less intricate and fragmented than in the shoreline zone. Therefore, it is relatively easier to classify and delineate the existing habitats both on imagery and in

the field. The hinterland terrain is also more conducive for the field data collection phase of the exercise because of the better going conditions. In this study the benefits of aerial survey were not fully utilized because of the skipping of the helicopter flyover. Hence, the field operations stage was more demanding and time-consuming than it would have been ordinarily. The GIS approach is quite ideal for ESI modeling because of its capability to sequentially overlay different data layers for various kinds of spatial statistical analysis and spatial modeling. The most critical element in the construction of the database: the relational database structure adopted greatly facilitates data search and analytical operations. ESI has potential for application for other types of environmental perturbations apart from oil spill.

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## **Influence of Climate Change on Agriculture, Hydrological Regime and Water Resources in Ghana**

**K. Nsiah-Gyabaah**

### **Abstract**

In the past few decades, temperature has been increasing and rainfall has been below average. These events, coupled with other climate factors have led to crop failures and increased the depletion of water resources to the extent that some rivers and streams have dried up completely and reservoirs such as the Akosombo dam has fallen below the minimum electricity operating level. The deduction in the volume and flow of water in the Volta River has affected the Akosombo dam, making it impossible for the dam to generate enough hydroelectricity from the power plant to meet the energy demand of consumers.

In addition, the ecological effects of climate change has been severe, leading to intense heat, prolonged drought and rampant bush fires which are destroying forests, wildlife and vital resources on which the people, especially the poor depend for a living. As a result of the adverse impacts of climate change on livelihoods and human security, African countries have been called upon to design and implement adaptation strategies to address the problem. However, there is a clear need for the public to understand fully the potential impacts of climate change on the ecology and livelihood systems including agriculture, hydrological regime and water resources before the public would participate actively in the design and implementation of strategies to address the problem.

The ultimate objective of the paper is to provide useful information on the nature, causes and effects of climate change as bases for designing adaptation strategies that would be accepted and implemented by local people to reduce the adverse impacts of climate change in Ghana.

# An Appraisal of Government Policies on Drought and Desertification in Nigeria

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**Abstract—** Desertification constitutes one of the international environmental problems whose global importance has been recognized by the international community. This importance is clearly visible in the massive endorsement that states have given to the United Nations Convention to combat desertification in those countries experiencing drought and/or desertification, particularly in Africa adopted in 1994. However desertification in Nigeria arises from the demand of growing population that settles on the land in order to grow crops and graze animals. The extent and severity of desertification in Nigeria has not been fully established neither has the rate of its progression been properly recognized. However, it is estimated that the country is currently losing about 351,000 hectares of its landmass to desert conditions annually, and such conditions are estimated to be advancing southwards at the rate of about 0.6km per year. The purpose of this paper is to evaluate government policies in addressing desertification and to offer new measures based on the findings. The study reveals that the government's top-down approach, inconsistency of policies, neglect of indigenous knowledge, use of inappropriate technology constitute the major factors for the failure in combating desertification and mitigating the effect of drought in Nigeria.

**Keywords—** Desertification, Drought, Drylands, Nigeria, Policy evaluation.

## I. INTRODUCTION

The United Nations Conference on Environment and Development defines desertification in Chapter 12 of Agenda 21 as "land degradation in arid, semi-arid and sub-humid dry areas caused by climatic changes and human activities". It is accompanied by a reduction in the natural potential of the land and depletion in surface and ground-water resources. But above all it has negative repercussions on the living conditions and the economic development of the people affected by it. Desertification not only occurs in natural deserts, but can also take place on land prone to desertification processes. Desertification is a worldwide phenomenon which causes the earth's ecosystems to deteriorate. It affects about one sixth of the world's population, 70% of all dry-lands, amounting to 3.6 billion hectares, and one quarter of the total land area of the world [18]. The most obvious impact of desertification, in addition

to widespread poverty, is the degradation of 3.3 billion hectares of the total area of rangeland, constituting 73% of the rangeland with a low potential for human and animal carrying capacity; decline in soil fertility and soil structure on about 47% of the dry-land areas constituting marginal rain fed cropland; and the degradation of irrigated cropland, amounting to 30% of the dry-land areas with a high population density and agricultural potential [18].

## II. BACKGROUND OF THE STUDY

Desertification is accepted to be a complex phenomenon requiring the knowledge of researchers in such disciplines as climatology, soil science, meteorology, hydrology, range science, agronomy, veterinary medicine, as well as geography, political science, economics, anthropology and environmental planning. It has been defined in many different ways by researchers in these and other disciplines, as well as from many national and bureaucratic (institutional) perspectives, each emphasizing different aspects of the phenomenon. A review of the desertification literature shows a great diversity (and confusion) among definitions [9]. This mix of definitions (meanings attributed to the concept) leads to miscommunication among researchers, among policy-makers, and most important, between researchers and policy-makers [8] and [18]. An analysis of the definitions of desertification could prove useful in developing an improved understanding of the phenomenon, of how it is viewed from different disciplines and countries (and bureaucratic units), and of whether progress in combating it has in fact been as slow as many observers suggest [18].

The question now is what constitutes desertification? Some researchers consider desertification to be a process of change, while others view it as the end result of a process of change. This distinction underlies one of the main disagreements about what constitutes desertification. According to [12] desertification as a process has generally been viewed as a series of incremental (sometimes step-wise) changes in biological productivity in arid, semi-arid, and sub humid ecosystems while [7] viewed desertification-as-event is the creation of desert-like conditions (where perhaps none had existed in the recent past) as the end result of a process of change. To many, it is difficult to accept incremental changes as a manifestation of desertification. In fact, these two views

represent different aspects of a broader concept of desertification. Thus, seemingly different statements such as "the creation of desert-like conditions in areas once green", "encroachment of desert-like conditions", "the intensification of desert-like conditions", as well as less drastic projections like "changes in soils and in climate" or "the land becoming less fit for range and crops", can be encompassed by the concept of desertification.

In terms of the changes it brings, desertification is viewed as an adverse environmental process. The negative descriptors used in these definitions of desertification include: deterioration of ecosystems [20], degradation of various forms of vegetation [7], destruction of biological potential [20] diminution of biological potential, decay of a productive ecosystem [5], reduction of productivity [15], decrease of biological productivity [19], alteration in the biomass, intensification of desert conditions [20], and impoverishment of ecosystems [6]. Then, what is changed by desertification? Different definitions focus on changes in soil (e.g. salinization), or vegetation (e.g. reduced density of biomass), or water (e.g. water logging), or solar radiation (e.g. increased albedo). Most of them, regardless of primary emphasis, also describe changes in biological productivity, with comments related to the type, density, and value of vegetation. As a final comment on what desertification is, it is important to note that disciplinary and institutional biases may appear in any given definition of the phenomenon. For example, a meteorological bias might require for the use of the term "desertification" that a change take place in the meteorological parameters of a given region, so that they become similar to those for a desert region (e.g. high evaporation rates, aridity, increased rainfall intensity, and so on).

### III. THE STUDY AREA

Nigeria, which is located between latitudes 4°N and 14°N and longitudes 2° 2' and 14° 30' East has a total land area of 923,773 km<sup>2</sup> and the population of Nigeria in 2006 was put at 140,019,952, divided almost equally between females 48.68% and males 51.32%. Thus, Nigeria today accounts for about a quarter of the total population of the African countries south of the Sahara and its people consist of over 200 ethnic groups, speaking about 395 languages and dialects. The country is bordered by the Republics of Niger and Chad to the north, to the south by the Atlantic Ocean, to the east and west by the Republics of Cameroon and Benin, respectively as shown in Figure 1. By virtue of its spatial extent the country encompasses various climatic regimes and physiographical units that give rise to a wide variety of ecological zones.

These zones range from flush forest vegetation in the south to Guinea savanna in the middle belt region, Sudan savanna in the north and Sahelian vegetation in the extreme northern part of the country. Of these ecological zones, the Sudan and Sahelian regimes are most vulnerable to climatic and human pressures.

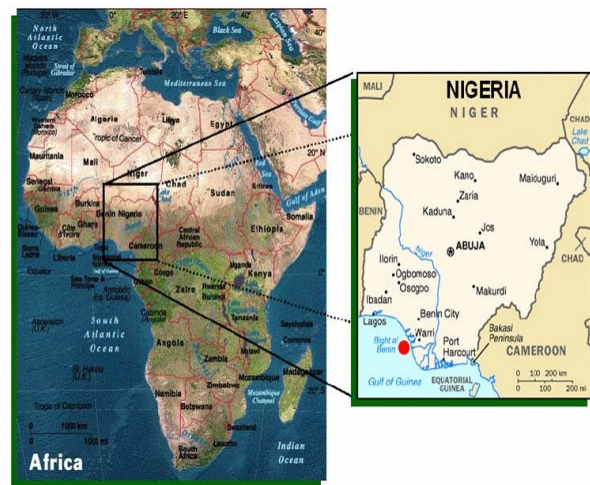


Figure 1. Map of Africa Showing Nigeria

### IV. DESERTIFICATION IN THE DRY-LAND OF NIGERIA

There is a general consensus that desertification is by far the most pressing environmental problem in the dry-land parts of the country. The visible sign of this phenomenon is the gradual shift in vegetation from grasses, bushes and occasional trees, to grass and bushes; and in the final stages, expansive areas of desert-like sand. It has been estimated that between 50% and 75% of Adamawa, Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe, and Zamfara States in Nigeria are being affected by desertification. These states, with a population of about 50 million people [15], account for about 43% of the country's total land area. In these areas, population pressure resulting in overgrazing and overexploitation of marginal lands has aggravated desertification and drought. Entire villages and major access roads have been buried under sand dunes in the extreme northern parts of Katsina, Sokoto, Jigawa, Borno, and Yobe States. The pressure of the migrating human and livestock populations from these areas are absorbed by pressure point buffer states such as the Federal Capital Territory, Plateau, Taraba, Niger, Kwara and Kaduna states. It is reported that these buffer states have about 10-15% of their land area threatened by desertification. This action leads to an intensified use of fragile and marginal ecosystems resulting into progressive degradation even in years of normal rainfall. However, desertification is made very severe in the dry lands of the country by increasing human attempts to exploit the resources of the ecological zone in the face of persistent drought. Before now, Nigeria has been tackling the problem of desertification the best way it could, but with little success. It is now obvious that the menace should be addressed in a holistic manner in order to ensure that the dry-land of the country continue to support human and natural resources.

### V. CAUSES AND IMPACTS OF DESERTIFICATION IN NIGERIA

[17] states that the natural causes of desertification in Nigeria include the poor physical conditions of soils,

vegetation and topography as well as the inherent extreme climatic variability as evidenced in periodic droughts. Climate variation is perhaps the most important natural cause of desertification and drought in the dry-land of Nigeria while the anthropogenic factor is mainly the disruption of the ecological system caused by poor land use and ever-increasing pressure put upon the available resources by the expanding population. According to [14], there are four primary causes, notably overexploitation, overgrazing, deforestation and poor irrigation practices; and these are influenced by factors such as changes in population, climate and socio-economic conditions. It is obviously a complex inter-relationship, which includes: poor physical conditions in terms of soils, vegetation, topography and inherent extreme variability of climate as manifested in frequent drought; disruption in ecological balance caused by poor land use and ever increasing demand being made on the available resources by the expanding population and socio-economic systems of the affected areas; and improper land-use practices and poor land management. Thus desertification is a result of complex inter-relationships between social and natural systems. Figure 2 shows the interplay among them.

In addition to the causes mentioned above according to [10] and [14] the following are the main causes of desertification in Nigeria through anthropogenic factor which are: 1) wood extraction for fuel and construction, 2) bush burning, 3) grazing, 4) cultivation of marginal land, 5) faulty irrigation management and 6) Poverty.

In Nigeria, drought and desertification have severe impact on the following:

1) *Socioeconomy*: Desertification and drought have severe impact on food security, livelihood, socio-economic and cultural activities of the affected people. This has aggravated the food situation in the area resulting in low food security index. Drought causes a lot of economic disruption. For example, it was held responsible for the drastic fall in the GDP of 18.4% in 1971-72 and of 7.3% in 1972-73 (at constant 1974-75 prices) [3]. It was also seen as causing the rapid rise in price index for foodstuff and relative decline in non-oil exports.

2) *Land and water resource*: In addition to the socio-economic impacts, drought and desertification do have serious consequences on available water resources. Long term drought could adversely affect the level of upper groundwater and stream flows, as well as the underground water.

They also affect the level of large lakes, thereby affecting riparian access as in Lake Chad, which has receded beyond the borders of Nigeria.

3) *Destruction of habitat and loss of biodiversity*: The flora and fauna of the Sudano-Sahelian zone have been badly depleted as a result of climatic variation and human mismanagement and/or overexploitation of the environment [16]. Some fauna species such as the sitodunga antelope, cheetah, lion, giraffe and elephants are endangered. Other endangered species are the crowned crane, the bustard, Palarctic migrants, ostriches, and fulvov tree ducks.

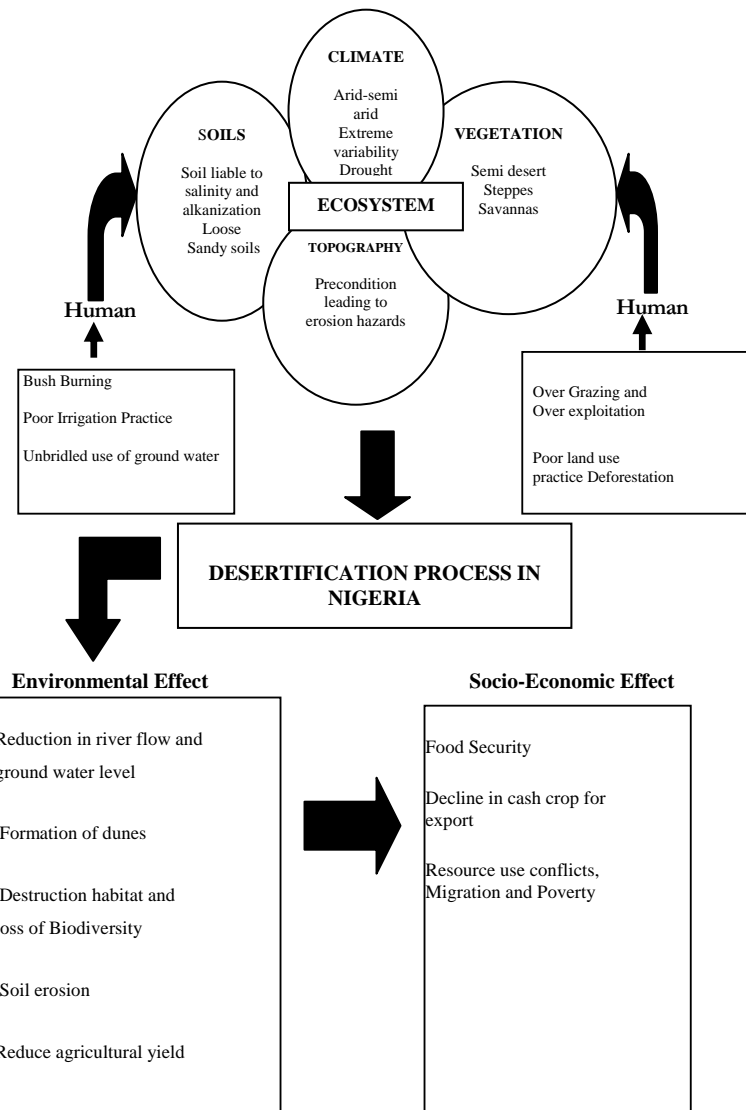


Figure 2: Model of desertification process in Nigeria (Adapted from Oladipo 1993a)

4) *Resource use conflicts*: As contained in the [14], desertification and land degradation encourage economic and social strife as shown in the wars of the Sahel and the Horn of Africa in the last two decades. This is often accentuated by lack of proper natural resource planning and management as well as rapid population increase in the arid zone and the diminishing environmental resource base. In the dry-land of Nigeria, conflicts over land resources are focused on areas of high productivity, especially those that provide seasonally critical resource such as the wetlands. The most of which have competitive uses amongst the various rural land users, notably farmers, herders, fishermen and hunters.

## VI. POLICY EVALUATION METHOD

The literature on policy evaluation [1], [17], [4] summarizes that policy evaluation can be conducted in three major ways namely:

1) *Monitoring of program performance*: Involves the ongoing systematic collection of data on the program activities. It also includes the development of standardized performance indicators and reporting systems. The information is primarily of two types, i.e. inputs and outcomes. The inputs are resources consumed by carrying out program activities while outcomes are the products of the program activities.

2) *Conducting impact evaluations*: Conducted to determine the degree to which a policy achieves its intended objectives. Impact evaluations are more elaborate than program monitoring since impact evaluations focus changes in social and physical condition. Analysts attempt to design studies that allow them to determine how much of this change is attributable to the policy that is undergoing evaluation. Impact evaluations provide conceptual and technical challenges for policy analysts.

3) *Conducting process evaluation*: Determines why a program is performing at current levels, and what can be done to improve the performance. Accordingly, process evaluations are concerned with identifying specific links between policy implementation activities and program performance. Study findings are not intended to determine whether a program is meeting specified goals, as in impact evaluations, but to develop recommendations for improving program implementation procedures.

For this study, data were collected from both primary and secondary sources. Secondary data on the national programs for fighting desertification and the success of the programs were collected from various government agencies; among them The Department of Drought, Desertification and Amelioration of The Federal Ministry of Environment, The Federal Ministry of Agriculture, The Federal Ministry of Water Resources and Rural Development, and State Ministries responsible for combating drought and desertification in the eleven affected states.

Primary data were obtained through personal interviews of some of the affected residents as well as the government officers in charge of the programs to fight desertification. Interviews were carried out using an interview guide as well as a standardized format interview. The interview guide consisted of a list of issues or questions to be raised during the interview and it was prepared to ensure the same material coverage in all interviews. It provided topics or subject areas within which the interviewer was free to probe to obtain more complete information about a particular subject. The standardized format interview was carried out when comparable responses were desired from each interviewee on the same questions or issues being investigated. Both open- and closed-ended questions were prepared for the interviews exactly as they were to be asked. The collected data were then sorted and analyzed to evaluate the impacts of past and present government programs in fighting desertification. The evaluation was carried out in the manner suggested by the impact evaluation technique mentioned before.

#### A. *Historical trends of national efforts in combating draught and desertification*

The major concern about the possible southward shift of the Sahara desert into Nigeria was expressed in 1930s. In response, an Anglo-French Commission in 1937 investigated the report in the northern parts of Nigeria and directed the border emirates to embark on tree planting to stop the encroachment. Thousands of seedlings were distributed at nominal prices. The catastrophic Sahelian drought of 1972/73, however, jolted the Federal Government into action. This drought, which was recognized as a national disaster, prompted an *ad hoc* relief packages consisting, where feasible, the provision of subsidized food, supply of water by water tanks, bore holes and wells as well as making available seeds at planting time, among others. The drought nonetheless encouraged the establishment of afforestation programs and the construction of dams for irrigation as well as the establishment of the initial three River Basin Development Authorities (i.e. Chad Basin, Hadejia-Jama'are and Sokoto-Rima). In 1977, the Federal Government set up a National Committee on Arid Zone Afforestation Project with the responsibility of examining the in-depth problem of desertification and drawing up a suitable program of afforestation geared towards checking desert encroachment. A program of shelterbelt plantings for the protection of adjoining agricultural lands against desiccating winds in the extreme northern part of the region was also embarked upon. Since Rio summit in 1992, Nigeria has made significant efforts in addressing the environmental and sustainable development issues, which were identified and agreed upon at United Nations Conference on Environment and Development (UNCED).

#### B. *Current national policies in combating desertification and mitigating the effect of drought*

The government has taken cognizance of the multi-sectoral problems of desertification. In this regard, it has developed a number of policies and plans ranging from agricultural to energy.

Some of these, which contain provisions relevant to desertification control, are highlighted below:

1) *National Policy on Environment (1989-2020)*: The policy clearly indicates synergies with other sub-sectors relating to population, culture, housing and human settlements, biological diversity, conservation of natural resources, land-use and soil conservation, agriculture, water resources, forestry, wildlife and protected areas, mining and mineral resources, energy, education, science and technology, flood and erosion control and the cross-sectoral issues of public participation.

2) *National Agricultural Policy (5-10 years)*: Within the National Agricultural Policy, there are sub-sectoral policies covering livestock, forestry, food production, and land and



water resources.

3) *National Energy Policy(1987-2010)*: The objectives of this policy is for the promotion of the use of renewable energy resources (wind, water) and improving efficiency of domestic energy utilization as well as minimizing and mitigating harmful practice of extracting energy from woods (plants).

4) *National Forestry Policy and Action Plan (1987-1998)*: It is a framework for halting deforestation and associated destructive impacts. Among its objectives are: protection of forest resources, achieving 25% forest coverage in Nigeria and sustainable utilization of forest products.

5) *National Environmental Action Plan and State Environmental Action Plans*: The policies, plans and programs include: overall protection of the Nigerian environment, promotion of renewable energy technologies, conservation of threatened flora and fauna species, environmental education and awareness creation and reduction of resource use conflict among land users.

6) *National Conservation Strategy (5-10 years)*: The aim is to manage the ecosystems in such a way that they yield greatest sustainable benefit to present generations while maintaining the potential to meet the needs and aspirations of future generations in such a way that essential ecological processes and life support systems are maintained.

7) *Natural Resources Conservation Action Plan (2005-date)*: This plan aims at collating and evaluating data and knowledge on natural resources with a view to developing programs of action for management and sustainable use.

8) *National Water Resources Master Plan (1995-2020)*: The Master Plan aims at sustainable utilization of water resources, particularly in the semi-arid zone of the country.

9) *National Biodiversity Strategy and Action Plan (2005-2010)*: The goals and objectives are to conserve and enhance the sustainable use of the nation's biodiversity resources and to integrate biodiversity-planning considerations into national policy and decision making and the Green Agenda of the Vision 2010.

10) *National Agenda 21*: This is essentially designed to integrate environment and development, which seeks to attain sustainable development. Its main focus is on how to redress the major existing environmental problems.

11) *National Action Program to Combat Desertification (1998-2000)*: This National Action Program (NAP) is a report that spells out critical activities to be taken in a holistic manner to tackle the menace of desertification of the country.

12) *National Economic Empowerment and Development Strategy (NEEDS)*: NEEDS focuses on four key strategies: reorienting values, reducing poverty, creating wealth, and generating employment.

#### VIII. INSTITUTIONAL AND LEGISLATIVE FRAMEWORK

Several institutional arrangements have been put in place in the country for management of matters relating to desertification. Some of the institutions are policy making bodies while some are actually involved in implementation of

deliberate government policies and projects to prevent and mitigate the menace of desertification. Among these are

1) *Federal Ministry of Environment*: The ministry is charged with responsibilities on environmental protection, biodiversity and natural resources conservation including policy matters relating to desertification control and is in fact the National Focal Point for the Convention to Combat Desertification in Nigeria.

2) *Federal Ministry of Agriculture*: Federal Department of Forestry in the Ministry has the responsibility for forestry matters including implementation of afforestation programs and projects as a means of checking the menace of desert encroachment in the country.

3) *Federal Ministry of Water Resources and Rural Development*: The Ministry is responsible the management of water resources generally in the country since water is very crucial to the phenomenon of desertification.

4) *Federal Ministry of Science and Technology*: In this ministry, Energy Commission of Nigeria is handling all the issues related to combating drought and desertification and the ministry also has two research centers conducting research on the alternative source of energy for the country.

5) *States Environmental Protection Agency (SEPA)*: In each of the 36 States and the Federal Capital Territory, there is a State Environmental Protection Agency (SEPA) charged with the responsibility of protection of the environment and biodiversity conservation.

#### IX. ONGOING PROGRAMS AND ASSESSMENT OF THEIR SUCCESS

There are some ongoing and planned interventions that are geared towards desertification control in Nigeria. These are measures to alleviate poverty, conserve biodiversity, restore degraded lands, and promote desertification awareness activities and environmental education programs. Other measures include the development of an environmental information system, conducting research and surveys, promoting energy efficiency and renewable energy technologies, institutional strengthening and capacity building measures. The Federal Government of Nigeria has approved the following projects for implementation:

1) *The Greenbelt Project*: The Greenbelt Project is an integrated and participatory scheme with the following components: nursery development, poverty reduction, promotion of livelihood, watershed management, rural water supply, micro-credit facility, eco-tourism, rural energy, biodiversity conservation, environmental education and awareness creation, capacity building and research.

2) *Model Village Development (Integrated, Community-based Approach)*: Fourteen communities spread over the eleven desertification frontline states have been selected for this project, which is now being implemented. The project is estimated to cost about five hundred and fifty million naira (equivalent to US \$4.0 m).

3) *Pilot Project on Sand-dune Fixation*: This pilot project is being implemented to raise awareness level and demonstrate

the appropriate technologies for sand-dune fixation for adoption by the communities.

4) *Pilot Project on Rangelands*: This project is designed to demonstrate to communities in the dry-land of Nigeria technologies for establishing rangelands in order to improve the carrying capacity of the land for livestock, particularly cattle, goats and sheep that have been implicated in land degradation.

5) *Development of National Drought Forecasting and Early Warning System*: The capacity to predict the occurrence of drought will no doubt facilitate timely development of early warning systems for effective adoption of appropriate mitigation measures.

6) *Assessment and Preparation of Desertification Map for Nigeria*: A major output of the project will be the production of National Desertification Map using satellite imagery and GIS. This is of course in addition to yielding credible data on the extent, severity and rate of desertification in Nigeria.

7) *Nigeria-Niger Trans-boundary Ecosystem Management Project*: Integrated Ecosystem Management of Trans-boundary Areas between Nigeria and Niger is a global environment facility (GEF) funded project aimed at creating conditions for sustainable integrated ecosystem management and thereby improve livelihoods in areas covered by the Maiduguri Agreement between the two countries.

8) *Nigeria-Japan (JICA) Master Plan for Utilization of Solar Energy in Nigeria*: A master plan study for utilization of solar energy in Nigeria currently ongoing by the Japan International Cooperation Agency from June of 2005 in collaboration with the Energy Commission of Nigeria, Federal Ministry of Power and Steel, and the National Planning Commission

9) *UNIDO-Energy Commission of Nigeria Small Hydro Power (SHP) Program*: Energy commission of Nigeria (ECN), with the assistance of the United Nations Industrial Development Organization (UNIDO), is carrying out activities in the area of small hydropower.

In spite of the various efforts/programs discussed above, desertification continues to be a serious problem in the dry-land of Nigeria. The findings of the study point to various weaknesses in the formulation as well as the implementation of some of these programs. These include adoption of the top-down approach that limits consultation between and among the various stakeholders, inconsistency of government policies, neglect of indigenous knowledge, use of inappropriate technology, sectoral approach, inadequate funding, inadequate awareness and rural poverty which compels the people to rely heavily and unsustainably on the environment. Elaboration on some of the weaknesses is given below:

1) *Government Top-down Approach*: Environmental conservation strategies in Nigeria have been top-down, with limited consultation between and among the various stakeholders. Such strategies usually turn out to be at variance with the basic needs of the people. Resource users and other stakeholders commonly have no access to the decision-making

process of the decisions that directly affect them and their resources. The report of the Federal Ministry of Environment and NGOs campaigns across the nation, show that government policies have been top-down approach [14].

2) *Frequent Policy Shifts*: Efforts to combat desertification have been adversely affected by frequent shifts in policy by the government. Such policy shifts have been observed to be as frequently as leader's come-and-go and such shifts are dictated by the country's economic fortune or misfortune. Most of the programs examined in the previous part have been affected by these changes. A good example is the River Basin Development Authorities (RBDAs), which was an attempt to develop the country's water resources for multi-purpose use to combat desertification as well as mitigate the negative consequences of drought in this zone. The RBDAs have since the 1970s witnessed a number of policy shifts and the bodies have undergone a number of reorganization exercises. Thus RBDAs expanded from 3 in 1973 to 11 in 1976 and to 18 in 1984, and then scaled down back to 11 in 1986 following the economic reforms of the early 1980s, which culminated to the adoption of the structural adjustment program (SAP). Another example of such shift is the reorganization of some federal ministries like The Federal Ministry of Agriculture. The ministry was originally The Federal Ministry of Agriculture, Water Resources and Rural Development before 1999 and then in 2000 it was separated from the water resources and rural development before returning to its original form in 2006.

3) *Use of Inappropriate Technology*: The Nigerian Government's response to the Sudano-Sahelian droughts of 1972-74 and the accompanying ecological and human disasters was the adoption of medium and large scale irrigation. However, this has exacerbated rather than ameliorated the hazards of desertification and drought in Nigeria as it has increased income inequality as well as access inequality to the productive resources, according to the report of national action program to combat desertification in 2005 cited in [14]. Technological manipulation of the environment in the form of irrigation often produces new hazards such as salinity, water-borne diseases, weed infestation, and accentuates animal, human and plant diseases. In Nigeria, construction of upstream dams has meant loss of productive base as well as productivity for the down streamers as witnessed by the construction of the Tiga dam in Kano that is now depriving the water users in Hadejia of access to water. Also, in the South Chad Irrigation Project uncontrolled land clearing has exposed much of the area to intense desertification process which is worsened by the recession of the lake [14].

4) *Neglect of Indigenous Knowledge (IK)*: A major lesson from the previous efforts is the lack of incorporation of indigenous knowledge poses a serious problem to adaptation of recommended amelioration measures by the people [11]. Farmers and herders in the dry-land of Nigeria have always existed in a precarious balance with the harsh and inhospitable environment, dominated by risk and uncertainty. There have

evolved over the years some traditional response mechanisms of coping with such risk and uncertainty in managing the environment. Indigenous knowledge should complement modern scientific knowledge as these two approaches may work well to improve the well being of Nigerians in the affected areas.

5) *Sectoral Approach*: Another lesson to be learned from past efforts is that the sectoral approach adopted has not been able to tackle the multidimensional problem of desertification. This approach has often meant that the relevant ministries and agencies have been operating in compartmentalized fashion. There is also a high degree of overlapping and duplication of efforts as a result of lack of effective coordination at all levels. An institutional approach towards comprehensively addressing these environmental problems in Nigeria should adopt the proposal draws largely on the model developed by [2].

6: *Inadequate Funding*: The magnitude of desertification problem in Nigeria requires funds that are far in excess of what is currently allocated by government. This has meant that the fund allocated so far has not been able to have any significant impact in combating desertification. Funding of projects in Nigeria are constrained by the following issues; inadequate funding and timely release of such funds, lukewarm approach to obtaining financial assistants from national and international bodies, and unfavorable and inappropriate prioritization of financing drought and desertification related programs.

## X. CONCLUSIONS

This paper has highlighted the gap in policy formulation and strategies in combating drought and desertification in Nigeria, especially the treatment of desertification concern as a sectoral issue rather than an integrated, holistic issue having relevance with other sectors. The paper has also noted the inability of the government to provide adequate funds for desertification control and has emphasized the need for the review and streamlining of legislations targeted at arresting the spread of desert conditions in the country. Finally, the paper has also emphasized that national policy for drought and desertification should ensure sustainable development, based on proper management of human-environment interactions in the affected areas. Such a policy must balance environmental issues within the society-environmental systems in the areas. This requires that a number of complementary policies, strategies and management approaches be put in place and such strategies, policies and management approaches must take cognizance of the existing institutional settings and professional groupings as well as the complex historical, social, cultural, and legal considerations. Such policy in particular, must aim at providing a rational, practicable and comprehensive approach for finding solutions to the problems of drought and desertification.

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# Incidence of trace metals of health importance in river water utilised for domestic activities by informal settlers in South Africa

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## ABSTRACT

**Incidence of trace metals (Cd, Pb, Mn, Zn, Cu and Ni) of toxicological potential in water and sediment from the Reitvlei River in Pretoria, South Africa was investigated. The river, whose water quality has not been previously established, was visibly plagued with illegal solid waste dumps. Total trace metal digestion by mineral acids in water and sediment samples and analyses by Inductively Coupled Plasma-Atomic Emission Spectrometry was carried out. The mean concentration of analysed trace metals in water samples ranged from Cd: trace –  $0.01 \pm 0.003$  mg/l; Pb: trace –  $0.01 \pm 0.002$  mg/l; Mn:  $2.30 \pm 0.07$  –  $15.0 \pm 0.05$  mg/l; Zn:  $0.09 \pm 0.005$  –  $2.11 \pm 0.02$  mg/l; Cu:  $0.15 \pm 0.006$  –  $0.57 \pm 0.005$  mg/l and Ni:  $0.03 \pm 0.002$  –  $0.22 \pm 0.004$  mg/l. Also, the mean levels of the metals in sediment samples varied between Cd: trace –  $0.05 \pm 0.004$  µg/g; Pb: trace –  $0.05 \pm 0.002$  µg/g; Mn:  $5.82 \pm 0.04$  –  $33.4 \pm 0.17$  µg/g; Zn:  $0.26 \pm 0.003$  –  $2.54 \pm 0.07$  µg/g; Cu:  $0.08 \pm 0.002$  –  $2.83 \pm 0.06$  µg/g and Ni:  $0.12 \pm 0.007$  –  $0.48 \pm 0.02$  µg/g. Metallic load in sediment samples were in most cases, higher than those in corresponding water samples. Above safety limits of some metals such as Cd and Pb were obtained which has dire consequences across the food chain.**

Keywords: Prevalence; surface water, trace metals; informal settlers; Reitvlei River; South Africa

## I. INTRODUCTION

The importance of ground and surface waters in the lives of many rural dwellers in developing countries, including South Africa, cannot be overemphasized. Therefore, it is imperative that the quality of such water systems be evaluated and monitored regularly. Although the influence of natural factors such as the weathering of rocks, erosional processes and variable precipitation on the quality of the stream cannot be ruled out, influence from anthropogenic factors are by far the most predominant [1]. Anthropogenic factors such as run-offs from agricultural activities, discharges from domestic and industrial waste treatment plants, contamination from improperly managed landfill sites, illegal dumping of waste on land and into the water systems are among the major sources of concern of human factors on the quality of ground and surface waters.

Issues of water safety, conservation and protection are of priority to the national government of South Africa, but more particularly to the Gauteng Provincial Government due to the geographical location of this province in the country. The low cost housing project embarked upon by the national government is far away to its target; hence many people are living in vacant land across the country generally referred to as “informal settlements”. There is often no supply of basic amenities in these settlements; hence dependence mostly on surface water within close proximity to the settlement for several activities including drinking. They also make use of the river water for the irrigation of small farmlands and drinking by their livestock. It could be said that the chemical status and to a large extent, the quality of surface water would reflect on the users. For instance, if the water is contaminated, it might possibly contaminate the produce cultivated on such land. An earlier study has revealed the influence of surface water on the metallic load of agricultural soil and its produce [2].

Several toxic metals such as lead (Pb), cadmium (Cd), nickel (Ni) and arsenic (As) which are important to environmental and human health, have been detected in aquatic media. These toxic metals are continually monitored due to their health implications since they are non-essential metals and are of no benefit to humans. The presence of these metals in the aquatic ecosystem has far-reaching implications directly to the biota and indirectly to man. Cd is of environmental and human health concern due to its carcinogenic and endocrine disrupting effects in humans [3]. It accumulates mainly in the kidney and liver and high concentrations have been found to lead to chronic kidneys dysfunction. It induces cell injury and death by interfering with calcium (Ca) regulation in biological systems. It has been found to be toxic to fish and other aquatic organisms [4].

Apart from the health implication, the metal (Cd), together with other elements such as zinc (Zn), form a toxic “soup”

that often acts synergistically. Sources of Cd include wastes from Cd-based batteries, incinerators and runoff from agricultural soils where phosphate fertilisers are used, since Cd is a common impurity in phosphate fertilizers [5]. Lead (Pb), another toxic metal, has been found to be responsible for quite a number of ailments in humans such as chronic neurological disorders found especially in foetuses and children. Sources in aquatic systems include used dry-cell batteries, sewage effluent, runoff of wastes and atmospheric deposition. Although, Zn has been found to have low toxicity to man, prolonged consumption of large doses can result in health complications such as fatigue, dizziness, and neutropenia [6].

Copper (Cu) is classified as essential to life due to its involvement in certain physiological processes. However, acute toxicity of copper resulting in human death [7] as well as toxicity to fish has been reported [8]. Nickel is a naturally occurring element found in a number of mineral ores including Ni sulphides, oxides and silicates. It is present in the enzyme urease and as such is considered to be essential to plants and some domestic animals. However, this metal has also been found to be toxic and their accumulation in the environment may constitute serious health hazard to the health of human and aquatic organisms. Among the known health related effects of nickel are skin allergies, lung fibrosis, variable degrees of kidney and cardiovascular system poisoning and stimulation of neoplastic transformation. All nickel compounds except for metallic nickel were classified as carcinogenic to humans [9]. Toxicity of Ni to rainbow trout have also been reported [10]. While water is a medium commonly used to assess the level of several aquatic pollutants including trace metals, sediment can also provide a deeper insight into the long-term state of pollution of the water-body. Sediment has been described as a ready "sink" or reservoir of pollutants including trace metals where they concentrate according to the level of pollution [11]. The need to evaluate the quality of water from Reitvlei River and assess possible influence on various activities to which the river is applied and utilised becomes paramount in view of the health implications that cut across the food strata. The quality of sediment from the water channels in terms of its metallic load would also be assessed.

The research work on which this article is based reports the level of trace metals of toxicological potential (Cd, Pb, Mn, Zn, Cu and Ni) in water and sediment samples from Reitvlei river in Pretoria, South Africa. This river, which was visibly plagued with illegal dumping of various solid wastes could contribute to or affect the quality of the river water. Informal settlers (people living in wooden/iron make shift shacks erected on government or private land) along this river utilise the river water for domestic purposes including

drinking. Information search revealed the absence of water quality data on the river; hence preliminary results from the study will show the need for governmental intervention in terms of the provision of safe drinking water and shelter for affected people. In addition, the metallic load of the sediment and some physico-chemical parameters of the water were also assessed.

## II METHODOLOGY

### *Sampling and sample treatment*

The locations of the four sampling sites were: S1 = downstream (S 26° 02m' 24.1s; E 27° 43m' 15.8s); S2 = Mid-stream (S 26° 00m' 32.4s; E 27° 44m' 02.0s) S3 = upstream (S 25° 58m' 53.5s; E 27° 47m' 17.1s) and S4 = (S 26° 06m' 27.4s; E 27° 43m' 20.5s). Grab samples were collected from the four sampling points along the river channel with approximate between 1-2 km distances between each sampling point. Each grab sample consisted of 1 l of the surface water taken from the river bank, which was approximately 500 m from the highway. Both samples were collected into 1-l Nalgene plastic containers which were thoroughly washed with detergent, rinsed with water and then with distilled water before soaking in 5% HNO<sub>3</sub> for about 24 h. Containers were finally rinsed with double distilled water before use. Water samples were kept cooled en route to the laboratory and stored at 4°C while sediment samples were kept frozen at -18°C until analysed. Treatment and analysis of samples usually took place within 24 h of collection. Sediment samples were allowed to defrost; air-dried in a circulating oven at 30°C and thereafter sieved mechanically using a 2 mm sieve. All determinations were based on the fine sediment particles obtained, since metals are known to adhere to these fine particles.

### *Physical parameters*

The temperature, pH and electrical conductivity (E.C) of water samples were determined directly on site, immediately after collection using unfiltered sample. pH meter 330 and conductivity meter supplied by Merck NT Laboratory (Pty) Ltd and Hanna Inc respectively were employed in the determinations. Water samples were preserved after physico-chemical analyses on site with 5 ml of concentrated HNO<sub>3</sub>.

### *Limits of detection, quality assurance and sample analyses*

Limits of detection of the analysed metals were determined as thrice the standard deviation (3σ) of their lowest detectable concentrations from the mean of six replicate analyses. Good linearity was obtained from the calibration curves prepared from 1 000 mg/l of each metal standard from BDH laboratory, England. Digestion protocols for water and sediment samples as previously described were applied [2]. Quality assurance was by standard metal additions to double-distilled water and pre-digested sediment samples.

TABLE I

Metals	Detection limits (mg/l) and *mean % recoveries ( $\pm$ SD) of trace metal standards added to double-distilled water and pre-digested sediment			
	Detection limits	Spiked concs.	Recoveries	
			Water	Sediment
Cd	0.002	0.05	95.7 $\pm$ 0.002	91.2 $\pm$ 0.004
Pb	0.004	0.05	92.3 $\pm$ 0.002	82.7 $\pm$ 0.005
Mn	0.004	5.0	90.5 $\pm$ 0.004	90.3 $\pm$ 0.001
Zn	0.005	5.0	87.8 $\pm$ 0.001	84.0 $\pm$ 0.002
Cu	0.003	5.0	95.5 $\pm$ 0.003	86.5 $\pm$ 0.003
Ni	0.005	5.0	96.4 $\pm$ 0.005	85.6 $\pm$ 0.003

DL = Detection limit, \*Values are mean of triplicate analyses

This was at the fortification level of 0.05 mg/l for Cd and Pb; and 5.0 mg/l for Mn, Zn, Cu, and Ni. Triplicate digestion of each sample together with the blank was carried out. The quality assurances for water and sediment gave high and acceptable recoveries and were applied to the analyses of environmental samples.

#### Analysis of samples

The mineral acid digestion protocols were applied for the chemical analysis of water and sediment samples since the quality assurance of both protocols gave high and acceptable recoveries and reproducibility. Three replicate digestions were carried out for each sample.

### III RESULTS AND DISCUSSION

#### Metals quality assurance and detection limits

Result of the limits of detection of analysed metals and their percentage recoveries from spiked double-distilled water and pre-digested sediment with metal standards are presented in Table I. Percentage recoveries from spiked double-distilled water ranged from 87.8  $\pm$  0.001 to 96.4  $\pm$  0.005 while those of the pre-digested sediment varied between 82.7  $\pm$  0.005 and 91.2  $\pm$  0.004. Good instrumental detection limits were obtained and recoveries from spiked samples were quite appreciable. This was an indication of the applicability of the method used in the analyses of water and sediment samples.

#### Physico-chemical parameters

Results of some physico-chemical parameters determined in water samples are as shown in Table II. The pH, electrical conductivity, (E.C) and the temperature of sampled water across the four periods of collection ranged from 6.10 – 8.30; 380 - 820  $\mu$ S $\text{cm}^{-1}$  and 18 - 25 $^{\circ}$ C respectively. The hydrogen ion concentration level (6.10 – 8.30) of water samples as indicated by the pH were within the Target Water Quality Range (TWQR) of 6 to 9 for pH in water intended for domestic use [12] and also within 6.5 – 8.5 recommended by United States Environmental Protection Agency (USEPA) for water intended for drinking purposes [13]. Water acidity is known to influence the solubility, availability and toxicity of metals in the aquatic ecosystems. No harmful effect is

expected for consuming this water with respect to pH. E.C gives a measure of water conductivity as well as an indication of the level of inorganic constituents in water. Typical conductivity values recommended for drinking water ranged from 50 to 1500  $\mu$ S $\text{cm}^{-1}$  [14]. All samples were within the recommended range; hence no detrimental health effect is expected. Values for water temperature obtained were within the Council of European Community (CEC), recommendation of 25 $^{\circ}$ C for water intended for drinking purposes [15]. Temperature is known to influence water chemistry and the toxicity of metals. Generally, the colour of water samples appeared cloudy during sampling with those from informal settlement appearing slightly brownish.

#### Trace metals in water and sediment

The level of trace metals in the river water and sediment at various sampling periods are presented in Figs 1-4. The mean concentrations of Cd in river water ranged from trace (S1, S2, S3) – 0.01  $\pm$  0.003 mg/l (S3) while those in sediment varied between trace (S1, S2) – 0.05  $\pm$  0.004  $\mu$ g/g (S3) for all sampled periods. The metal was below detection limit in over 60 % of all samples (water and sediment) across the periods of collection. However, more detection was recorded in sediment samples than in water across the sites. Concentrations of Cd obtained in water samples from this study were higher than the TWQR guideline of 0 – 0.005 mg/l in river water for domestic use [12] and also higher than 0.005 mg/l as the maximum contaminant level (MCL) specified by [13]. The values were also higher than the South African TWQR of 0 – 0.01 mg/l recommended for irrigation and livestock watering [16]. This showed that water from the stream is unsuitable for these activities with regard to the value obtained in this study.

If water from this river were to be used for irrigation, the metals could bioaccumulate in consumers of produce from the farmland resulting in detrimental health effects.

TABLE II

Some physico-chemical parameters analysed in river water samples					
Sampli ng sites	Dates	pH	E.C ( $\mu$ S $\text{cm}^{-1}$ )	Temp ( $^{\circ}$ C)	Appearance
S1	7/9/06	7.14	620	20	Slightly cloudy
S2	..	8.30	820	23	Cloudy
S1	6/10/06	6.10	740	25	Clear
S2	..	6.79	570	18	Cloudy
S1	9/11/06	7.25	650	23	Cloudy
S2	..	6.52	590	22	Cloudy
S3	..	6.79	740	21	Slightly cloudy
S1	05/01/07	7.09	380	20	Slightly cloudy
S2	..	6.74	640	20	Cloudy
S3	..	6.36	720	24	Slightly brown

S1 = Up stream; S2 = Down stream; S3 =Mid-stream sampling point (informal settlement)

For example, bioaccumulation of Cd could occur in livestock that drink this water and in ruminates that feed on grasses irrigated with the water. However, the level of the metal was below instrumental detection limit in some water and sediment samples (S2 and S3). Higher levels of Cd (0.01 – 0.26 mg/l) in South African water systems had been previously reported [17]. The higher level of Cd obtained in some sediment samples (S1 and S3) relative to that in water samples might be due to the fact that metals are generally known to bind to organic matter in accumulated sediment under aquatic ecosystems. Apart from natural sources, other probable sources of this metal in the water include leaching from Ni-Cd based batter wastes [18], runoff from agricultural soils where phosphate fertilizers are used and other metal wastes [5].

Concentration of Pb obtained in water samples varied between trace (S1, S2) –  $0.01 \pm 0.002$  mg/l (S1, S3) while that in sediment ranged from trace (S2) –  $0.05 \pm 0.002$   $\mu$ g/g (S3). More detection of Pb was also obtained in sediments than in water samples, hence sediment is usually referred to as “sink” for pollutants including trace metals. Various solid wastes including dry-cell batteries that were observed at the river mouth could contribute to the higher value of Pb obtained from sediment at site S3. The TWQR for Pb in river water for domestic use is 0 – 0.01 mg/l [12]. 0.11 mg/l in water samples were obtained at sites S1 and S3. This upper range of the limit could be interpreted as making the water unsuitable for domestic use. Continual consumption of this river water with respect to Pb could result in long-term health problems. Chronic exposure to Pb has been linked to growth retardation in children [19]. Levels of Pb > 0.1 mg/l have been reported to be detrimental to foetuses and children, with possible development of neurological problems. Pb toxicity studies conducted on female mice revealed mostly miscarriages, premature delivery and infant mortality [20].

TWQR of 0 – 0.2 mg/l and 0.1 mg/l has been set for Pb in river water for use in irrigation and livestock watering respectively [16]. Levels of Pb in water samples obtained in this study were lower than these ranges, with the exception of values of 0.10 and 0.12 mg/l obtained in sediment at sites S1 and S2 respectively. The possibility that the level of this metal in water samples could become higher than the limit is most probable due to various dynamic influences and interactions of water chemistry and the sediment core. For example, lower water pH can influence metal bioavailability from sediment. The water was not noticeably used for recreational purposes because of the aesthetic state.

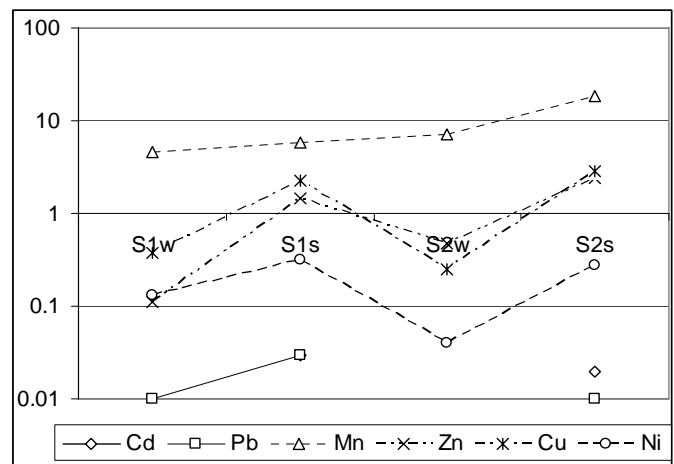


Fig 1: Logarithm plot of the concentration of trace metals in river water (mg/l) and sediment ( $\mu$ g/g) during 7/09/2007; S1 = Up stream; S2 = Down stream sampling point; S3 = Mid-stream (informal settlement); w and s are water and sediment samples respectively.

Level of Mn obtained in river water across the period of sampling varied from  $2.30 \pm 0.07$  (S2) –  $15.0 \pm 0.05$  mg/l (S3) and  $5.82 \pm 0.04$  (S1) –  $33.4 \pm 0.17$   $\mu$ g/g (S3) in sediment respectively. Mn was detected in all the samples. The World Health Organization (WHO) recommended 0.5 mg/l as the provisional health-based guideline for Mn in water for domestic use [21] while 0.05 mg/l limit was specified by USEPA [13]. The level obtained in this study for both water and sediment samples were much higher than these limits, hence the water is highly unsuitable to be used for domestic purposes. Although Mn is considered to be an essential element, an excess amount in the body can cause damage to the brain, liver, kidney and to a developing foetus [22].

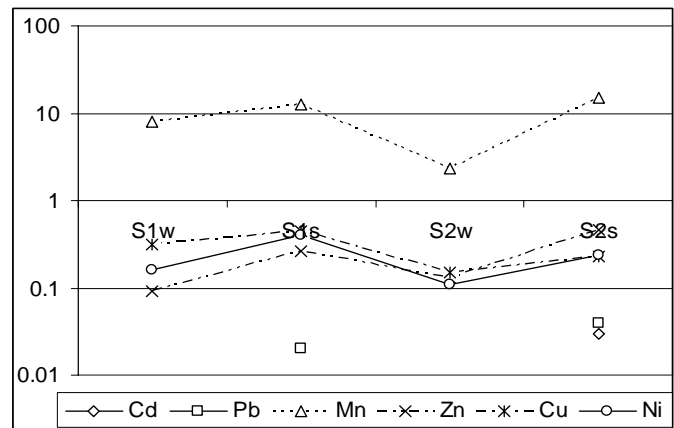


Fig 2: Logarithm plot of the concentration of trace metals in river water (mg/l) and sediment ( $\mu$ g/g) during 6/10/2007; S1 = Up stream; S2 = Down stream sampling point; S3 = Mid-stream (informal settlement); w and s are water and sediment samples respectively.



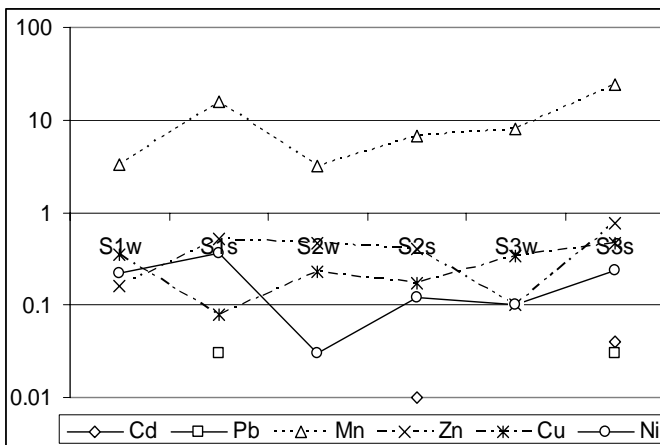


Fig 3: Logarithm plot of the concentration of trace metals in river water (mg/l) and sediment ( $\mu\text{g/g}$ ) during 5/11/2007; S1 = Up stream; S2 = Down stream sampling point; S3 = Mid-stream (informal settlement); w and s are water and sediment samples respectively.

Zn concentration ranges were  $0.09 \pm 0.005$  (S1) -  $2.11 \pm 0.02$  mg/l (S1) and  $0.26 \pm 0.003$  (S1) -  $2.54 \pm 0.07$   $\mu\text{g/g}$  (S1) for water and sediment samples respectively. The TWQR for Zn in water for domestic use is 3.0 mg/l [12]; hence no detrimental effects from domestic water usage could be expected if the water is utilised for domestic purposes. Levels of copper in water and sediment samples were from  $0.15 \pm 0.006$  (S2) -  $0.57 \pm 0.001$  mg/l (S2) and  $0.08 \pm 0.001$  -  $2.83 \pm 0.06$   $\mu\text{g/g}$  (S2) respectively. This metal was also detected in all analysed samples. The South African TWQR guideline for Cu in domestic water supply is 0 to 1.0 mg/l [12]. The range obtained in this study was lower than the set value; hence adverse effects from domestic use are not expected).

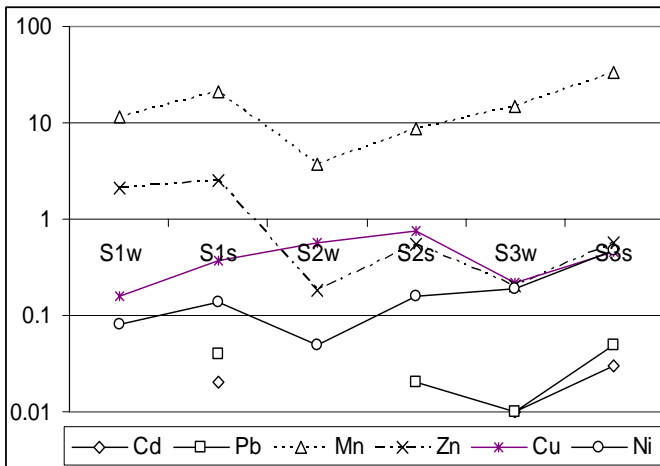


Fig 4: Logarithm plot of the concentration of trace metals in river water (mg/l) and sediment ( $\mu\text{g/g}$ ) during 25/01/2007; S1 = Up stream; S2 = Down stream sampling point; S3 = Mid-stream (informal settlement); w and s are water and sediment samples respectively.

The level of Ni varied between  $0.04 \pm 0.003$  (S2) -  $0.22 \pm 0.004$  mg/l (S1) in water samples and from  $0.12 \pm 0.007$  (S2) -  $0.48 \pm 0.02$   $\mu\text{g/g}$  (S3) in sediment samples. Attention has been focused lately on the toxicity of Ni in low concentrations. For instance, it has been shown that Ni can cause allergic reactions and that certain Ni compounds may be carcinogenic [23]. Typical concentrations of Ni in unpolluted surface water were given as  $5.0 \times 10^{-4}$  mg/l [24] and 0.015 to 0.020 mg/l [25]. The range obtained in this study was much higher than the above limits, indicating that the water is contaminated with this metal. All Ni compounds except for metallic Ni have been classified as carcinogenic to humans [9]. Possible sources of Ni in the surface water are mostly anthropogenic sources including old battery wastes, components of automobiles, old coins and other Ni alloys. Among the known health-related effects of Ni are skin allergies, lung fibrosis, variable degrees of kidney and cardiovascular system poisoning and the stimulation of neoplastic transformation.

Results obtained from the determination of trace metals in water and sediment samples were subjected to the Pearson Moment Correlation Coefficient. This was to check possible relationship between the analysed metals in both samples. From Fig 4, good correlations ( $r = 0.97$  and  $r = 0.98$ ) were obtained between Mn and Pb as well as Zn and Cu respectively in water samples. Also in sediment, good correlation ( $r = 0.99$ ) was recorded between Cd and Cu while Pb and Ni was poorly correlated ( $r = 0.82$ ), also from Fig 4. The various correlations obtained between analysed metals in both water and sediment samples showed common sources of the metals.

## CONCLUSIONS

The importance of regular assessment of the level of pollution and monitoring the quality of environmental waters especially surface waters cannot be overemphasized. This becomes more important if the water body is used for domestic, agricultural and recreational purposes. The detection of toxic metals such as Cd and Pb above safety limits for water intended for irrigational purposes gave cause for concern because ruminants that feed on grasses irrigated with this water might be at risk of bioaccumulating the toxic metals. This risk could be passed up the food chain. People that are without access to potable water, such as homeless, informal settlers and those that live in remote areas depend on surface and ground waters for their sustenance. Hence, governmental departments that are responsible for the provision of potable and safe drinking water should be alive to their responsibilities.

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## **CONFERENCE DIVISION:**

Geographic Information Systems (GIS), Remote Sensing  
& Surveying

# Investigation on the Impact of Tropospheric Delay on GPS Height Variation near the Equator

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**Abstract**—One of the major problems currently facing satellite-based positioning is the atmospheric refraction of the GPS signal caused by the troposphere. The tropospheric effect is much more pronounced at the equatorial region due to its hot and wet conditions. This significantly affects the GPS signal due to the variability of the refractive index, which in turn affects the accuracy of GPS positioning, especially in the height components. This paper presents a study conducted in Malaysia located at the equatorial region, to investigate the impact of tropospheric delay on GPS height variation. Five GPS reference stations forming part of the Malaysian real-time kinematic GPS network (MyRTKnet) in Johor were used. RINEX data from these stations were integrated with GPS and ground meteorological data observed from a GPS station located at the Universiti Teknologi Malaysia (UTM), at varying antenna heights for each session of observation in four campaigns with each campaign lasting for three days. A computer program called TROPO.exe was developed based on Saastamoinen tropospheric model. The result shows variations in the height component of GPS measurement with a maximum value of 119.100 cm and a minimum value of 37.990 cm. Similarly, the results show that, the tropospheric delay is a distance-dependent error, which varies with changes in meteorological condition. Furthermore, result of simulated data shows decrease in tropospheric delay with increase in antenna height.

**Keywords**— Ground meteorological data, height component, Saastamoinen model, tropospheric delay.

## I. INTRODUCTION

The troposphere is the lower part of the atmosphere close to the Earth's surface; it is 9 km over the poles and 16 km over the equator [7], which extends from the sea to about 50 km [2]. It is considered as a neutral atmosphere, with an index of refraction that varies with altitude. The variability of refractive index causes an excess group delay of the GPS signal usually referred to as *tropospheric delay*. This delay induces variation in GPS positioning and is a matter of great concern to the geodetic community in terms of high accuracy applications. The positioning error due to improper estimation of the tropospheric delay can be over 10 m because; the tropospheric delay can range from 2 m at the zenith to over 20 m at lower elevation angle [1].

There are two classes of tropospheric biases that affect GPS measurement; there are those that influence the height component and others affecting the scale having significance in terms of positional accuracy [4].

The tropospheric delay consists of the hydrostatic component, also known as the *dry part* and the non-hydrostatic component, also known as the *wet part*. Several researchers have made attempts to model the tropospheric delay. The most widely use expression for tropospheric refractivity  $N$  is [3] and given by the expression:

$$N = 77.6 \frac{P}{T} + 3.73 \times 10^5 \left( \frac{e}{T^2} \right) \quad (1)$$

where:

$P$ , the total atmospheric pressure in mbar;  $T$ , temperature in Kelvin;  $e$ , partial pressure of water vapour in mbar. [9] asserts that, the hydrostatic contributes approximately 90% of the total tropospheric delay. Nevertheless, the hydrostatic part can be computed from pressure measured at the receiver antenna. It is given by the expression:

$$D_{dz}^{trop} = (77.62) \frac{P}{T} \quad (2)$$

where  $D_{dz}^{trop}$  is the hydrostatic tropospheric delay at given angle from the zenith. The wet component only accounts for 10% of the total tropospheric delay. However, it is more difficult to model due to the diversity of the water vapour distribution. As a result of this, error in the wet component contributes the most significant factor of the signal refraction. It is given by the expression:

$$D_{wz}^{trop} = -(12.96) \frac{e}{T} + (3.718 \times 10^5) \frac{e}{T^2} \quad (3)$$

where  $D_{wz}^{trop}$  is the wet tropospheric delay at given angle from zenith.

There are two basic types of models for estimating the tropospheric delay. The first relates the meteorological parameters in (1) to surface meteorological measurements. These surface meteorological models are based on radiosonde profiles measurements taken at the ground surface. Examples include the Hopfield tropospheric delay model [5] and the

Saastamoinen tropospheric delay model [6]. The second relates to global standard atmosphere.

The refined Saastamoinen tropospheric model is used in this study. It is expressed in the form [10]:

$$D_z^{trop} = \frac{0.002277}{\cos z} \left[ P + \left( \frac{1255}{T} + 0.05 \right) e - B \tan^2 z \right] + \delta R \quad (4)$$

where:

$D_z^{trop}$ : propagation delay in terms of range (m)

$z$ : zenith angle of the satellite

$P$ : atmospheric pressure at the site in milibar (mbar)

$T$ : temperature at the station in Kelvin (K)

$e$ : partial pressure of water vapour in milibar (mbar)

$B, \delta R$  are the correction terms for height and zenith angle

Based on equation (4),  $e$  is calculated as a fractional of 1 from the relative degree of moisture. It is expressed as [8]:

$$e = 6.108RH \times \exp \left[ \frac{17.15T - 4684}{T - 38.45} \right] \quad (5)$$

where:

$RH$  is the relative humidity. The pressure  $P$  at height above sea level  $h$  (in kilometres) is given in terms of the surface pressure  $P_s$  and temperature  $T$ . Pressure  $P$  can be defined as:

$$P = P_s \left[ \left( \frac{T - 4.5h}{T} \right) \right]^{7.58} \quad (6)$$

## II. FIELD DATA COLLECTION

Static GPS observations using Leica™ System 500 dual frequency receivers and a ground meteorological sensor called Davis GroWeather™ System were set up next to one another at GPS station G11 in UTM. Fig. 1 shows the observation set up.

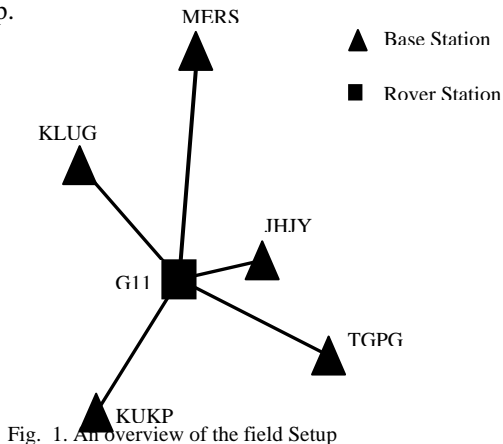


TABLE 1

TIME SCHEDULLING OF FIELD OBSERVATION

GPS Campaigns		1	2	3	4
Observation Period		29–31 Aug 06	01–03 Dec 06	06–08 Jan 07	09–11 Jan 07
9 hours	1st Session (9 am – 12 pm)	Antenna Height : 0.5 m			

2nd Session (12 pm – 3 pm)	Antenna Height : 1.0 m
3rd Session (3 pm – 6 pm)	Antenna Height : 1.5 m

Four GPS campaigns were conducted as shown in Table 1. Series of field observations were carried out for a total of nine hours per day and divided into three sessions of 3 hours each. For each session, the antenna height was increased systematically. Ten minutes interval of ground meteorological data of temperature, pressure, and relative humidity were measured in each session. The procedures were repeated in all the campaigns forming four sets of observation where each set consists of three consecutive days of data collection. Table 1 shows the scheduling of the field observation.

Five GPS reference stations forming MyRTKnet stations in Johor were used as the base stations, thus producing the baselines for processing and analysis. Table 2 shows the description of the selected MyRTKnet stations relative to the rover station G11 located in UTM.

### A. Multi-station Analysis

In order to establish the availability of the GPS satellites during the observation sessions, a Multi-station Analysis is carried out. This allow for checking simultaneous observation of same satellite, satellite elevation and the Dilution of Precision (DOP). Low Geometry Dilution of Precision (GDOP) indicates strong satellite geometry with a higher possibility of accuracy. Tables 3-5 present the GDOP of satellites for the 4<sup>th</sup> campaign between 9<sup>th</sup> and 11<sup>th</sup> January 2007. Good GDOP were obtained between 1500 hours and 1800 hours in all cases. However, best GDOP of 1.67 is obtained on 11<sup>th</sup> January 2007.

TABLE 2

DESCRIPTION OF MYRTKNET STATIONS IN JOHOR

ID	JHIY	KUKP	TGPG	KLUG	MERS
Station	Johor Bahru	Pontian	Pengerang	Mersing	Mersing
Location	SMK Tmn JohorJaya (1)	JPS Bandar Permas	SK Tanjung Pengelih	Pejabat Daerah Kluang	SMK Mersing
Latitude	01° 32' 12.518"	01°19' 59.790"	01° 22' 2.679"	02° 01' 31.361"	02° 27' 12.482"
Longitude	103° 47' 47.510"	103° 27' 12.355"	104° 06' 29.730"	103° 19' 0.521"	103° 49' 43.505"
Ellipsoidal Height (m)	39.1959	15.4282	18.0874	73.5879	18.0812
Distance Relative to G11 (km)	17.9051	32.1902	56.5244	62.7530	101.2633

TABLE 3

MULTISTATION ANALYSIS OF GEOMETRY DILUTION OF PRECISION FOR 9<sup>TH</sup> JAN. 2007

09/01/07	Time	No. GPS Satellite	GDOP
	09:00	6	4.79

	10:00	8	6.76
	11:00	10	2.38
	12:00	9	2.34
	13:00	10	2.26
	14:00	9	2.87
	15:00	9	2.34
	16:00	11	2.41
	17:00	11	2.10
	18:00	12	1.83

TABLE 4  
MULTISTATION ANALYSIS OF GEOMETRY DILUTION OF PRECISION FOR 10<sup>TH</sup> JAN. 2007

10/01/07	Time	No. GPS Satellite	GDOP
	09:00	6	5.01
	10:00	8	6.29
	11:00	10	2.35
	12:00	9	2.35
	13:00	10	2.34
	14:00	9	2.79
	15:00	9	2.36
	16:00	11	2.45
	17:00	11	2.08
18:00	12	1.82	

The elevations of the satellites during the observation periods were determined. Satellites at low elevation angle (in this case below ten degrees) contribute to errors in propagating signals through the atmosphere. Figures 2-4 show satellite elevation plots for the 4<sup>th</sup> campaign. None of the satellite was found below ten degrees cut-off angle.

TABLE 5  
MULTISTATION ANALYSIS OF GEOMETRY DILUTION OF PRECISION FOR 11<sup>TH</sup> JAN. 2007

11/01/07	Time	No. GPS Satellite	GDOP
	09:00	6	5.22
	10:00	8	5.72
	11:00	10	2.32
	12:00	9	2.37
	13:00	10	2.42
	14:00	9	2.71
	15:00	9	2.38
	16:00	11	2.48
	17:00	11	2.06
18:00	13	1.67	

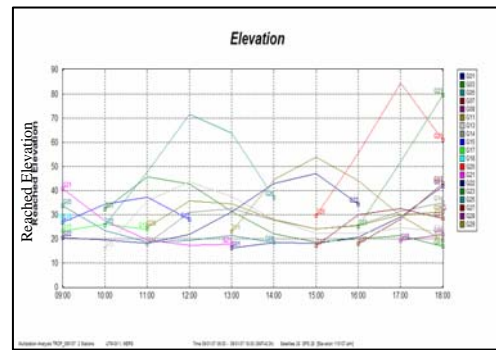


Fig. 2. Satellite Elevation for UTM and MERS on 9<sup>th</sup> Jan. 2007

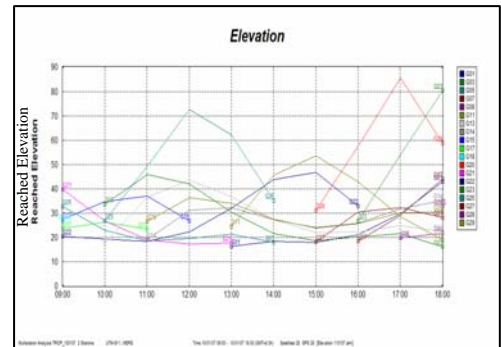


Fig. 3. Satellite Elevation for UTM and MERS 10<sup>th</sup> Jan. 2007

### III. DATA PROCESSING

In order to study the impact of troposphere on height determination, the tropospheric effect has been left uncompensated as no standard tropospheric model was applied during processing. To eliminate the effect of ionosphere, satellite and receiver clock bias, the ionospheric free double difference solution was applied. Multipath effects were assumed to be eliminated entirely by the long hours of observations. Each observation session was 3 hours long. The GPS receivers were calibration and in excellent condition, antenna phase centre variation in this study has also been neglected.

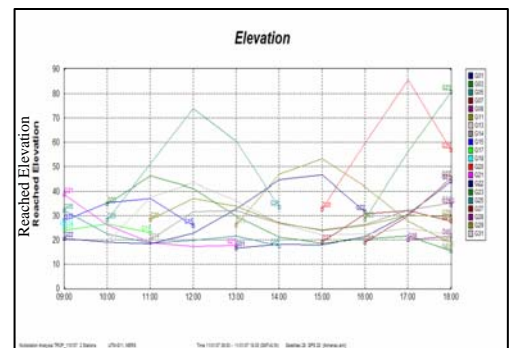


Fig. 4. Satellite Elevation for UTM and MERS on 11<sup>th</sup> Jan. 2007

HORIZONTAL AND VERTICAL COMPONENTS RESIDUAL FOR BROADCAST AND PRECISE EPHEMERIDES

BASELINE	LENGTH (KM)	PRECISE EPHEMERIS			BROADCAST EPHEMERIS		
		NE	EE	UE	NE	EE	UE
UTM - JHJY	17.90	1.35	0.30	0.59	1.35	0.30	0.59
UTM - KUKP	32.19	1.36	0.31	0.58	1.36	0.31	0.58
UTM - TGPG	56.52	1.35	0.29	0.56	1.35	0.29	0.56
UTM - KLUG	62.75	1.35	0.32	0.59	1.35	0.32	0.59
UTM - MERS	101.26	1.37	0.29	0.61	1.56	0.24	0.88

The processing is done at 1 hour interval using the broadcast and precise ephemerides to gauge at what baseline lengths the use of the precise ephemerides becomes worthwhile. The horizontal and vertical components residual for each baseline in each case (i.e. broadcast and precise ephemerides) as a function of the baseline length is presented in Table 6. The 3D error in each case is computed as follows:

$$3D \text{ Error} = \left[ (\Delta E)^2 + (\Delta N)^2 + (\Delta U)^2 \right]^{\frac{1}{2}}$$

where  $\Delta E$ , and  $\Delta N$  are errors in the horizontal component and  $\Delta U$  is the error in the height component. The result is presented in Table 7

From Tables 6 and 7, the precise and broadcast ephemerides 3D error values are virtually identical. The largest difference of 0.286 cm is seen at baseline UTM-MERS. It is evident that, with the current improvement on the broadcast ephemeris, there is no clear benefit to using the precise ephemeris for baselines of less than 100 km. Therefore, as baselines range from only 17 to 100 km in this research, the broadcast ephemeris has been used. Table 8 shows a summary of the processing parameters.

TABLE 7  
OBSERVED 3D ERROR AS A FUNCTION OF BASELINE LENGTH USING 1 HOUR OF DATA

Baseline	Length (km)	3D Error (cm)	
		Precise Ephemeris	Broadcast Ephemeris
UTM - JHJY	17.9051	1.5103	1.5103
UTM - KUKP	32.1902	1.5126	1.5126
UTM - TGPG	56.5244	1.4979	1.4979
UTM - KLUG	62.7530	1.5171	1.5171
UTM - MERS	101.2633	1.5309	1.8169

TABLE 8

SUMMARY OF PROCESSING PARAMETERS USED

Cut-off angle	10°
Orbit Type	IGS Broadcast
Solutions	Ionosphere-free double difference fixed
Tropospheric Models	None

IV. ANALYSIS OF RESULTS

A. Tropospheric Effect on the Ellipsoidal heights

Residuals in the computed ellipsoidal height at G11 of four sets of field observation compared to the known value were calculated first. As mentioned earlier, in this process, tropospheric effects have been left uncompensated. To visualize the variation on the height component of GPS measurement due to the tropospheric delay, discrepancies of ellipsoidal height between computed and known value for each baseline in the four campaigns have been plotted against each hour of observation as shown in Figures 5-16.

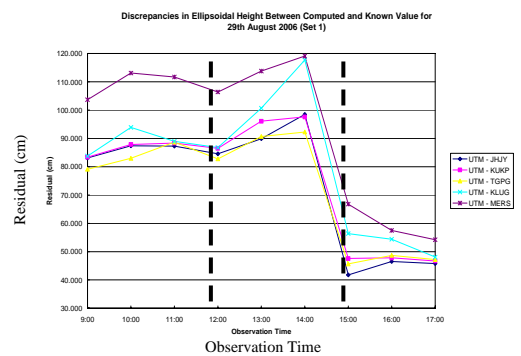


Fig. 5. Discrepancies of Ellipsoidal Height Between Computed and Known Value of 1<sup>st</sup> Campaign of 29<sup>th</sup> August 2006

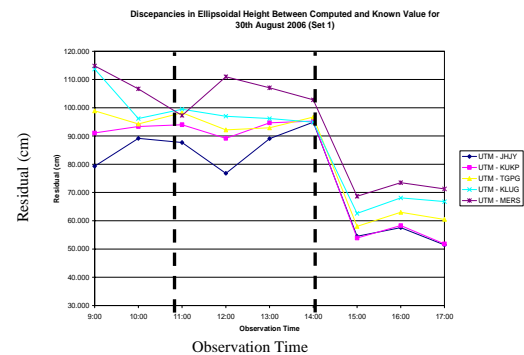
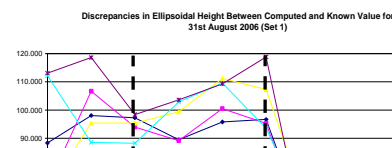


Fig. 6. Discrepancies of Ellipsoidal Height Between Computed and Known Value of 1<sup>st</sup> Campaign of 30<sup>th</sup> August 2006





Residual (cm)

Observation Time

Fig. 7. Discrepancies of Ellipsoidal Height Between Computed and Known Value of 1<sup>st</sup> Campaign of 31<sup>st</sup> August 2006

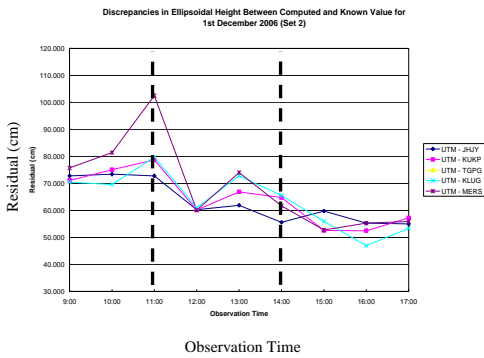


Fig. 8. Discrepancies of Ellipsoidal Height Between Computed and Known Value of 2<sup>nd</sup> Campaign of 1<sup>st</sup> December 2006

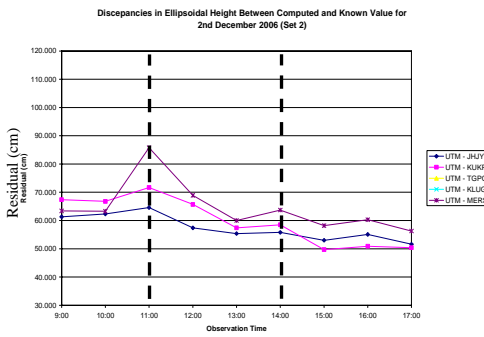


Fig. 9. Discrepancies of Ellipsoidal Height Between Computed and Known Value of 2<sup>nd</sup> Campaign of 2<sup>nd</sup> December 2006

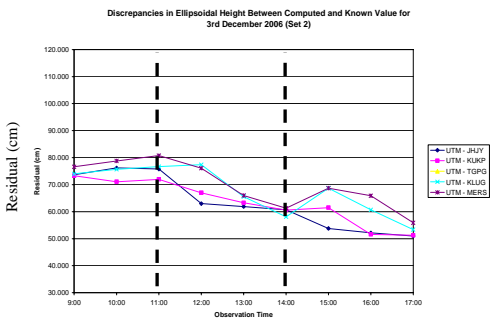


Fig. 10. Discrepancies of Ellipsoidal Height Between Computed and Known Value of 2<sup>nd</sup> Campaign of 3<sup>rd</sup> December 2006

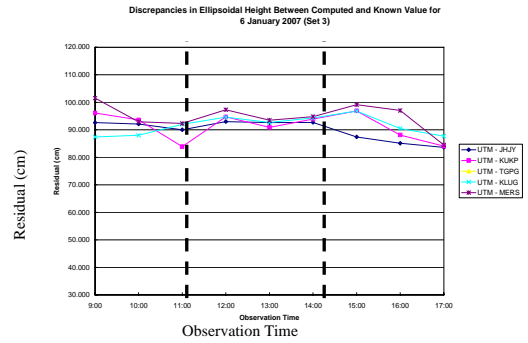


Fig. 11. Discrepancies of Ellipsoidal Height Between Computed and Known Value of Set 3<sup>rd</sup> Campaign of 6<sup>th</sup> January 2007

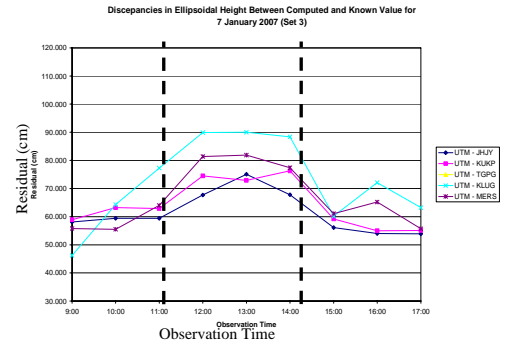


Fig. 12. Discrepancies of Ellipsoidal Height Between Computed and Known Value of Set 3<sup>rd</sup> Campaign of 7<sup>th</sup> January 2007

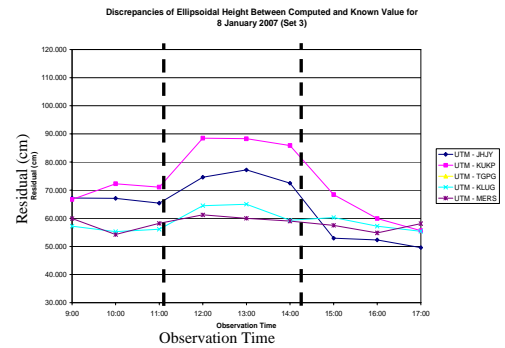


Fig. 13. Discrepancies of Ellipsoidal Height Between Computed and Known Value of Set 3<sup>rd</sup> Campaign of 8<sup>th</sup> January 2007

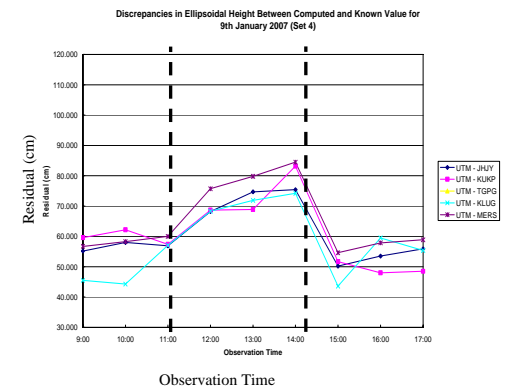
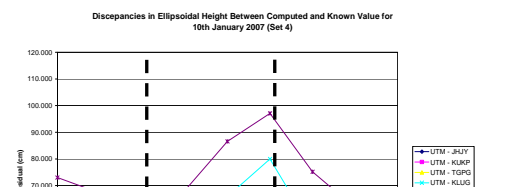


Fig. 14. Discrepancies of Ellipsoidal Height Between Computed and Known Value of Set 4<sup>th</sup> Campaign of 9<sup>th</sup> January 2007



METEOROLOGICAL DATA CONDITION AT MAXIMUM AND MINIMUM RESIDUAL VALUE FOR UTM-MERS BASELINE OF 4<sup>TH</sup> CAMPAIGN

Residual (cm)

Observation Time

Fig. 15. Discrepancies of Ellipsoidal Height Between Computed and Known Value of Set 4<sup>th</sup> Campaign of 10<sup>th</sup> January 2007

From the results obtained, neglecting the use of a standard tropospheric model leads to variations in the height components of the GPS measurement. A maximum difference of 119.100 cm and minimum of 37.990 cm in the height component were obtained between computed and known value. This value increases between 10 am and 12 noon followed by another occurrence period at 2 pm to 3 pm. On the other hand, better results in computed height were generally confined around 5 pm to 6 pm.

The result of the computed baseline residual at maximum and minimum between UTM-MERS during the 4<sup>th</sup> campaign were analyzed and compared with the meteorological value at maximum and minimum. The result, as shown in Table 9 indicates differences in terms of meteorological condition at occurrence time of maximum and minimum residual.

It is clear that slight changes in meteorological condition can affect the amount of computed discrepancies. This is attributed to satellite geometry as shown in Tables 3-5 and the satellite signal refraction through the atmosphere. Similarly, the location of Malaysia in the equatorial and tropical region makes it susceptible to strong atmospheric effect.

Differences up to 29.9 cm between maximum and minimum residuals (9/1/2007) were detected when changes in temperature and pressure were at 0.9 C and 0.4 Hpa respectively. However for observation on 10/1/2007, differences up to 39 cm between maximum and minimum residuals were detected when changes in temperature, pressure and relative humidity were at 2.9 C, 2.4 Hpa and 3% respectively.

UTM-MERS Baseline				
4 <sup>th</sup> Campaign	9/1/2007	Max Residual (cm)		84.500
		Min Residual (cm)		54.600
		Met Value@ Max Residual	Temperature (C)	24.6
			Pressure (Hpa)	1009.4
			R.Humidity (%)	37
		Met Value@ Min Residual	Temperature (C)	23.7
	Pressure (Hpa)		1009.0	
	R.Humidity (%)		37	
	10/1/2007	Max Residual (cm)		97.090
		Min Residual (cm)		58.000
		Met Value@ Max Residual	Temperature (C)	31.9
			Pressure (Hpa)	1010.4
R.Humidity (%)			38	
Met Value@ Min Residual		Temperature (C)	29.0	
	Pressure (Hpa)	1008.0		
	R.Humidity (%)	35		
11/1/2007	Max Residual (cm)		79.000	
	Min Residual (cm)		56.900	
	Met Value@ Max Residual	Temperature (C)	23.8	
		Pressure (Hpa)	1012.9	
		R.Humidity (%)	43	
	Met Value@ Min Residual	Temperature (C)	24.1	
Pressure (Hpa)		1010.0		
R.Humidity (%)		41		

For observation on 11/1/2007, differences up to 22.1 cm between maximum and minimum residuals were detected when changes in temperature, pressure and relative humidity were at -0.3 C, 2.9 Hpa and 2% respectively. Based on these results, conclusion can be made that there is a direct correlation between the meteorological condition and the amount of discrepancies due to tropospheric delay.

*B. Tropospheric Delay on differences in Baseline lengths*

In order to investigate whether tropospheric delay is also a distance-dependent error, comparisons have been made on the residuals between short (UTM-JHJY) and long (UTM-MERS) baselines from each of the campaigns. Figures 17 –20 show the differences of height value derived from both baselines of a set of observation taken from the four campaigns each.

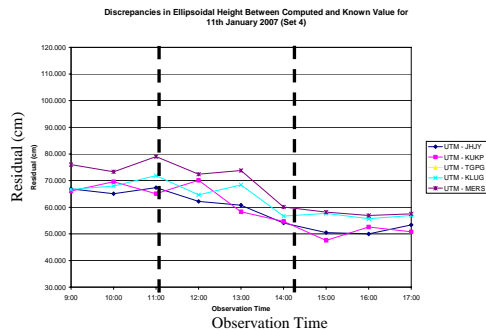
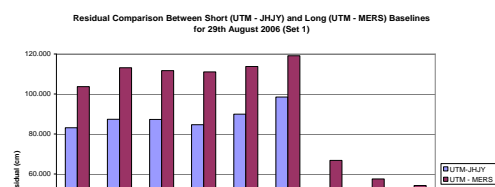


Fig. 16. Discrepancies of Ellipsoidal Height Between Computed and Known Value of Set 4<sup>th</sup> Campaign of 11<sup>th</sup> January 2007

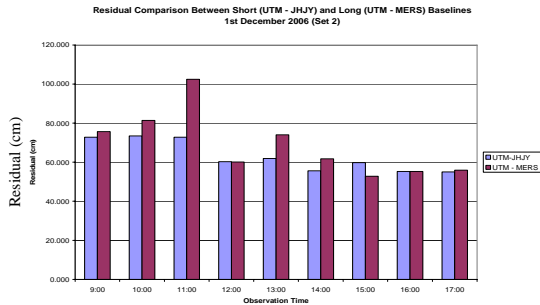
TABLE 9



Residual (cm)

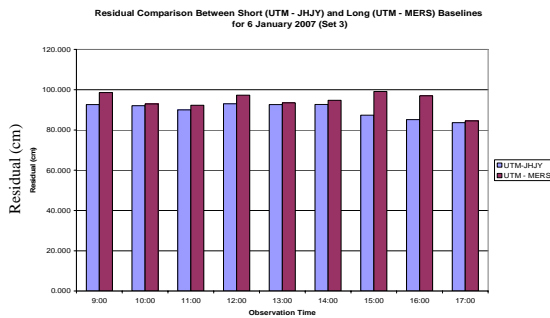
Observation Time

Fig. 17. Residual Comparison Between Short (UTM - JHJY) and Long (UTM - MERS) Baselines of 1<sup>st</sup> campaign of 29<sup>th</sup> August 2006



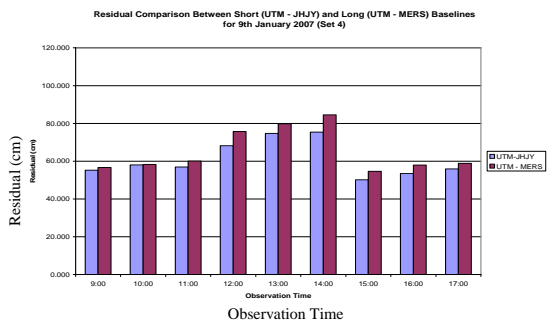
Observation Time

Fig. 18. Residual Comparison Between Short (UTM - JHJY) and Long (UTM - MERS) Baselines of 2<sup>nd</sup> campaign of 1<sup>st</sup> December 2006



Observation Time

Fig. 19. Residual Comparison Between Short (UTM - JHJY) and Long (UTM - MERS) Baselines of 3<sup>rd</sup> campaign of 6<sup>th</sup> January 2007



Observation Time

Fig. 20. Residual Comparison Between Short (UTM - JHJY) and Long (UTM - MERS) Baselines of 4<sup>th</sup> campaign of 9<sup>th</sup> January 2007

increases in the baseline length between two stations. For long baseline of UTM-MERS, the difference in tropospheric refraction will primarily be a function of the difference in the weather condition. This is due to the fact that signals transmitted from a satellite need to propagate through different amount of atmospheric content such as gases and water vapour within the troposphere due to large difference in baseline length before arriving to both receivers on the ground.

However, for short baseline, signal paths from satellite to both receivers are essentially identical. This is because the errors common to both stations tend to cancel during double differencing with the tropospheric correction decomposing into the common station parts and the satellite-dependent part [11]. Therefore, better result in the derived position is expected compared to long baseline.

### C. Estimation of GPS Signal Propagation

Within the troposphere, the propagation speed of signals transmitted from GPS satellites are equally reduced with respect to free-space propagation. To determine signals propagation delay of each available satellite, a computer program called TROPO.exe was developed based on refined Saastamoinen model. A total of four available satellites were used in this study. The satellites include; SV 1, 7, 22 and 27. they were observed from UTM-JHJY baseline on 29<sup>th</sup> August 2006. The estimated delay recorded in UTM-JHJY baseline on 29<sup>th</sup> August 2006 for each satellite is shown in Figure 21-24.

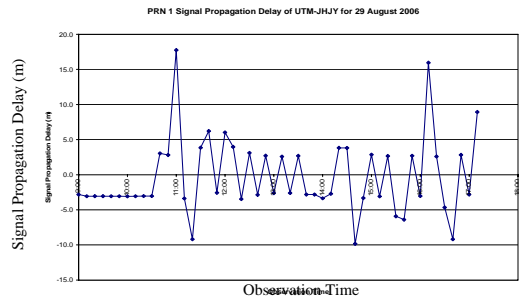


Fig. 21. Signal Propagation Delay of SV 1 UTM-JHJY Baseline for 29<sup>th</sup> August 2006

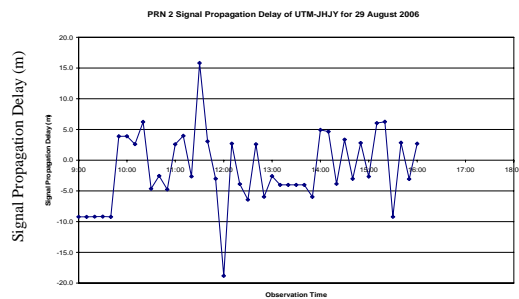
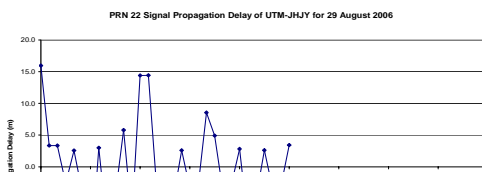


Fig. 22. Signal Propagation Delay of SV 2 UTM-JHJY Baseline for 29<sup>th</sup> August 2006

The result reveals that tropospheric error increases with the



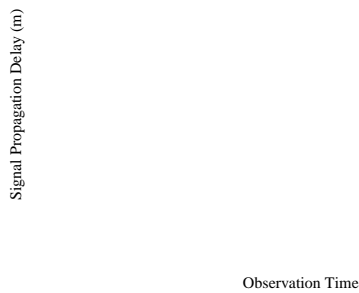


Fig. 23. Signal Propagation Delay of SV22 UTM-JHJY Baseline for 29<sup>th</sup> August 2006

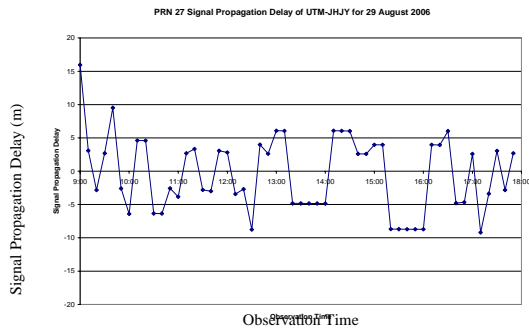


Fig. 24. Signal Propagation Delay of SV 27 UTM-JHJY Baseline for 29<sup>th</sup> August 2006

Figures 21 to 24, shows inconsistency in the delay variation. Reaching maximum delay up to 18 meters in pseudo range, the peak of the delay was detected at 11 am for SV 1. For SV 2, the occurrence time is at 12 pm. Maximum latency of signal propagation for SV 22 was detected at 10 am followed by 9 am for SV 27.

#### D. Tropospheric Delay on differences in antenna height

From the results obtained from Figure 2 to 13 increments on the antenna height at 0.5 m per session shows no significant effects or improvement towards the accuracy of computed ellipsoidal height obtained from each baseline. This might be due to the fact that 0.5 m increment is very small compared to the range of coverage of the troposphere medium above the earth surface (16 km above equator).

To study in which way the delay are influenced by differences in station height above mean sea level, a test was conducted using seven sets of simulated data. While both ground local meteorological condition (temperature, pressure and relative humidity) and satellite elevation angle being kept constant, signal propagation delay at each condition was computed using different value of station heights. List of simulated data used in this study is shown in Table 10.

Based on these simulated data, Table 11 shows the amount of signal propagation delay computed using TROPO.exe for each set of data.

Set	Temp. (C)	Pressure (Hpa)	R.Humidity (%)	Sat. Elev. (deg)	Stn Height (m)
1	32.3	1010.2	56	60.00	0.00*
2					5.00
3					50.00
4					100.00
5					1000.00
6					10000.00
7					50000.00

TABLE 10  
SIMULATED COMPUTATIONAL DATA  
\* at mean sea level (MSL)

TABLE 11  
AMOUNT OF SIGNAL PROPAGATION DELAY

Set	Signal Propagation Delay (m)	Differences (m)
1	2.6863	CONSTANT
2	2.6850	0.0013
3	2.6729	0.0134
4	2.6595	0.0268
5	2.4294	0.2569
6	0.9929	1.6934
7	0.2714	2.4149

Theoretically, the lesser the amount of signal propagation delay, the better the derived position results can be obtained using GPS. It is obvious therefore, that the higher station, the smaller amount of signal propagation delay can be detected. The amount of signal propagation delay for station at MSL is 2.6863 m whereas at 5 m above MSL is 2.6850 m. This shows 5 m of differences in height can only give an effect or improvement around 0.0013 m or 1.3 mm in signal propagation delay. Changes up to 1 cm can only been seen if differences in station height range up to at least 50 m above the mean sea level.

#### V. CONCLUSION

In order to mitigate the tropospheric delay effect, a priori tropospheric models such as Saastamoinen, Hopfield, Davis et al, etc. are often employed. In this research, a TROPO.exe programme was developed based on the refined Saastamoinen global tropospheric delay model in estimating the amount of signal propagation delay as presented in Figures 21-24. This is followed with simulation test as shown in Table 11.

From the results obtained in this study, it is obvious that neglecting the use of a standard tropospheric model leads to variations in height component of GPS measurement. The tropospheric refraction varies with changes on meteorological condition.

Tropospheric delay is also distance-dependent error that

increases when the baseline length between two stations increases. Based on a test using simulated data; the amount of tropospheric delay decrease with increase on the antenna height.

#### ACKNOWLEDGMENT

The authors thank the Geodesy Section, Department of Surveying and Mapping Malaysia (DSMM) for providing data used in this study.

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# The Implementation of Global Navigation Satellite System (GNSS) in Africa: A Proposal for EGNOS Extension and Institutional Framework

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**Abstract**— The introduction of Global Navigation Satellite System (GNSS) is creating opportunities for regional and international technological advances, resulting in a wide range of economic and social benefits. The system is composed of two operational satellite systems namely: the American GPS and the Russian GLONASS and the soon-coming European Galileo. Several augmentation systems designed to provide greater accuracy for GNSS users and also increase integrity; availability and continuity at both local and regional levels have been developed and are at various implementation stages. The European Geostationary Navigation Overlay Service (EGNOS) is one of such augmentation system. Several trials have been conducted in Africa by the European Space Agency (ESA) to ascertain the coverage and performance of EGNOS. The results showed that, 95% positional accuracy is achievable by integrating with the European service area, thereby complying with Approach with Vertical Guidance-1 (APV-1). This paper proposes EGNOS extension and institutional framework for Africa as well as the benefits to be derived. The proposed extension architecture is an independent solution whereby the processing and uplink of the navigation message is to be done in Africa with the institutional framework providing the guiding regulations. The benefits to be derived are also outlined.

**Keywords**—Augmentation, Extension, Global navigation satellite system, Institutional framework.

## I. INTRODUCTION

Global Navigation Satellite Systems (GNSS) have evolved from an early period of limited programs such as the American Global Positioning System (GPS) and the Russian Global'naya Navigatsionnaya Sputnikovaya Sistem (GLONASS) to a point where a number of systems and their augmentations are underway. The introduction and implementation of satellite navigation technology to the development of the African continent is a right step that needs to be pursued vigorously. In recognition of the strategic importance of satellite navigation, its potential applications and the need for the African states in joining

the rest of the world to enjoy the benefits of the outer space; organizations such as the International Civil Aviation Organization (ICAO), Africa and Indian Ocean (AFI), the Agency for Air Navigation Safety in Africa and Madagascar (ASECNA), the European Space Agency (ESA), and the European Organization for Safety of Air Navigation (EUROCONTROL) have been actively involved in inspirational collaboration to ensure the introduction and implementation of GNSS in Africa.

EGNOS is an acronym for "European Geostationary Navigation Overlay Service". It is a Satellite-Based Augmentation System (SBAS) designed to improve GPS and GLONASS and the in-coming European Galileo services in terms of accuracy, integrity, availability and continuity. It is being implemented by the European Tripartite Group (ETG) comprising of European Space Agency (ESA), the European Commission (EC) and EUROCONTROL as Europe's contribution to the development of the Global Navigation Satellite System (GNSS-1) [1]. EGNOS consist of three geostationary satellites and a complex network of ground stations, which when fully operational will transmit GPS-like navigation signals containing integrity and differential corrections by the geosynchronous ranging satellites. The corrections are applied to GPS and GLONASS and EGNOS navigation signals and signals of other geosynchronous ranging satellites overlay systems to GNSS users within the area of coverage [2].

## II. MOTIVATION FOR EGNOS

The goal of the international community is to achieve an internationally provided, funded and controlled Global Navigation Satellite System (GNSS). Although GPS and GLONASS are seen to constitute elements of an interim GNSS leading to a final international GNSS; they lack the accuracy, integrity, availability and continuity to satisfy many of the more-critical and safety-related applications.



Similarly the dependency on this system that is solely owned and controlled by the military of one country has heightened the concern of the international community in terms of system availability especially during international crisis. This institutional uncertainty of a single state ownership and control, simultaneous dual military and civil use, couple with the technical limitations, particularly availability and vulnerability to interference has led to the development of various augmentation systems that will meet the requirement for safety-critical applications.

### III. EGNOS SYSTEM ARCHITECTURE

The EGNOS system consists of the Space segment, Ground segment and User segment as shown in Figure 1.

#### A. Ground Segment

The Ground segment is made of the Master Control Centres (MCC), Range and Integrity Monitoring Stations (RIMS), Navigation Land Earth Stations (NLES), Wide Area Networks (WAN) and Support facilities.

#### B. User Segment

The User segment is made of EGNOS Standard Receiver, which will verify the Signal-In-Space (SIS) performance, and a set of prototype user equipment for the various applications for which EGNOS is to provide which include; civil aviation, maritime and land [2].

#### C. Space Segment

The space segment consists of navigation transponders onboard YHM, Inmarsat III Indian Ocean Region (IOR-E) at  $64.5^{\circ}$  E and ESA ARTEMIS at  $21.4^{\circ}$  E. They cover not only the whole of Europe but Africa, South America and most part of Asia. The space segment therefore improves the geometry of the GPS constellation by broadcasting GPS-like signal thereby providing integrity and wide area differential corrections [3].

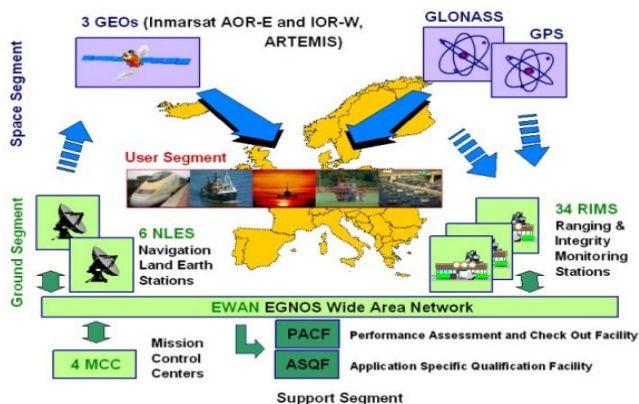


Fig. 1. EGNOS segments [4]

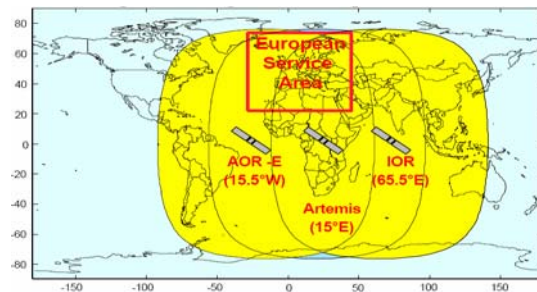


Fig. 2. European EGNOS service area [4].

### IV. EGNOS SERVICE AREA

The EGNOS coverage area includes all European states with a landmass. Figure 2 shows the European Service area for which EGNOS covers.

A pre-operational transmission of the EGNOS signal through the EGNOS test bed (ESTB) is currently going on. The EGNOS System Test Bed (ESTB) is the EGNOS prototype, which has been broadcasting a Signal in Space (SIS) since February 2000. It is meant to support and test the development of the EGNOS system, to demonstrate EGNOS to potential users, to prepare for the introduction of EGNOS and to test the possibility of extending this system outside Europe. However, the performance of this test bed is quite good achieving accuracy within few meters. This provides a GPS –augmentation signal so that users can determine their position [4].

### V. EXISTING EGNOS GROUND INFRASTRUCTURE IN AFRICA

Three African sites are included in the EGNOS 34 Range and Integrity Monitoring Stations (RIMS) as part of the EGNOS ground infrastructures. African sites as shown in table 1 and Fig. 3 are to be equipped with RIMS channel A, B and C to detect GPS satellite dysfunction and provide raw data to the EGNOS Central Processing Facilities (CPF) in order to carry out differential corrections and integrity monitoring to avoid system failure [5].

TABLE I  
EGNOS AFRICAN GROUND INFRASTRUCTURE

Country	Site	RIMS Channel
Tunisia	Dierba	A, B and C
Egypt	Mersa Matrouh	A and B
South Africa	Hartebeeshoek	A and B



TABLE 2  
EGNOS BANDWIDTH USAGE [8]

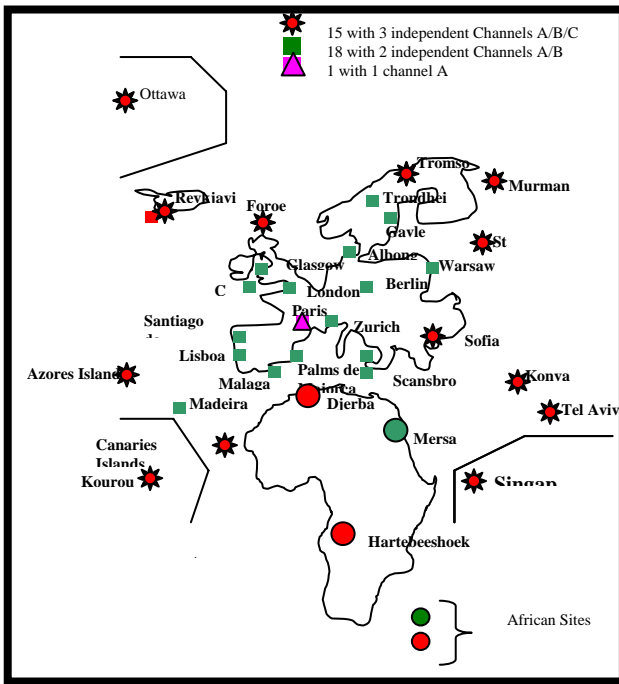


Fig. 3. EGNOS RIMS showing the location of the African sites

## VI. PROPOSED EGNOS EXTENSION

### A. EGNOS Extension Requirements for Africa

The basic concept for the extension of EGNOS outside Europe is the enhancement of navigation performance that is only attainable by the user of EGNOS within the service area. This basic concept is achieved by transmitting ranging corrections that are applicable to GPS that are valid to users irrespective of their position. The extension requirements include the following:

#### 1) Technical Requirement

One of the fundamental issues in the technical requirement is the ability to properly establish the size of the extension area. This requires analysis of the bandwidth that is available in the geostationary satellites (IMARSART and ARTEMIS).

Table 2 provides information on the EGNOS bandwidth usage. About 17 % of the total EGNOS bandwidth has been utilised mainly on the European service area [8]. From the foregoing, there is the need for an increase in the bandwidth of the geostationary satellites to meet the extension requirements. Other aspect of the technical requirements include proper site location of the Range and Integrity Monitoring Stations (RIMS); modification of the current EGNOS Central Processing facilities software to compute the user differential range error; developing ionospheric models that will mitigate the ionospheric effects; a real-time communication network (Wide Area Network) to allow data transfer to the processing centres and the navigation messages to the Navigation Land Earth Services (NLES) [6].

Data type	No. of message instances	Maximum broadcast interval (sec.)	Bandwidth filling
Nominal Service area (ECAC)			
SBAS in test mode	0	6	0.00%
PRN mask	1	120	0.83%
Fast corrections GPS	2	6	33.33%
URDEi	1	6	16.67%
Long-term corrections	12	120	10.00%
Geo ranging function data	1	120	0.83%
Fast correction degradation	1	120	0.83%
Degradation Parameters	1	120	0.83%
Ionospheric grid mask	4	300	1.33%
Ionospheric corrections, GIVEi	16	300	5.33%
Timing data	1	300	0.33%
Almanac data	2	300	0.67%
Service level	1	300	0.33%
<b>TOTAL</b>			<b>71.34%</b>

#### 2) Environmental Requirement

Provision of an infrastructure for RIMS indoor equipment to meet up with the indoor environmental requirement, are necessary. This could be a building, and the building could contain some offices for administrative purposes. There should be an indoor canalisation to allow for separation of power and communication cables. Cables made of metal that could cover all indoor interconnection cables. Considering relatively hot African climate, an air-conditioning system that will provide temperature in accordance with requirements need to be put in place [7].

#### 3) On-going ESTB trials in Africa

Beginning from June 2003, there have been EGNOS mobile trials in Africa, known as EGNOS Signal Test Bed (ESTB). The aim of these trials was to assess the strength of the EGNOS signal with the view of preparing for the full implementation of the system. Africa is zoned into three namely; Central Africa as Zone A, Southern Africa as Zone B and Eastern Africa as Zone C [11]. Two Inmarsat satellites (AOR-E and IOR-E), which are directly above Africa, are being used for transmission of signal-in-space. Mobile RIMS stations were installed at various locations in each of the zones. They are equipped with independent Very Small Aperture Terminal (VSAT) for communication purposes. In zone A the message type MT27 was used in 2003. However, there was a good accuracy but poor availability for Approach with Vertical Guidance -1 (APV-1). As a result of this, in February 2004, ESA integrated zone A into the ECAC area, but without the MT27. Sets of 24 hr data were collected for each week at the Douala (Cameroon) RIMS station [11].

The result of the trials allows the coverage of continental AFI including Madagascar, except Mauritius and Seychelles. The result of the tests shows that the accuracy achieved after integrating with the ECAC service area complied with Approach with Vertical Guidance -1 (APV-1) having a horizontal positional error of about 3 m, representing 95% and vertical position error around 4.5 m,

which is also 95%. More than 98% was achieved for the Availability of APV-1 service.

### B. Proposed Extension System Architecture

This section presents the proposed architecture for such extensions having considered the extension requirements. Fig. 4 presents a design of an independent solution, where two Monitoring and Control Centres (MCC) with one Navigation Land Earth Station (NLES) for up-link of the message received from the MCC are implemented. The idea is that, the African Centres will perform real-time processing of the RIMS data that will allow an on-line monitoring of the African ground infrastructure. Such a real time-time processing includes the computation of the wide area corrections and also the provision of integrity data from those satellites (GPS/GLONASS) that are visible within the African region.

Due to its independency, it would require a dedicated message type MT28 (provides availability inside service area and increase integrity outside) considering the fact that it provides an increased integrity outside the service area (ECAC). In view of this therefore, a Wide Area Network is required for transmission of messages. The African Monitoring and Control centres could also be linked to one of the European MCC, thus forming a network. The advantage of this design is that, there will be the provision of enough infrastructures within the African region for GNSS, similarly, it will provide independent for Africa not relying on Europe.

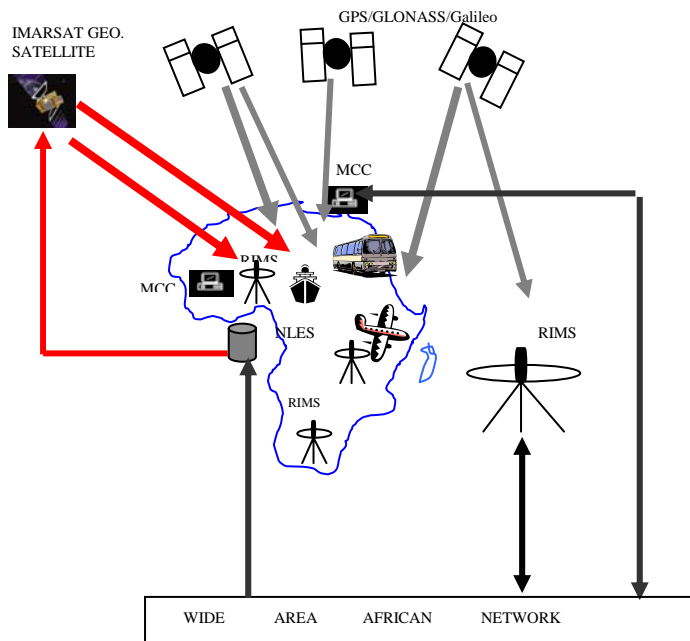


Fig. 4. Proposed Extension Architecture for Africa

## VII. PROPOSED INSTITUTIONAL FRAMEWORK

Considering the final architecture of EGNOS, the need for an international framework to support operation and exchange of information among system designers, operator

and international user communities is very important. The framework includes collaboration among the service providers, providing favourable and flexible mechanisms where there will be a shared interest in the use of the EGNOS system irrespective of the region in which they operate. Fig. 5 shows the institutional framework for EGNOS extension to Africa.

### 1) Technical Cooperation

The technical cooperation allows the sharing of both expertise and the costs of developing the expertise. It involves conducting joint research and publication of the results. With the extension of EGNOS there will be the sharing of ideas between Europe and Africa researchers in space related research given the diversity of the two continents. It will be of immense advantage to the African scientist giving the opportunity to participate in space-related activities that have been previously seems impossible. The technical cooperation include among others the following:

- Spectrum management
- Man power development
- Cooperation among the service providers
- The provision of expert services.

### 2) Political Cooperation

EGNOS has political advantages that will foster the relationship between Europe and Africa. Such relationship will aid in the management of the airspace of both countries. Europe could help Africa in the area of capacity building as the safety of life services offered by EGNOS will be of much demand by the African States, this will therefore facilitate in the establishment of EGNOS in completing the first phase of GNSS-1, of the European policy on global navigation satellite system. The extension will therefore facilitate Galileo's market launch in Africa, as EGNOS services are a precursor to future Galileo's application.

### 3) Economic Motivation.

Regional economic motivation and integration is an important factor in fostering relationship. The relationship will strengthen regional economic integration bringing about sustainable development. Lack of or insufficiency of GNSS infrastructure in Africa justifies the urgent need for such cooperation. In addition to the infrastructure deficiency, financial resources mean another specific obstacle for the African States in addition to the technical and political constraints, hence the need for economic cooperation.

### 4) Funding

The extension of EGNOS requires heavy investments. Although the cost of the existing GNSS services is free, however, the provision of EGNOS would require funding from both nations. The funding cooperation would involve a capacity outlay for deployment and operational costs.

This includes transmission cost, processing of data and provision of signal-in-space, monitoring and maintenance.

5) *Legal Framework*

It is important to note that, lack of legal framework for GPS has made it impossible for other nations to adopt the use of the Basic GNSS. An elaborate legal principle governing the extension of EGNOS to Africa is very essential. Such a legal framework should include series of private law contracts in which the relationship among various stakeholders involve in the implementation,

operation, provision and use of the EGNOS signals and systems is be addressed. The legal framework should address issues such as unlawful interference with GNSS systems, outages and other legal principles relating to communications by satellite. It should also address the issue of ownership putting in place a legal ownership concept, management and control of the system. When this is put in place, there will that understand between Europe and Africa in an event of system failure and the- likes.

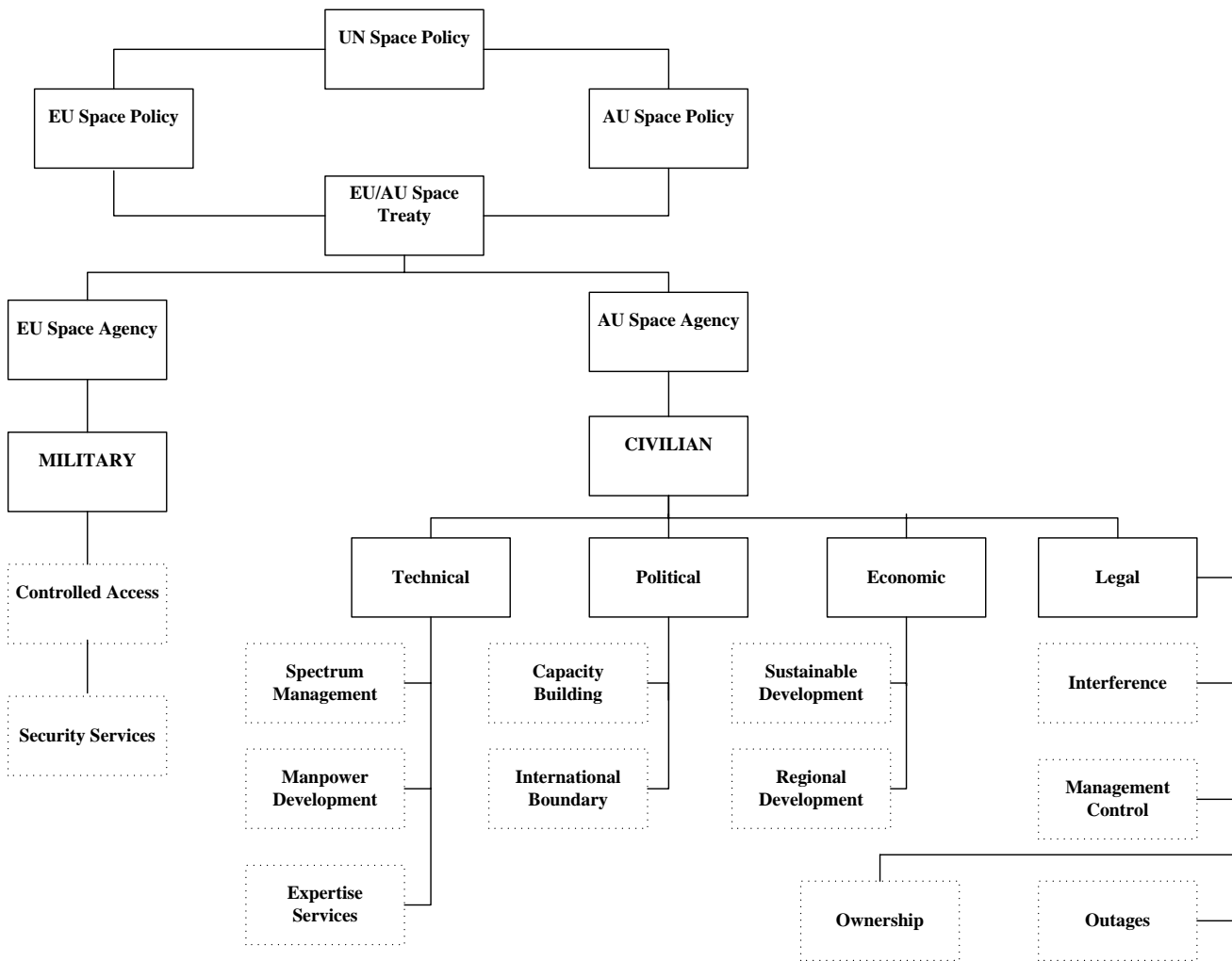


Fig. 5. Proposed EGNOS Institutional Framework

I. **BENEFITS TO AFRICA**

The benefits of GNSS applications are growing in areas including aviation, maritime and land transportation, surveying and mapping, agriculture, power and telecommunications networks and disaster warning and emergency response. Especially for developing countries,

GNSS applications will offer cost-effective solutions to pursue economic growth without compromising the present and future needs to preserve the environment, thus promoting sustainable development.

1) *Aviation.*

The African airspace has a disproportionately high rate of accidents associated with the en-route; approach and landing phase of flight which underscores an urgent need for the upgrade infrastructure and implement the use of

modern technology. Among these detriments are poor radar coverage and large number of non-precision approaches that are the norm. Safety is the key requirement for civil aviation, and this demands high levels of performance. GNSS will enable gate-to-gate navigation and all-weather operation capabilities for suitable equipped aircraft. By providing more precise accurate landing systems, GNSS will make flying not only safer, but also more efficient. It will also allow for closer aircraft separation on more direct routes, reduce en-route and terminal delays, and eliminate circling by allowing straight-in approaches to any runway, precise approaches and mapping the precise location of aircraft.

### 2) Surveying and Mapping

Surveying and Mapping has always been a pioneer of GNSS applications. Using GNSS to survey and map precisely, saves time and money. Developments in this area, however, have been very slow in Africa. This is because different region use different reference ellipsoid in surveying and mapping. However, there are moves to establish the African Reference Frame (AFREF), which is aimed at providing a unified spatial reference frame, which will provide co-ordinate systems that will be consistent with the International Terrestrial Reference Frame (ITRF) thereby ensuring Spatial Data Infrastructures (SDI) enabled by GNSS [9].

### 3) Road/Rail Transport.

Vehicle tracking and Fleet management system is an application area where practical benefit of GNSS technology can easily be demonstrated and appreciated particularly in Africa where road transport systems has remained the backbone of the mass movement and the haulage industry. The potential large market for the GNSS industry comes from this area of application.

### 4) Agriculture

The main application of GNSS in the agricultural sector is in precision agriculture; due to the need for a more efficient agricultural production practices, and environmentally friendly requirements over the traditional farming method. The four main objectives of this technology are: reduced inputs, improved machine control, increase management and field efficiency. Africa will benefit tremendously, since most of the continent sources of income is in agriculture.

### 5) Maritime.

GNSS enhanced-performance and safety is highly relevant in the maritime environment. Information supplied by GNSS could be used in developing guidance systems for waterways and efficient management of ports operations. With the introduction of Automatic Identification System (AIS) for merchant ships, there will be reliability on information on the ships position and the monitoring of their movement using GNSS. This will solve the problem of vessels declared missing in the most of the African ports.

### 6) Management of Environment and Natural Disaster.

The management of environment and natural disaster is a major concern of the entire global community. The environment is the life supporting system for all living organisms including humankind. Its sustainable use is essential for the current and future generations. At the same time, natural disaster continues to lead to losses of life and property, enhanced poverty and vulnerability affecting any efforts towards achieving sustainable development. The GNSS has an enormous potential to contribute to the management of environment and natural disaster by utilizing: positioning, signal delay and signal reflection amongst many other concepts [10]. GNSS can be used in monitoring vessels to reduce oil and dangerous wastes spills caused by marine accidents. Also, in mapping natural disaster risk zones such as floods, droughts, marine, inland lakes, rivers and disease prone areas e.g. malaria, rift valley fever etc) in support of the habitats and sustainable development.

## II. CONCLUSION

The Extension of EGNOS to Africa constitutes one of the most promising space applications that could be of benefit to African. The immediate and exponential benefits will result in a safer and more efficient infrastructure, which can positively influence trade potential and economic viability of

Africa, and serving as a catalyst for trade and economic growth of the country. Clear government policy, with a national multimodal approach to GNSS related issues, will benefit service providers, service users and Africa as a continent.

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# Legal Issues in GIS: A Perspective on Rights and Liability

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## Abstract

A Geographic Information System (GIS) provides an opportunity for its creators to articulate spatial information in a format which enables its users to visualize and solve complex problems. The issues that arise from the use of the information contained within the GIS are many. The intent of the article is to provide an overview of legal issues confronting the parties in the United States involved in the production or use of a GIS or its information.

## Introduction

Technologies have emerged that have revolutionized how information is collected, stored, and distributed. One such area of impacted by such technologies is the Geographic Information System (GIS) sector which is routinely asked to information and the tools necessary to visualize the information in a useful format and to make decisions accordingly. The use of GIS in making decisions to solve complex problems gives rise to legal issues such as ownership, access, privacy, and liability for the use and dissemination of GIS information.

## Access

GIS is a relatively expensive tool which many sectors have adopted to aid in their decision making processes. Private, governmental, and quasi-governmental sectors utilize GIS as a tool to make important social and economic decisions. The information gathered by the private sector is protected from access by a grant from the federal government; i.e., the copyright laws and the international treaties. Thus, the public is precluded from the information unless the private enterprise chooses to disseminate the data without charge. It is highly unlikely that this would occur. It is more likely that the individual will gain access to GIS information from a

governmental office or from what I refer to as the quasi-governmental sector. The quasi-governmental sector may be a university based GIS funded in part with governmental funds and required to provide the public access to the information, albeit not all of it free of charge.

In the United States, the public sector through its governmental units is subject to freedom of information acts, commonly referred to as (FOIA)<sup>1</sup> at the federal level and at the regional or state level referred to as freedom of information laws (FOIL)<sup>2</sup> or right to know acts and/or statutes. A complication arises at the state level since the agencies charged with implementing the laws may act as gatekeepers rather than providers and public officials required to carry out the law. As you may have quite accurately perceived it's a virtual nightmare for the individual citizen requesting access to "public information." To complicate matters each state as well as the federal government charge fees for access. For example, all agencies within the State of New York have the following structure: **Fees-** Copies of records must be made available on request. Except when a different fee is prescribed by statute, an agency may not charge for inspection, certification or search for records, or charge in excess of 25 cents per photocopy up to 9 by 14 inches (section 87(1)(b)(iii)). Fees for copies of other records may be charged based upon the actual cost of reproduction.<sup>3</sup> There are instances whereby states have claimed protection under the federal copyright laws of the federal government

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<sup>1</sup> 5 U.S.C. §552

<sup>2</sup> New York Freedom of Information Law (FOIL): N.Y. Pub. Off. Law, sec84-90

<sup>3</sup> *Id.*

to prevent access to state produced GIS data.<sup>4</sup> All states which have addressed this copyright protection debate have sided with the public having access to all enumerated categories of information reserving exception where an invasion of privacy may lie.<sup>5</sup> The copyright laws may not protect government copyrights of GIS data since the government is under an obligation to gather and disseminate information and that GIS data produced by the government is not produced for financial gain. However, public access to GIS records does raise several issues with respect to misuse and interpretation of the information. That is, the data is in most instances highly technical in nature and somewhat useless without the aid of a professional and may contain private information about individuals that is not in the public domain.<sup>6</sup> However, these concerns must at all times be outweighed by the overarching principle of the public's right to access the very information which the government itself requested to be collected and stored. States and regional governmental agencies must ensure that access is unbridled excepted for those limited number of enumerated categories which limit access based on balancing the equities of access against those of privacy. As in the words of one legislative body: "Access to such information should not be thwarted by shrouding it with the cloak of secrecy or confidentiality. The legislature therefore declares that government is the public's business and that the public, individually and collectively and represented by a free press, should have access to the records of government in accordance with the provisions of this article."<sup>7</sup>

#### Privacy

With respect to a government agency using GIS data for regulatory purposes, issues arise about privacy in terms of whether or not the agency's regulation becomes an invasion of an

individual's right to privacy.<sup>8</sup> It does matter whether or not the individual is real or fictitious. A fictitious individual is a company or corporation which is given de jure person status by statute; i.e. artificial entity.<sup>9</sup> An individual's right to privacy varies from that of a corporation or fictitious person. A person is entitled to a reasonable expectation of privacy in his home and the immediate surroundings of the home, the "curtilage."<sup>10</sup> The curtilage "harbors the intimate activity associated with the sanctity of a man's home and the privacies of life."<sup>11</sup> Courts make this determination by examining "whether the area is included within an enclosure surrounding the home, the nature of the uses to which the area is put, and the steps taken by the resident to protect the area from observation by people passing by."<sup>12</sup> On the other hand a corporation or business entity is entitled to a reasonable expectation of privacy within its "industrial curtilage" rather than its "open fields"<sup>13</sup> where activities are conducted out of doors or in its open air spaces.<sup>14</sup> However, there is no expectation of privacy as between companies. Thus, companies must be aware of their surroundings and that all proprietary information be subject to industrial espionage.

#### Evidentiary Aspects

Unlike commodities, information contained by a GIS is intangible or non-physical and is generally not traded on the open markets. However, information has value and is routinely purchased by public and private sectors alike. As the raw data is entered into the database of a GIS, the graphical information and tabular information both undergo a transformation which ESRI describes as a six step process.<sup>15</sup> During this process data is acquired, entered, stored, manipulated, distributed, and used. And during each step an error may occur causing a compound problem throughout the data transformation process. GIS produced

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<sup>4</sup> See Scott D. Makar & Michael R. Makar, Jr., *Geographic Information Systems: Legal and Policy Implications*, 69 Fla. B.J. 44

<sup>5</sup> New York Freedom of Information Law (FOIL): N.Y. Pub.Off.Law. secs 84-90

<sup>6</sup> See David Michael Ryfe, *Information Systems in the San Diego Region*, 36 Cal.W.L. Rev 367 (2000)

<sup>7</sup> New York Freedom of Information Law (FOIL): N.Y. Pub.Off.Law. secs 84-90

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<sup>8</sup> 11 Alb.L.J. Sci. & Tech. 359 (2001)

<sup>9</sup> 15 Pa.C.S.A. §1309, et.seq.

<sup>10</sup> *California v. Greenwood*, 486 U.S. 35

<sup>11</sup> *United States v. Dunn*, 480 U.S. 294, 300 (1987)

<sup>12</sup> *Id.* at 301

<sup>13</sup> See *Dow Chemical Co. v. United States*, 476 U.S. 277 (1986)

<sup>14</sup> *Hester v. United States*, 256 U.S. 57

<sup>15</sup> 12 Duke Env L & Pol'y F 219 (2002)



information such as maps and other types of geographical information are often used in court to as either demonstrative evidence or real evidence. Demonstrative refers to the information serving a function to demonstrate or illustrate factual contentions or to help the jury understand the case. Whereas, the information may be real evidence if the evidence has any tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence.<sup>16</sup> That is, the map may at time be both demonstrative evidence if it is used to help the jury understand some piece of information, location of oil well, that is important to the outcome of the case or it may be considered real evidence<sup>17</sup> if the map itself is placed as the issue to be resolved by the court; i.e. the map is used for landing at an airport and the information contained on the map is used by the pilot during landings at this particular airport. Whether real or demonstrative, all evidence must be relevant<sup>18</sup>, material, and competent. Material evidence is material if it is offered to prove a fact that is at issue in the case. Competent if the proof that is being offered meets certain traditional requirements of reliability. Competency is determined by a procedure referred to as authentication. Authentication requires that the evidence is sufficient to support a finding that the matter in question is what its proponent claims. For example, lets say that the witness states that it was raining on a given date authentication would require some inquiry into whether or not it rained on the particular day in question even though rain may play no factor in the outcome of the case. Authentication is utilized to certify. The map which is introduced during a court must be certified that it is a true and accurate representation. In instances where maps are published by the government they are self-authenticating and no witness testimony is required. Although the maps or other records are authenticated the federal rules of evidence considers these items hearsay. Hearsay is a legal term referring to oral or written assertions that were made at some other time and at some other location and today, in this court, the document(s) is being used to prove the matter asserted in the

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<sup>16</sup> FRE 401

<sup>17</sup> a thing the existence or characteristics of which are relevant and material. It is usually a thing that was directly involved in some event in the case.

<sup>18</sup> See note 16

document or report.<sup>19</sup> The courts have deemed hearsay evidence as inherently unreliable. However, they have fashioned exceptions to this rule for situations which it has deemed that this type of testimony is reliable.<sup>20</sup> It follows that information produced by a GIS would fit the definition of hearsay. In general, maps or for that matter any GIS produced information would also be classified as hearsay. The hearsay exceptions that apply are the business records exception and the public records exception. But the main hurdle that must be overcome is that of accuracy and reliability contained within the records. The courts may ask where the information in the map originated from, how the information was transformed, and how the map itself was created.<sup>21</sup> In addition, because the GIS process contains a number of steps, courts look to inquire about, amongst others, programming errors, equipment malfunctions, and data entry errors.<sup>22</sup> Accordingly, parties must prove that the process or system produces accurate results.<sup>23</sup>

Proving that the process or system, GIS, produces accurate results may ultimately rely on testimony of experts or trained employees involved in the process and may describe how the process operates to produce results. In the US the Supreme Court has set forth certain requirements in determining the reliability of a particular scientific theory or technique<sup>24</sup> to ensure that scientific or any expert opinion testimony is reliable. For expert testimony to meet the requirements of the court, it must comply with the factors set out in *Daubert*: – testing, peer review, error rates, and “acceptability” in the relevant scientific community—which might prove helpful in determining the reliability of a particular scientific theory or technique.<sup>25</sup> Therefore, it is imperative that the process or system and expert witness(es) withstand the scrutiny as laid out by the Court in *Daubert*.

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<sup>19</sup> FRE 801, et.seq.

<sup>20</sup> FRE 804

<sup>21</sup> State of Connecticut v. Wright, 752 A.2d 1147

<sup>22</sup> Chung and David J. Byer, the Electronic Paper Trail: Evidentiary Obstacles to Discovery and Admission of Electronic Evidence, 4B.U. J. Sci. & Tech. L. 5 para 40 (1998)

<sup>23</sup> FRE 901(b)(9)

<sup>24</sup> *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579

<sup>25</sup> *Id. at* 593-594

## Data Ownership

Data is inherent to any GIS. And ownership of this data and any information resulting from transforming this data is or can be lucrative. This data is property in which an owner certain rights which protects the information from the rest of the world. The owner has the right of exclusive ownership, right to sell, and the right to alienate or will this property.<sup>26</sup> These rights are referred to a "bundle of sticks" -- a collection of individual rights which, in certain combinations, constitute property. State law determines only which sticks are in a person's bundle.<sup>27</sup> There are several types of property, some of which are protected by state statutes and some by federal statutes and international agreements and/or treaties. Property may be classified as either: real, personal, or intellectual. Real property is that which relates to real estate or permanent attachments to the real estate; personal property is that which is physical and tangible; intellectual is intangible personal property.<sup>28</sup> In the United States, most databases are insufficiently original in the selection or arrangement of their contents to attract copyright protection.<sup>29</sup> Even those databases that do attract copyright protection are only protected to the extent of their fixed literal expression.<sup>30</sup> There are no property rights in their contents.<sup>31</sup> Therefore in the United States, a database containing raw data will not enjoy copyright protection. However, if the data is arranged in special patterns to enable the GIS to transform it, then protection exists in that arrangement.

In establishing ownership of this data the copyright laws of the United States look to the author of the original work.<sup>32</sup> Works specified in the copyright code sections 102 and 103 that are unpublished. are subject to protection under this title without regard to the nationality or domicile

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<sup>26</sup> U.S. v. Craft, 535 U.S. 274 (2002)

<sup>27</sup> *Id.*

<sup>28</sup> Jacqueline Lipton, Mixed Metaphors in Cyberspace: Property in Information and Information Systems, 35 Loy. U. Chi. L.J. 235

<sup>29</sup> Feist Publ'ns, Inc. v. Rural Tel. Serv. Co., 499 U.S. 340, 361-62 (1991).

<sup>30</sup> Stephen Elias, Patent, Copyright & Trademark: A Desk Reference to Intellectual Property Law

<sup>31</sup> *Id.* at 66

<sup>32</sup> 17 U.S.C. 106

of the author. Published works are protected regardless of nationality so long as the author(s) are nationals or are domiciled in a country having a treaty with the U.S.<sup>33</sup> When the author is an employee then ownership belongs to the employer under "work for hire" provision if the work is completed within the scope of employment and if not it belongs to the employee. If the author is under contract to author the work and no contract exists as to copyright ownership, a copyright will likely belong to the author as a "work for hire."<sup>34</sup> An owner of a copyrighted work has limitations<sup>35</sup> placed on the exclusive rights provided by the statute. From my perspective, the most important limitation on exclusive rights is that of "fair use" whereby under certain condition members of the public may use the copyrighted work without violating the code so long as the work is being used for purposes such as criticism, comment, news reporting, teaching (including multiple copies for classroom use), scholarship, or research.<sup>36</sup> In determining whether the use made of a work in any particular case is a fair use the factors to be considered shall include —(1) the purpose and character of the use, including whether such use is of a commercial nature or is for nonprofit educational purposes; (2) the nature of the copyrighted work;(3) the amount and substantiality of the portion used in relation to the copyrighted work as a whole; and(4) the effect of the use upon the potential market for or value of the copyrighted work. The fact that a work is unpublished shall not itself bar a finding of fair use if such finding is made upon consideration of all the above factors.<sup>37</sup>

## Liability

Since GIS data is compiled both by the public and private sector it follows that liability issues also are based on whether the accused is a public or private entity. Thus it's important to look to the GIS liability chain which includes a number of potentially liable parties that are involved in the six step process described by ESRI. The parties include the GIS technology provider, the provider of the underlying information, data

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<sup>33</sup> 17 U.S.C. 104(b)

<sup>34</sup> 17 U.S.C. 101

<sup>35</sup> 17 U.S.C. 107-112

<sup>36</sup> 17 U.S.C. 107

<sup>37</sup> *Id.*

compiler, GIS producers, and users of GIS. The GIS technology provider may be either a government agency or private sector company. \*\*\*finish describing the potentially liable parties

A government agency will for the most part seek protection in the name of governmental immunity. However, governmental immunity does not necessarily flow to the employee(s) or agencies. Once an agency takes on a task, such as a GIS and produces information that the public relies on, it is obligated to use the same due care as a private party in accomplishing its tasks.<sup>38</sup> In litigation cases involving the private sector at least three theories of liability are advanced, negligence, breach of warranty, and/or product liability depending on whether the deliverables to the customer/client were a product/goods or service.<sup>39</sup> A product is a good produced or manufactured, either by natural means, by hand, or with tools, machinery, chemicals, or the like. Something produced by physical or intellectual effort. Service is a duty or labor rendered by one person to another. In a seminal case involving navigational charts, Jeppesen as producer was found liable on the theories of liability: negligence, breach of warranty, and products liability. The court classified the navigational chart as a product based on its mass production of such. In addition, the court opined that “by publishing and selling the charts, Jeppesen undertook a special responsibility, as seller, to insure that consumers would not be injured by the use of those charts.”<sup>40</sup> In cases decided by advancing a negligence theory, a distinction is made as to the parties to the litigation. When the party is a professional as defined by professional licensing boards the standard of care is that of professional offering a professional service. This higher standard is that of a reasonably prudent professional in that profession having the same education, training and level of experience, and sometimes geographic location. Since the opportunities for the professional to participate in continuing education is abundant and readily available in a multiplicity of formats the professional is expected to have the same attributes as another professional having similar professional vitae. Currently, there are no

professional registration boards that provide oversight of licensing the GIS professional.

Thus, when the GIS employee is not a licensed professional; i.e. professional engineer, surveyor, or geologist the standard of care that is appropriate for a party involved in litigation is that of reasonably prudent person and the damage suffered by the opposing party was foreseeable at the time of the conduct which caused the damage and that the damage is of the type that was foreseeable. The reasonably prudent person is the archetypical person who generally does all the right things all the time.

### Conclusion

The legal issues confronting the GIS community involve access to the data, right of privacy to data, liability for disseminating GIS information in either product form or as a service, and ownership of the data. These issues are becoming more complex as technology is advanced on the capturing, transformation, and depiction of the results of the GIS. Prudent steps should be taken to prevent exposure to liability by educating all employees on all aspects of the GIS with which they are working. In general, ownership rights and access to a GIS are controlled by statute at the federal or state levels. To ensure one’s proper rights attention should focus on the state and federal statutes that control ownership rights.

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<sup>38</sup> Indian Towing Co. v. U.S., 350 U.S. 61

<sup>39</sup> Saloomey v. Jeppesen & Co., 707 F.2d 671

<sup>40</sup> *Id.* at 677

## **CONFERENCE DIVISION:**

Geology; Minerals and Materials Processing, Science &  
Engineering; Mining

## MINERALOGICAL STUDY OF AMD – BASE WASTE ROCKS IN A GOLD MINING REGION IN TARKWA, GHANA

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**Abstract:** Acid Mine Drainage (AMD) due to the weathering of reactive sulphide containing minerals invariably poses a serious environmental problem, warranting systematic investigations for its effective mitigation. Sulphur bearing minerals such as pyrite, pyrothite and arsenopyrite characteristically generate acid as a result of exposure to molecular oxygen rich aqueous environment. In this study, gangue rocks at a gold producing area in Tarkwa, Ghana, some of which lead to AMD, have been characterized using microscopic /petrological, Acid-Base Accounting (ABA) and Net Acid Generation (NAG) analyses. Two gangue or waste rock types, one meta-diorite and the other, quartzite, were identified where the latter led to AMD. The meta-diorite predominantly contained plagioclase (10-12 %), amphibole+chlorite (30-40%) and quartz (2-6%) as primary mineral phases with pyrite (0.5-3.0%), calcite (7-12%) and other clay phases as the secondary mineral components. The quartzite, on the other hand, contained quartz (50-60%), amphibole+chlorite (5-8%) and plagioclase (13-20%). The secondary component included pyrite (2-15%) and other clay minerals. The pyrite associated with the meta-diorite was euhedral whilst that associated with the quartzite was found to be anhedral. The anhedral pyrite together with the lower content of acid consuming chlorite phase of the quartzite rock make it more prone to acid generation, a finding that was confirmed by the NAG test.

*Key Words:* Acid mine drainage, acid consuming minerals and acid producing minerals

### 1 Introduction

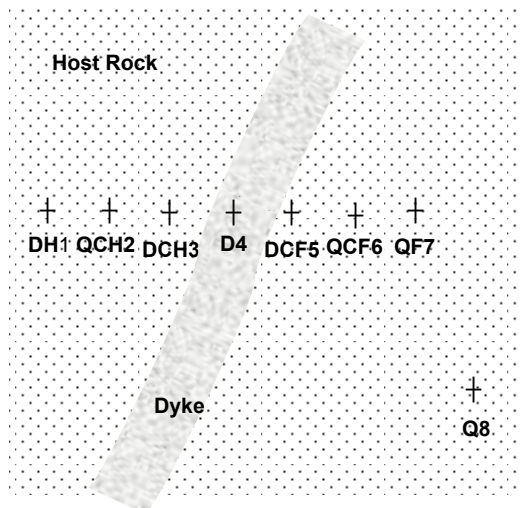
The detrimental effect of AMD on the environment makes it an undesired phenomenon in mining communities, especially in developing countries like Ghana where the resources and solution are not readily available to treat it sustainably. Once AMD starts, its mitigation is not only difficult but also costly. Consequently, accurate predictive methods for and preventive action of its occurrence are essential. Although such predictive methods may not always translate into readily achievable cost-effective solutions they, invariably, increase the options for scientifically, technically, and environmentally sound approach to planning to address the problem (Warhurst and Noronha 2000). Predictive tools such as mineralogical composition assay, ABA and NAG test are useful and are commonly employed in accessing waste rock's potential to produce acid. Of pivotal role potential for a given rock to generate or neutralise acid is its mineralogical composition, in tandem with the individual mineral grain size, shape, texture and inter-granular and spatial relationships of different mineral phases. Rock mineralogical composition and crystallo-chemical properties essentially determine the sources and magnitude of Neutralization Potential (NP) and Acid Production Potential (AP). These are basic parameters forming the basis of ABA tests used as a screening tool to predict the occurrence of AMD from the balance between the Acid Producing Minerals (APM) and Acid Consuming Minerals (ACM) of wastes (Coastec Research, 1991; Warhurst and Noronha 2000). Complementary NAG tests are also

routine laboratory analysis carried out to measure the capacity of acid generation of waste rocks. The aim of this work therefore was to employ predictive tools in identifying the waste rocks that have the capacity to generate AMD, hence its prevention. Two waste rock types of meta-diorite and quartzite found in a gold mining area in Tarkwa Ghana were investigated. The analytical procedures and tools were employed in identifying the waste rock with the potential of generating AMD in the study area.

## 2 Materials and Methods

### Mineralogy/Petrology of Rock Samples:

Fresh rock samples were taken from the working surface of a Pit in the study area for mineralogical study. Thin and polished sections of samples were prepared and studied under the microscope Lietz Laborlux 11 Pol. The samples were taken across a dyke as shown in Figure 2.1. Where DH1 is sample 1 Diorite Hanging Wall, QCH2 is sample 2 Quartzite-Contact Hanging Wall, DCH3 is sample 3 Diorite-Contact Hanging Wall, D4 is sample 4 Diorite, DCF5 is sample 5 Diorite-Contact Footwall, QCF6 is sample 6 Quartzite-Contact Footwall, QF7 is sample 7 Quartzite Footwall and Q8 is sample 8 Quartzite. The distance between each sample point is about 10 m.



**Figure 2.1** A Schematic Diagram showing the Order in which Rock Samples Were Taken (approximately 120 m wide).

**ABA Concept:** Using the ABA concept, NP and AP were calculated using standard procedures as proposed by (Sobeck *et al.*, 1978).

**NAG Test:** Diorite and quartzite rock samples taken from the study area, were dried, crushed to an average size of 4 mm and then pulverized to approximately 200 mesh (< 75  $\mu\text{m}$ ) sizes. 250  $\text{cm}^3$  of 15% hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) solution, previously acidified with nitric acid ( $\text{HNO}_3$ ), followed by pH adjustment to 4.0 by drop-wise addition on sodium hydroxide (NaOH), was added to 2.5 g of the pulverized rock sample in a 500  $\text{cm}^3$  wide mouth conical flask. The mixture was immediately covered with a watch glass and placed in a fume chamber for sometime. After effervescence, it was placed on a hot plate and gently boiled for about two hours until effervescence ceased. It was allowed to cool and then the pH was measured. The NAG capacity in Kg  $\text{H}_2\text{SO}_4$ /tonne was calculated using equation 2.1.

NAG Capacity (kg  $\text{H}_2\text{SO}_4$ /tonne)

$$= \frac{49 * V * M}{W} \quad 2.1$$

where;

V is the volume ( $\text{cm}^3$ ) of base NaOH titrated, M is the Molarity (moles/ $\text{dm}^3$ ) of base NaOH and W is the weight (g) of sample reacted.

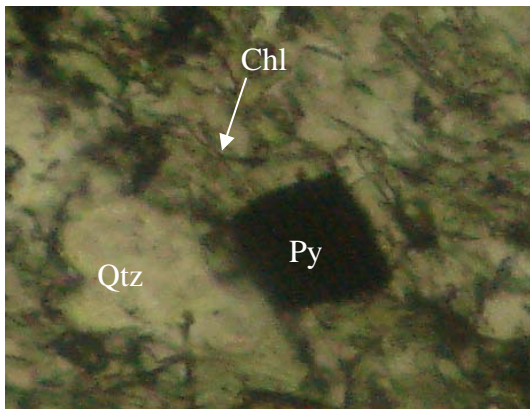
## 3 Results and Discussions

**Mineralogy of Rock Samples:** Two types of rocks identified for systematic investigation in the study area were meta-diorite (a dyke) and quartzite (the host rock).

The meta-diorite hand specimen was massive, dark green and medium-grained, with irregular alignment of amphiboles and subhedral plagioclase. It had occasional patches of carbonates (DH1 and DH4). The dark green colouration was due to higher carbonate alteration, which occurred also as spots or patches (DCF5). In sample DCH3, a vein comprising of quartz (Qtz), carbonate, chlorite (Chl) and alkali feldspar traversed the rock allowing chlorite and carbonate to

grow at the contact between quartz and host rock and along fractures. Sulphide content was lower in DH1 and D4 and moderate in DCF5 but higher in DHC3 where it clustered into a vein which was sub-parallel to a weak foliation marked by chlorite. The rock was less altered in samples DH1 and D4 and shows metamorphism and/or alteration in DCF5 and DCH3 where pyrite (Py) exhibits textures characteristic of last phase of alteration.

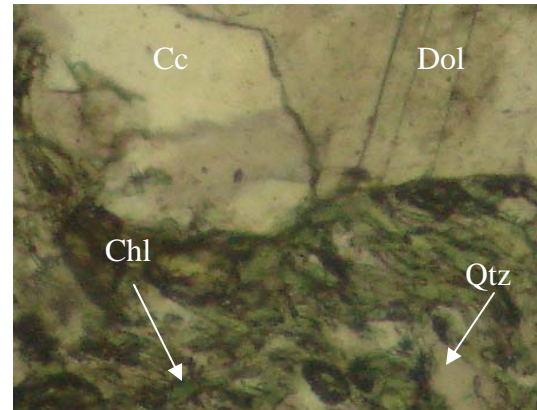
In thin section, the meta-diorite sample was generally medium grained with irregular alignment of subhedral plagioclase and occasional phenocrysts of feldspar. Ore mineral grains were prismatic, cubic, granular and were fine to coarse grained. They generally overprint all other minerals. They were barely adulterated by carbonates (Figure 3.1). In the polished section, the pyrite present was euhedral/cubic ( $0.015 \times 0.399 \text{ mm}^2$ ), bright yellow to white, clouded with gangue minerals, overprinted other minerals and was isotropic. Elsewhere, it was fractured with inclusions of gangue minerals (DCF5).



**Figure 3.1 Photomicrograph of Highly Altered Meta-Diorite (sample DCF5) Showing Overprint of Euhedral Pyrite (plane polarised light, x100).**

**Mineralogy of ACM in the diorite:** Dolomite (Dol) phase was coarse-grained ( $0.156 \times 0.097 \text{ mm}^2$ ), anhedral and occurs in lenses. It has two cleavages that intersect at  $56^\circ$  and shows twinkling. It was also impregnated with re-crystallised quartz and calcite (Cc) (Fig. 3.2). Elsewhere, dolomite shows alteration to calcite. Calcite was

colourless, fine to medium grained ( $0.01 \times 0.01 \text{ mm}^2$ ), anhedral to globular in shape. It weakly showed twinkling and occupied grain boundaries and fractures between primary and recrystallised quartz, and yet absent from triple junctions, suggesting pre- to syn-metamorphism. Dolomite and calcite are the main carbonate minerals providing alkalinity with NP of the former which was 1.1 times greater than that of the latter (Paktunc, 1999a).

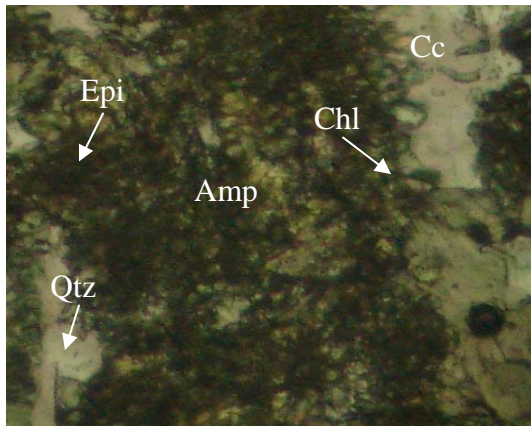
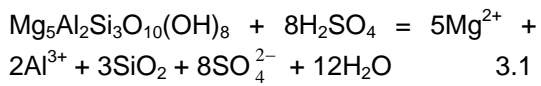


**Figure 3.2 Photomicrograph of Meta-Diorite (Sample DCF5) Showing the Relationship of some Metamorphic Minerals and Dolomite. Note Characteristic Twinkling of Dolomite replaced by Calcite (plane polarised light, x100).**

Plagioclase phase was medium grained ( $0.341 \times 0.049 \text{ mm}^2$ ), showing zoning and twinning with albite, carlsbad and carlsbad-albite. It was moderately altered to very fine sericite ( $0.008 \times 0.001 \text{ mm}^2$ ) and quartz. According to Paktunc 1999a, Ca and Mg bearing silicates such as plagioclase and hornblende have high acid neutralization potentials. Amphibole component present was medium grained ( $0.243 \times 0.020 \text{ mm}^2$ ), euhedral to subhedral with irregular alignment. It showed pleochroism from light green to dark green with parallel extinction and alteration to chlorite (Fig. 3.3). In DCF5, relic sheared amphibole was altered at the margin. The chlorite component was fine grained, platy and weakly pleochroic green. Since amphibole was being altered into chlorite, with time all amphibole will alter through weathering into chlorite hence their percentages are considered together. Chlorites are ACM (Addai-Mensah, 2007).



0.125 mole of chlorite will neutralise 1 mole of sulphuric acid as indicated in equation 3.1.



**Figure 3.3 Photomicrograph of Amphibole Highly Altered to Chlorite and Epidote in Sample D4. (Cross nicols x 100).**

**Mineralogy of APM in the diorite:** Pyrite ( $\text{FeS}_2$ ) was euhedral ( $0.015 \times 0.399 \text{ mm}^2$ ), bright yellow to white, clouded with gangue minerals and overprinted other minerals (Fig 3.1) and was isotropic. Magnetite ( $\text{Fe}_3\text{O}_4$ ) was tabular, corroded grey and overprinted by gangue minerals. When it is exposed to oxygenated environment, it oxidises to hematite which when hydrolysed is acidic.

The modal percent of the diorite is shown in Table 3.1. Measurements made on both thin and polished sections of the samples showed that the meta-diorite was made up of the following primary minerals: ~ 12 – 20 % plagioclase, about 30 – 40 % amphibole and about 2 – 6 % quartz. The secondary minerals include about 0.5 – 3 % pyrite, 7 – 12 % calcite, chlorite, sericite, fine quartz, alkali feldspar, actinolite, dolomite, epidote, tourmaline, magnetite and traces of gold

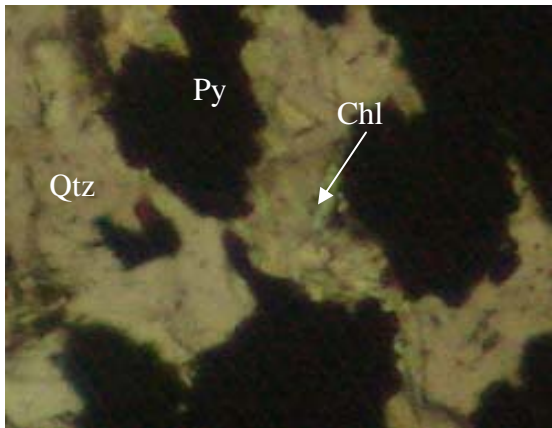
The quartzite hand specimen was greenish grey, bedded at 3 cm thickness. It consisted of alternations of sub-rounded, moderately sorted and medium to coarse-grained, poorly sorted sandstones. Dark grey quartz veins mark-bedding planes were also visibly present. Foliation was parallel to bedding

and was marked by chlorite (QCH2 and QF7, Table 3.2). Close to a recrystallised quartz vein was a light green zone where quartz appeared to be recrystallised. Quartzite near a strongly sheared zone contained milky quartz at grain margins. This probably was derived from recrystallised grey quartz (QCF6 and QF7). A glassy quartz vein cuts across earlier quartz vein and shear zone in QF7 and had high hydrothermal alteration minerals that occurred at all grain boundaries.

**Table 3.1 Modal % of Diorite**

Mineral/Sample No.	DH1	DCH3	D4	DCF5
Plagioclase	15	16	20	12
Amphibole + Chlorite	40	30	35	35
Quartz	6	2	5	3
Sericite	15	20	15	16
Fine quartz	9	11	10	15
Actinolite	-	-	-	1
Alkali Feldspar	-	2	-	-
Dolomite	-	-	-	1
Epidote	2	10	2.5	3
Calcite	10	7	12	10
Tourmalin	Trace	0.5%	Trace	<1%
Pyrite	1	0.5	0.5	3
Magnetite	1	-	-	-
Gold	Trace	Trace	-	Trace
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

In thin section, bedding was made up of alternation of medium to coarse grained sub-rounded to sub-angular, poorly sorted and grain supported sandstone; as against fine to medium grained sub-rounded to sub-angular, very poorly sorted and scattered medium to coarse grained pebbles. Foliation in the rock was weakly defined by stretched quartz grains (QCH2) and/or chlorites (QF7 and Q8). Rounded quartz grains occurred in QCH2 and Q8 and less common in QCF6 and QF7. In QCF6, hydrothermal alteration was much intense in zones that it gave an impression that entrained fluids permeated voids/matrix. Probably sample QF7 had more matrix than QCF6. Some ore minerals which overprinted other minerals are evident (Fig. 3.4).



**Figure 3.4 Photomicrograph of Quartzite (Sample Q8) Showing Overprints of a Cluster of Ore Minerals (plane polarised light, x1000).**

**Mineralogy of ACM in the quartzite:** Plagioclase (Oligoclase) phase was medium grained and sub-angular to sub rounded. It showed albite and calcsbad-albite twinning and was weakly altered to sericite and fine quartz granules. Chlorite was flaky, light green and weakly pleochroic from light green to green. It occurred at grain boundaries and overprinted all other minerals. It also marked foliation (Q8).

**Mineralogy of APM in the quartzite:** The pyrite ( $\text{FeS}_2$ ) component of the rock was anhedral and bright yellow to white in colour, clouded with other overprinting, gangue minerals (Fig 3.4). In polish sections, dimorphic marcasite ( $\text{FeS}_2$ ) phase which was fine and granular, was also indicated. Pleochroism was from yellow to green and had strong anisotropism of greenish yellow with pinkish tint. Since it appeared overlapped by secondary minerals, it was likely to be a primary sulphide. Marcasite has been noted to have a higher rate of acid generation under oxidising condition than crystalline pyrite (Marcus, 1997).

Pyrite is the most important sulphide mineral associated with AMD. It can occur in cubic (euhedral) or framboidal (anhedral) habits. Fine, framboidal pyrite has a significantly higher rate of acid generation when exposed to molecular oxygen rich aqueous environment than coarse grained euhedral pyrite (Marcus, 1997). The presence of anhedral pyrite in the quartzite makes it

more prone to acid generation. Furthermore, since the quartzite contained primary quartz, whilst the meta-diorite contains mostly secondary quartz, the latter would weather faster than the former since secondary quartz is an alteration product of primary quartz (PersCom, 2006). This is consistent with the fact that by the time the quartzite weathered, there will be no residual ACM in the meta-diorite to neutralise the acid generated. Thus, when the two waste rock types are stored at unsealed waste dumps, different rates and extent of acid generation will be experienced over a given period of time.

The modal percent of the mineral phases in the quartzite are shown in Table 3.2 where the percentage determined for the primary minerals were about 50 – 60 % quartz, 13 – 20 % plagioclase and about 5 – 8 % amphibole. The secondary minerals include about 2 – 15 % pyrite, biotite, sericite, epidote, tourmaline, magnetite and traces of marcasite. The photomicrograph of quartzite is shown in Figure 3.3.

**Table 3.2 Modal % of Quartzite**

Mineral/Sample No.	QCH2	QCF6	QF7	Q8
Quartz	60	50	50	55
Plagioclase	20	15	15	13
Amphibole + Chlorite	5	5	8	6
Boitite	-	1	-	-
Sericite	1	2	8	5
Epidote	10	15	10	5
Tourmalin	1	10	4	1
Pyrite	2	2	5	15
Magnetite	1	-	-	-
Marcasite	Trace	Trace	-	-
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

**ABA Concept:** The various NP and AP of individual ACM and APM are calculated and presented in Table 3.3. The NP/AP ratio of 16:1 of the diorite means it has enough ACM to buffer the effect of acid generation, whilst that of the quartzite 1:1 is well below the limit of 4:1 for a complete neutralization of  $\text{H}_2\text{SO}_4$  from a pyritic source (Sobeck *et al.*, 1978). This, therefore, underscore its high potential to generate AMD.

**Table 3.3 ABA of the Rocks**

MINERAL	DIORITE	QUARTZITE
Quartz		
Plagioclase	0.057	0.057
Amphibole + Chlorite	0.063	0.011
Boitite		
Sericite		
Epidote		
Tourmalin		
Pyrite	0.010	0.050
Magnetite	0.004	0.004
Marcasite		0.008
Fine quartz		
Gold		
Actinolite		
Calcite	0.098	
Dolomite	0.008	
Alkali feldspar		
<b>NP</b>	<b>0.226</b>	<b>0.068</b>
<b>AP</b>	<b>0.014</b>	<b>0.062</b>
<b>NNP</b>	<b>0.212</b>	<b>0.006</b>
<b>NP/AP</b>	<b>16.14</b>	<b>1.097</b>

**NAG Test:** The pH of the meta-diorite sample was slightly above 4, meaning there has not been any acid generation. The acidity of the quartzite, on the hand, was significantly lower, giving the indication of acid generation. Hence, to find its NAG capacity it was titrated against NaOH to pH of 4.5. The NAG capacity in Kg H<sub>2</sub>SO<sub>4</sub>/tonne of the quartzite was calculated to be 8, confirming its higher acid generating capacity.

#### 4. Conclusion

Two gangue or waste rock types, one meta-diorite and the other, quartzite, were identified where the latter led to AMD. The presence of anhedral pyrite in the quartzite and the lower content of acid consuming chlorite phase made it more prone to acid generation; furthermore since the quartzite contained primary quartz whilst the meta-diorite contained mostly secondary quartz, the latter will weather faster than the former. Due to significant mineralogical composition differences and concomitant weathering rates, there will be little or no residual ACM in the meta-diorite to neutralise the acid generated. When the two rock types are stored together in a waste dump and exposed to molecular oxygen rich aqueous environment, then theoretically, the waste will be acid generating over a long period of

time. The crystallo-chemical characteristics and mineralogical composition of quartzite rock render it more conducive to acid generation.

The NP/AP ratio of 16:1 of the meta-diorite rock means it has enough ACM to buffer the effect of acid generation, whilst that of the quartzite being 1:1, is well below the limit of 4:1 for a complete neutralization of H<sub>2</sub>SO<sub>4</sub> from a main reactive pyritic source (Sobeck *et al.*, 1978). Therefore, quartzite rock intrinsically has a high potential to generate AMD. Moreover the NAG capacity in Kg H<sub>2</sub>SO<sub>4</sub>/tonne of the quartzite was calculated to be 8 confirming the acid generating capacity of the quartzite.

Kinetic test should be conducted on pilot bases to determine the rate of acid generation of the quartzite.

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# The Influence of Fiber Characteristics of Nigerian Grown *Bambusa Vulgaris* (Schrad) on its Relative Density and Burst Strength

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**Abstract-** Variations in strength properties of *Bambusa vulgaris* (Schrad) with increasing culm height was looked into, considering its fiber characteristics with particular reference to the presence and absence of nodes. At the internode, investigations revealed an increase in fiber length with increasing culm height (2.78mm-3.73mm from base to top) while fiber diameter behaved conversely, showing a reduction from base to top (0.033mm-0.013mm). Relative density and burst strength had a similar trend as they both showed reduction in values from base to top (0.62-0.51 and 8.2KN/mm<sup>2</sup> – 5.3KN/mm<sup>2</sup> respectively).

At the node, investigations revealed a reduction in fiber length from base to top (1.79mm-1.39mm) while fiber diameter increased from base to top (0.023mm-0.031mm). Relative density showed a reduction from base to top (0.64-0.52) while burst strength had a similar trend having a range of above 11KN/mm<sup>2</sup>-5.4KN/mm<sup>2</sup> from base to top. At the node, statistical analysis revealed a strong direct correlation between fiber length and relative density while fiber diameter a weak and inverse relationship. Burst strength showed a direct but weak relationship with fiber length while it had an inverse and weak correlation with fiber diameter. At the internode, a weak and inverse relationship was established between density and fiber length while fiber diameter showed a direct but weak relationship. Burst strength and fiber length showed a strong but inverse correlation while fiber diameter and burst strength revealed a direct and significant correlation.

In conclusion, bamboo strength at the nodes is influenced more by fiber length while fiber diameter holds the key to bamboos' strength at the internodes.

**Keywords-** fiber length, fiber diameter, relative density, burst strength

## 1. INTRODUCTION

Bamboo belongs to a unique group of gigantic grasses of the family Poaceae or Graminae. Bamboo is a versatile fast growing species which has been described as segmented and complex subterranean system [1]. It attains its full length in 2 to 3 months and its maturity in 2 to 3 years [2]. Bamboos can grow at sea level to as high as 3000 meters above sea level and they are well adapted to growing in plains, hilly and high altitude mountain regions and in most soil types except desert, marsh and alkaline soils. The climatic requirements of bamboo for proper growth in most bamboos are warm climate, abundant moisture and productive soil [3].

Even though it grows in different parts of the world, it is found in abundance in most Asian countries and as a result of its ready availability, easy usability coupled with

high strength to weight ratio, it plays a vital role in the rural economy of many countries [2]. Bamboo is fast growing, quick maturing, hardy, flexible, strong and renewable. Its reproduction rate is outstanding as it is said to be the fastest growing woody plant in the world [4, 5]. Some species are reported to have a growth rate of about 1m per day [4].

Having been recognized as a fast growing natural resource with better qualities in physical and mechanical properties compared to most wood species, they are said to be good substitutes for wood [6]. Bamboo species available in Nigeria are *Bambusa vulgaris* (Schrad), *Oxytenanthera abyssinica* (Munro), *Guadella macrostachys* (Pilger), *Guadella densiflora* (Clayton) and *Guadella humilis* (Pilger) of which *Bambusa vulgaris* is predominant [7].

The reason behind bamboos' strength is that each strand of the grain (fiber) is perfectly straight [8]. Bamboo fibers contribute about 60 - 70% by weight of total culm tissue [9] and their length shows considerable differences between species as well as within one culm [10]. The percentage of fibers is higher in the outer third of the wall than in the inner as well as in the upper part of the culm, compared to the base [9]. The properties of bamboo also depend on its microstructure [3].

Reference [11] noted that the physical and mechanical properties of a bamboo culm is directly linked with its anatomical structure reporting that specific gravity which varies between 0.5 to 0.9 depends mainly on the fiber content, fiber diameter and cell wall thickness. As the culm matures, it increases due to the thickening of fiber walls and it varies within culm and between species.

Reference [12] evaluated some physical properties of *Dendrocalamus hamiltonii*, a bamboo species found in Bangladesh and found that moisture content, specific gravity and volumetric shrinkage vary significantly with height, presence of node and branch. The node of the culm was found to have higher specific gravity but lower moisture content and volumetric shrinkage while the specific gravity of the culm was found to be higher than that of the branch. Reference [3] worked on the physical and mechanical properties of *Dendrocalamus strictus* also known as Calcutta bamboo. Results from his research showed that average relative density of *Dendrocalamus strictus* is 0.643. This is higher than that of some timber species used for composites production e.g. Yellow poplar and Douglas fir with relative densities 0.42 and 0.48, respectively.

Reference [13] attributed the density of bamboo (which is said to vary from 500 to 800kg/m<sup>3</sup>) to anatomical structure of the culm which for example is the distribution

and quantity of fibers around the vascular bundles. Furthermore, he stated that density decreases from the outer part to the inner portion while maximum density is obtained in about 3 year old.

Furthermore, [9] reported that the fiber length of different species show significant differences as well as the fiber diameter. Some species are known to have shorter fibers some of which are *Phyllostachys edulis* (1.5 mm), *Phyllostachys pubescens* (1.3 mm), while longer ones include *Dendrocalamus giganteus* (3.2 mm), *Oxytenanthera nigrociliata* (3.6 mm), and *Dendrocalamus membranaceus* (4.3 mm). He also stated that fiber length influences density and strength properties e.g. elastic bending stress while the number of vascular bundles per mm<sup>2</sup> is closely related to elastic modulus. Moreover, he noted that the shorter fibers are always at near the nodes.

Owing to its pipelike nature and considering the possibility of using bamboo in small scale irrigation and drainage applications, there is need to investigate these trends and the extent to which the fibers of *B. vulgaris* (Schrad) affect these properties (burst strength and relative density).

## 2. MATERIALS AND METHODS

After examining the physical conditions of potential culms, experimental samples were derived from mature and healthy ones felled at the Olodo forest in Egbeda Local government area of Ibadan, Nigeria. The culms were measured and then divided into three equal parts in line with the recommendations of [14]. They were labeled "Base", "Middle" and "Top". Samples were collected from these with some containing nodes at mid-span within the test region while others were taken from the internodes only.

The experiments were done in two stages the first being investigations into the fiber characteristics of the culms while the second involved the determination of relative density and burst strength; considering the presence or absence of nodes.

### 2.1 Fiber Characteristics

The bamboo specimens were cut into pieces of 2 x 1 cm dimensions and boiled in water for 24 hours to soften it after which they were sliced into small pieces and macerated using Schluz's fluid (a mixture of equal volumes of 10% chromic acid and 10% nitric acid) for two days. The macerates were preserved in 50% ethanol after they had been washed in five changes of water. From these, fiber length (FL) and fiber diameter (FD) were determined using the ocular/stage micrometer.

### 2.2 Relative Density (RD)

This was determined in accordance with the recommendations of [14]. The criteria used were:

$$\text{Ovendry mass/Green volume}$$

The volume was determined by water displacement method. The sampling intensity was 12 samples apiece and the mean was used to represent the relative density of the portion from which the samples were taken from. The test was carried out at the Agricultural and Environmental Engineering laboratory, University of Ibadan.

### 2.3 Burst Strength (BS)

This was performed to determine the maximum pressure in KN/mm<sup>2</sup> at which a bamboo section of 300 mm length would burst taking note of its thickness and moisture content. The samples were taken from the top, middle and base portions of the culm to see the differences in their burst strength with particular reference to the nodes and internodes.

The testing criterion was based on the principle of equipment used in testing burst strength of very large diameter steel pipes in some factories. The jig fabricated for the test incorporated an external water pump to serve the purpose of introducing water into the bamboo pipe which has been held tightly by the jig to prevent water leakage. Burst pressure was read directly from the pressure gauge in the jig.

### 2.4 Statistical Analysis

The Pearson's Product Moment Correlation Coefficient was used to analyze the correlation between the fiber characteristics (i.e. fiber length and diameter), density and burst strength of different portions of the culm as well as to establish the strength of these relationships.

## 3. RESULTS AND DISCUSSION

Tables 1 and 2 give the average values derived fiber characteristics and strength properties of *B. vulgaris* (Schrad):

Table 1  
Mean Values of Data Obtained from Specimens from the Internode

	FL (mm)	FD (mm)	Relative Density	Burst Strength (KN/mm <sup>2</sup> )
Base	2.78	0.033	0.62	8.2
Middle	3.41	0.018	0.59	6.9
Top	3.73	0.013	0.51	5.3

Table 2  
Mean Values of Data Obtained from Specimens from the Node

	FL (mm)	FD (mm)	Relative Density	Burst Strength (KN/mm <sup>2</sup> )
Base	1.79	0.023	0.64	11
Middle	1.74	0.028	0.6	8
Top	1.39	0.031	0.52	5.4

### 3.1. Variations in FL, FD, RD and BS with Increasing Culm Height

Figures 1-4 show the varying trends in FL, FD, RD and BS of *B. vulgaris* respectively. Observations reveal that FD, RD and BS at the nodes reduces with increasing culm height, being highest at the base and lowest at the top while FL behaves conversely; increasing with increasing culm height. At the internodes however; FL, RD and BS reduces with increasing culm height, being highest at the base and lowest at the top while FD behaves conversely; increasing with increasing culm height.

In comparison with the values obtained from samples taken from the node, RD and BS from the internode had the same trend while FL and FD behaved conversely, FD being lowest at the top while FL was highest at the top. RD variation trends is comparable with what is available for most tropical wood species but is contrary to what is reported for some other bamboos in which RD was found to be highest at the top and lowest at the base [15]. Also, average RD values obtained fell within the range given by other researchers such as reference [16] who stated a range of 0.5 to 0.8. Similarly, BS values obtained are similar to what was reported by reference [17].

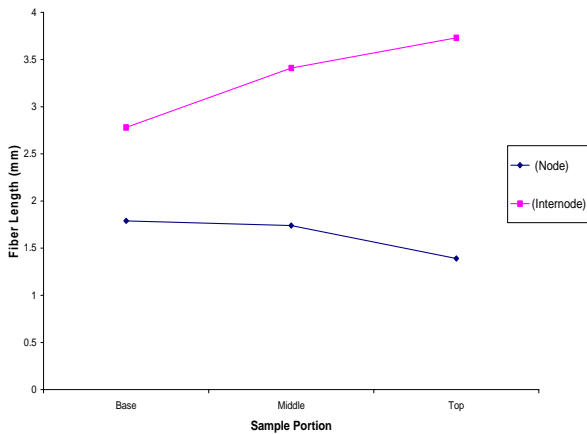


Figure 1: Variations in Fiber length of Bambusa vulgaris (Schrad) with increasing culm height

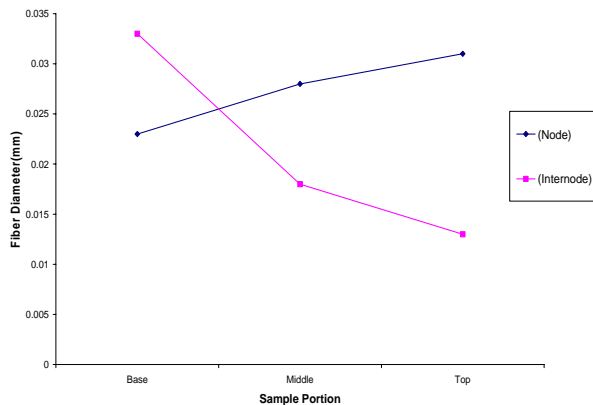


Figure 2: Variations in Fiber Diameter of Bambusa vulgaris (Schrad) with increasing culm height

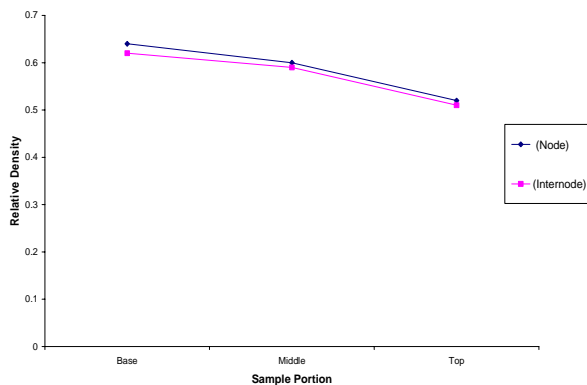


Figure 3: Variations in Relative density of Bambusa vulgaris (Schrad) with increasing culm height

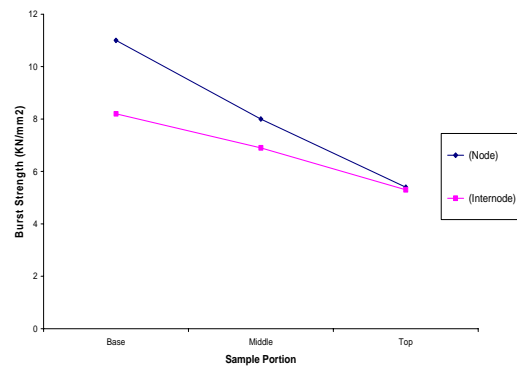


Figure 4: Variations in Burst strength of Bambusa vulgaris (Schrad) with increasing culm height

### 3.2 Correlation between Fiber Characteristics and Strength Properties

Statistical analysis was performed to know the effect of FL and FD on the RD of the *B. vulgaris* and this yielded a Pearson's correlation coefficient " $r^2$ " (at  $P < 0.05$ ) gave values of 0.76 and -0.397 for FL and FD respectively for the node. This implies that FL has a direct and significant relationship with nodal relative density (i.e. as FL increases, RD increases) and FD behaves conversely (i.e. as FD increases, RD decreases) whereas, a different pattern was established at the internodes as " $r^2$ " values were -0.103 and 0.470 for FL and FD respectively. This implies an insignificant and inverse relationship between FL and relative density (i.e. as FL increases, RD decreases) while FD similarly has an insignificant but direct relationship with relative density at the internode (i.e. as FD increases, RD increases).

Similarly, statistical analysis on the effect of FL and FD on the BS of *Bambusa vulgaris* yielded a Pearson's correlation coefficient " $r^2$ " (at  $P < 0.05$ ) of 0.406 and -0.488 for FL and FD respectively for the node. This implies that FL has a direct but weak relationship with nodal BS (i.e. as FL increases, BS increases) while FD both indirect and weak correlation with it (i.e. as FD increases, BS decreases).

Analysis at the internodes yielded Pearson's correlation coefficient " $r^2$ " (at  $P < 0.05$ ) of -0.674 and 0.723 for FL and FD respectively. This implies that FL has an indirect but strong correlation with internodal BS (i.e. as FL increases, BS decreases) while FD has both direct and strong correlation with internodal BS (i.e. as FD increases, BS increases). Figures 5 and 6 show the confidence interval standard error at 95% for values obtained from the node and internode respectively.

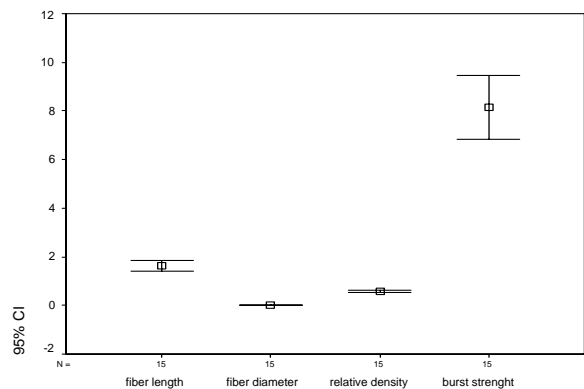


Figure 5: 95% Confidence Interval Standard Error for Values obtained from the Node



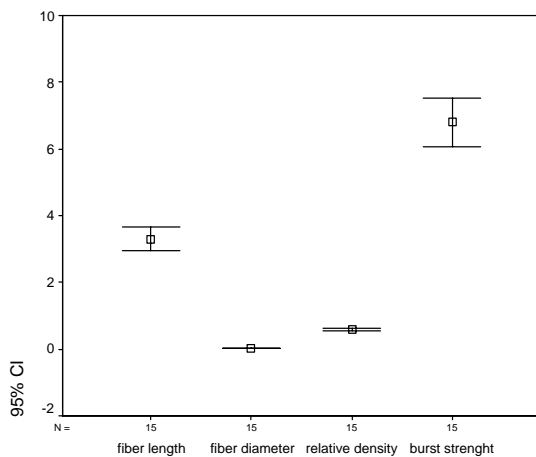


Figure 6: 95% Confidence Interval Standard Error for Values obtained from the Internode

#### 4.0 DISCUSSION

Observations from this study have shown that *B. vulgaris* possess a microstructure that aids its relative density and ultimately its strength. The dense arrangement of fibers at the nodes and generally at the base including parts of the middle portions constitutes reinforcement in these areas.

In general, fiber length is higher at the internode than at the node while fiber diameter is greater at node. The high concentration and compact arrangement of fibers at the node is responsible for the higher relative density of the node. Reference [18] noted that fiber length varies from species to species but it usually ranges between 1.5 to 3.5 on the average confirming that content and length influence the relative density which for bamboo ranges from 0.5 to 0.9. The fiber length of *B. vulgaris* (Schrad) obtained from this research is relatively higher than what was quoted by [3] who gave a range of 0.006-0.008 mm even though he did not specify whether it is *B. vulgaris* (Schrad) or *B. vulgaris* (vitata) otherwise known as Hawaiian gold.

Average fiber length value of 2.3 mm quoted by [6] falls within the range obtained for the internode while [19] gave a range of between 1.74-3.76 mm. Reference [18] also confirmed that bamboo fibers are shorter at the nodes and they have great influence on culms' mechanical strength due to higher specific gravity.

The presence of nodes is an advantage to the strength of the culm in withstanding burst pressure. Generally, the higher strength values found at the nodes can be accounted for by the increased density at the region (which has been attributed to higher concentration of fibers). Observations made while converting the culms into test specimens confirmed this as there was more resistance to cutting and conversion at the nodal areas than at the internodes.

#### 5.0 CONCLUSION

It can be concluded that fiber length at the nodes has positive effect on both relative density and burst strength while fiber diameter has a negative effect on them. At the internodes however, the reverse is the case as fiber diameter has positive effect on relative density and burst strength while fiber length has a negative effect on them. Also,

relative density has positive correlation with burst strength as portions of the culm with higher density recorded higher burst strengths.

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## **CONFERENCE DIVISION:**

Natural Sciences (Medicine, Physics, Chemistry,  
Mathematics, Biology, etc.)

# Screening of Intercellular Adhesion Molecule-1 Mutation In Children With Cerebral Malaria In Central Sudan

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**Keywords:** ICAM-1; cerebral malaria, children, Sudan

**Abstract:**

Malaria remains a major health problem in many countries; cerebral malaria is one of the complications of malaria. Intercellular adhesion molecule-1 (ICAM-1) act as a receptor for *Plasmodium falciparum* infected erythrocytes (PRBCs), located in the endothelial tissue including brain. Together with many others, adhesion of this receptor to (PRBCs) in the brain leads to accumulation of this complex in the cerebral vessel and obstructs blood flow, so development of cerebral malaria.

The study was conducted in 50 children confirmed to have cerebral malaria in central Sudan. The genetic analysis of ICAM-1 gene was compared with 50 children from school pupils with no history for cerebral malaria.

The incidence of cerebral malaria in this study is influenced by geographic, age, and ethnic factors with no gender variation. Ages from 4 – 8 years showed the highest incidence for cerebral malaria, about 68% of study group belong to four tribal stocks, [(28%) belong to Johayna tribal stock.

Four (8%) of study subjects died, 42(84%) were discharged alive and healthy, while 4(8%) survived with neurological sequelae (Hemiparesis, Hemiplegia, Aphasia, and Quadriplegia and Blindness).

The use of allele specific PCR (ASP) for genetic analysis in this study, indicated that the heterozygous (K29/M29) was 26% in CM patients and 12% in the control group, while only one (2%) mutant homozygous (M29/M29) was detected in CM patients group, but was not found in the control group. The distribution of alleles between subjects and control has shown significant difference, and all subjects who carried mutant allele (heterozygous and homozygous mutant) had 3 times susceptibility to CM than the other group, ( $P$ -value= 0.038, Odd Ratio = 2.5; 95% CI 1.011 - 6.181). The incidence of ICAM-1kilifi allele frequency in the study group was 11%, and this might increase the risk for susceptibility to cerebral malaria.

**Introduction:**

Malaria continues to be a major health problem in many parts of the world, with over 2400 million people at the risk of infection [1]. Mortality from malaria in African children under 5 years is 36/1000 per year [2]. Malaria results in up to 2.5 million deaths annually, with young children and pregnant women at greatest risk [3]. The patterns of pathology differ with changes in the degree of endemicity (Miller *et al.*, 1994). Cerebral malaria (CM) causes death in children and non immune adults [4].

In Sudan, malaria is the leading cause of morbidity and mortality, with an annual estimated 7.5 million clinical cases and 35,000 deaths. *P. falciparum* is the dominant parasite and the principal mosquito vectors are *Anopheles arabiensis*, *A. gambiae* and *A. funestus* [5]. Ninety percent (90%) of all malarial attacks are caused by *P.falciparum*, which causes the most severe form of disease and deaths attributable to malaria in Sudan [6]. High seasonal rainfall, variation in temperature and humidity which is observed during the rainy season in Sudan can favor mosquito breeding resulting in strong seasonal transmission. Malaria risk is present all over the country although too different degrees. In the northern, eastern, and western states, malaria is mainly low to moderate with predominately seasonal transmission and epidemic outbreaks. In southern Sudan, malaria is moderate to high or highly intense generally with perennial transmission. Although, in Sudan, whole population may be at risk to contracting the disease when they travel to the high risk areas, the following special groups are at higher risk to malarial infection; travelers from malaria free areas (visitors), pregnant women (specially during their first pregnancy), children in steroid or immunosuppressive drugs, expatriates and Sudanese returning from non- malarious areas [7]. As well as being receptor for parasite adhesion, ICAM-1 (CD54) also play a major role in normal immunofunction [8]. The various host

functions are mediated by specific interaction with a number of ligands, principally leukocyte function associated antigen 1 (LFA-1) [8], the plasma protein fibrinogen also binds to ICAM-1, [9;10], through its role in promoting cell-cell contacted and the resulting intercellular signaling, ICAM-1 facilitates leukocyte proliferation and transmigration across activated endothelium. ICAM-1 also has a role in diverse spectrum of disease including pathogen adhesion, for example *P. falciparum*- infected erythrocyte [11; 12]. Moreover, a number of inflammatory disorders such as septic shock [13], and autoimmunity [14] are involved.

*Methods:*

The study was carried out in an endemic area. Patients with *falciparum* malaria who had unrousable coma, not attributed to any other causes, this coma persisted for more than 1 hour after the convulsion; with asexual malaria parasites demonstrated on a peripheral blood were recruited from hospitals located in central Sudan cities (Wad Medani, Sinnar, and Singa). Fifty children with age and sex match were selected as a control from different schools in the three cities, or from patients from the three hospitals who were admitted for other diseases than CM and have no history for CM.

*Allele specific PCR (ASP):*

Also called the amplification refractory mutation system (ARMS). Is a simple method for the detection of any known point mutation or small deletion or insertion [15; 16].

In this method, we used two separate and complementary PCR amplifications for each sample; one was specific for ICAM-1Kilifi allele and the other for ICAM-1 ref allele, using three primers. One was common for the two reactions, and other two, one for each reaction, which differs from each other at their 3' ends, specific for the particular variant base (A/T).

*PCR reactions:*

The total volume of the PCR reactions was 30µl, containing 4µl genomic DNA, 10 picomoles for each primer of the two allele, 1picomole for internal control primers, 200µM dNTPs (dATP, dGTP, dCTP, and dTTP), 2.5µl from 10 x Taq Gold Buffer (100mM Tris HCl, pH 8.3, 500 mM KCl, 15 mM MgCl<sub>2</sub> and 0.01 % (w/v) gelatin (Perkin Elmer Cetus), 2 U AmpliTaq Gold™ polymerase (Perkin Elmer Cetus), and completed to the total volume with deionized water. 150bps of DNA fragment was PCR amplified using designed primers; primer1 common for both

reactions, primer2 for ICAM-1<sup>Kilifi</sup> reaction only, and primer3 for ICAM-1<sup>ref</sup> reaction only, also 330bps of internal control was amplified. The PCR condition was; 94°C as initial denaturation for 3 minutes, followed by 35 cycles of 94°C as melting temperature for 45 minutes, 64°C annealing for 45 minutes, and 72 as extension for 45 minutes. Then a final step in 72°C for 3 minutes as a final prolongation.

Table 1 Primers used for PCR amplification

Primer name	Primer sequences
Primer1	5'TGCCTGTCGCCTCTTCCCT3'
Primer2	GGTCTCTATGCCCAACAAC▼A
Primer3	GGTCTCTATGCCCAACAAC▼T

10µl of PCR product electrophoresed at 100v for 15 minutes in 2% agarose gel in 0.5xTBE (Tris base boric acid EDTA) buffer (running buffer), loaded with 5µl bromo phenol blue (loading buffer).The gel and running buffer contained ethidium bromide (0.5µg/ml), which stained the DNA before placed the gel on a UV light for visualization and finally photographed.

ICAM-1<sup>ref</sup> homozygous (Wild type- K29/K29) characterized by the amplification produced only in the ICAM-1<sup>ref</sup> reaction, a heterozygote (K29/M29) characterized by the amplification produced in the both reactions and ICAM-1<sup>Kilifi</sup> homozygous (Homozygous Mutant- M29/M29) characterized by the amplification produced only in the ICAM-1<sup>Kilifi</sup> reaction.

*Results:*

Fifty children were diagnosed as having cerebral malaria. Eighteen (36%) from Wad Medani Pediatric Teaching Hospital, 27 (54%) from Sinnar hospital, 5 (10%) from Singa hospital. All patients with blood film negative for asexual stages or having other diseases that may had contributed to the same complication of CM were excluded from the study. The highest incidence of disease was shown between the ages from 4 - 8years. 56% were males, 44% were females, and there is no significant difference between them ( $P=0.71$ ). The study subjects extended along 10 different tribal stocks, 68% of them belong to four tribal stocks, [(28%) belong to Johayna tribal stock, (16%) to Gaalian tribal stock, while (12%) belong to Nuba and Nigerian tribal stocks]. Four (8%) of the children were died, 42(84%) were discharged alive and

healthy, while 4 (8%) survived with neurological sequelae (Hemiparesis, Hemiplegia, Aphasia, and Quadriparesis and Blindness). ICAM-1 genotype was screened by ASP method. The wild type (K29/K29) was 72% in CM patients and 88% in their control, the heterozygous (K29/M29) was 26% in CM patients and 12% in the control group, while only one (2%) mutant homozygous (M29/M29) was detected in CM patients group, but was not found in the control group. There was no significant difference in the distribution of ICAM-1 genotypes, but the difference was found between the wild type and the carrier to mutant allele (heterozygous and homozygous mutant) with  $P$ -value = 0.046. The allele frequencies in the control group (n=50) were 0.94 for (K29), and 0.06 for (M29), and in CM subjects (n=50) were 0.85 for (K29), and 0.15 for (M29). The distribution of alleles between subjects and control has shown significant difference, and all subjects who carried mutant allele had 3 times susceptibility to CM than the other group ( $P$ -value = 0.038, Odd Ratio = 2.5; 95% CI 1.011 - 6.181) (Table 2 and 3).

Table 2 The genotype frequencies of ICAM-1 in CM patients and control

ICAM-1 Group	Genotypes		
	K29/K29	K29/M29	M29/M29
CM Patients	36(72%)	13(26%)	1(2%)
Control	44(88%)	6(12%)	0(0%)

Table 3 The allele frequencies of ICAM-1 in CM patients and control

ICAM-1 Group	Genotypes		Alleles	
	K29/K29	K29/M29+ M29/M29	K29	M29
CM Patients	36(72%)	14(28%)	0.85	0.15
Control	44(88%)	6(12%)	0.94	0.06
$P$	0.046		.038	

#### Discussion:

The distribution of study subjects shown that Sinnar was the highest incidence with CM compared to other two hospitals 54% (n=27). The highest age exposed to the disease was from 4 – 8 years in these children without any difference observed between sex and this may be attributed to the low immunity of these children most tribal stock had CM clustering (28%), while Beja, Nilotic, and Moroccan and Egyptian

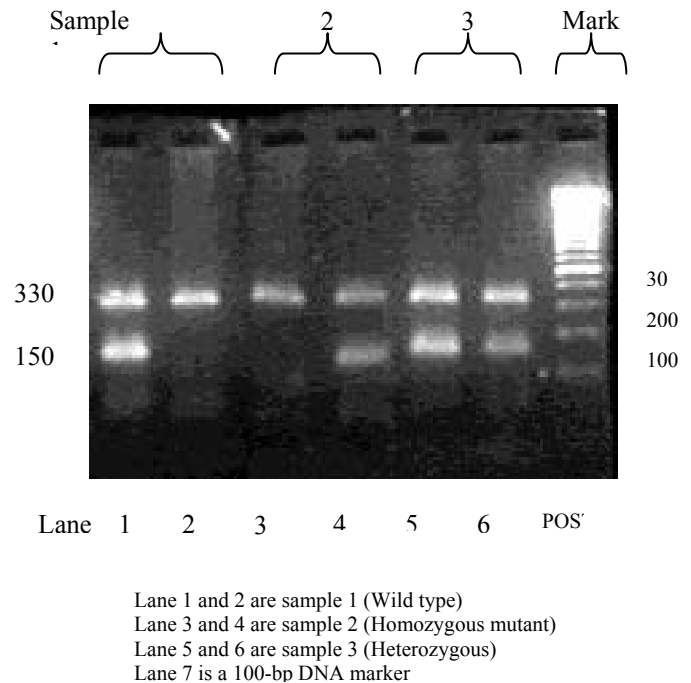


Fig 1 Detection of ICAM-1 polymorphism using ASP method

had the less clustering (2%). Confirming the distribution of the disease influences by geographic, age, and ethnic factors. Recently a mutation that caused A to T transversion in the ICAM-1 gene, causing a Lys to Met change in the amino acid sequence was recorded [17]. The distribution of this mutation was found in different populations in Africa and North America. In the North American population, it was found predominantly in African-Americans (41%), (n=41) [18]. No Caucasian was found to carry the ICAM-1 gene mutation [17]. In a two Asian populations studied in Papa New Guinea and Thailand, only in the Papa New Guinea was the ICAM-1 gene mutation found. No Thai had the mutation.

In contrast this mutation was found in Sudanese populations as shown in our study in frequency of (20%), 19% (n=13) were heterozygous, 1% (n=1) were homozygous. This agrees with the data from the study in Kenya, Nigeria, Gabone, and Papa New Guinea, indicated this mutation is predominant in the African populations at a high frequency comparable with the other populations. The results obtained from our study suggest that group carrier to this mutation is highly susceptible to CM than the other group ( $P$  = 0.046), this is an agreement with a recent study in Kenyan children which found this mutation had a high susceptibility to cerebral malaria. In a

study carried in the Gambian children, no correlation between ICAM-1 gene polymorphism and disease severity was found. Other study in Gabonese children, found this mutation protect against severe malaria. The exact causes for these discrepancies in these studies is return to geographic differences of *P. falciparum* strains that bind with different affinities to endothelial cells with this mutation. In the Gabon study compared patients had severe malaria with patients had mild malaria, the incidence of CM was rather low (n = 9), three were heterozygous and six were wild type, the influence of ICAM-1 may be by other genetic factors in other group of severe malaria than CM. It has been hypothesized that the intercellular adhesion receptors used by normal cells could also be operative in the spreading of circulating malignant cells to target organs; carriers to this mutation is resistant to the development of lymphoid malignancy compared with wild-type control.[19].

The presence of this mutation at a high frequency in populations in the malarious regions of Africa is explained by a protective effect to pathogens other than *P. falciparum*, such as bacterial infections, etc...

#### Conclusion:

The African mutation (ICAM-1kilifi) is predominant in Sudanese population as 20% for carriers and 0.11 for allele frequency. This allele increases the risk for susceptibility to cerebral malaria three times than the other allele (P= 0.038, Odd Ratio = 2.5; 95% CI 1.011, so we recommend the encouragement of experiences exploring vaccine, that may weaken the binding between ICAM-1 and infected erythrocytes. Since this mutation is present at a high frequency in populations in the malarious regions of Africa including Sudan, we think that it has a protective effect to pathogens other than *P. falciparum*, so we strongly recommend study of this mutation with other pathogens.

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## COMPARATIVE MICROBIOLOGICAL AND NUTRITIONAL STUDIES OF YOGHURTS FROM TIGERNUT, COCONUT AND SOYBEANS MILK

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**Abstract** - Yoghurts were prepared from tigernut (*Cyperus esculentus*), coconut (*Cocos nucifera*) and soybeans milk using pure culture of lactic acid fermenting organism *Lactobacillus bulgaricus*, *Streptococcus thermophilus* and *Streptococcus lactis*, in singles and in their combinations and the resulting yoghurts samples compared with commercial yoghurt. Proximate analysis revealed that pH of yoghurt samples decreased as the titratable acidity increased. Yoghurt produced from Soya beans milk fermented singly with *S. lactis*, *L. bulgaricus* and *S. lactis* resulted in yoghurts that are comparable to Fan milk yoghurt in all parameters. Protein values of samples ranged between 2.00% - 2.79% while the fat content ranged between 5.82% and 4.87% respectively. Calcium content of the prepared yoghurts was highest in Tigernut milk (0.36%) while Coconut yoghurt had the highest value in magnesium (0.16%). Sensory evaluation showed that yoghurts from plant milk were accepted as substitute to commercial yoghurt.

**Keywords:** Microbiology, nutritional, yoghurts, tigernut, coconut, soybeans

### I. INTRODUCTION

Milk is the normal secretion by the mammary gland of female animals for the nourishment of their young and contains a balanced array of essential nutrients that are palatable and digestible [1]. Animal milk is the most widely consumed all over the world and is composed of 87.7% water 3.60% fat 3.29% protein 0.7% ash 4.65% lactose [2]. Milk and milk products are important in human diet because of two principal nutrients: protein and calcium. Milk is an essentially good source of protein which is of high biological value in promoting the growth of children, and repair of worn out tissues in adults. It is the best source of calcium in the diet for development of bones and teeth. Due to the high cost of dairy milk, people in Nigeria and other African countries have a diet low in protein and they consume less than ideal quantity, therefore there is a great need for high-protein foods to be easily reached by low income people all over the world [3].

Milk can be obtained from plants such as soya beans (legumes) coconut fruits (palms) and tigernut (root nut). These plant milks also contain balanced arrays of essential nutrients comparable to animal milk [4]. They are found to be high in iron but low in B vitamins, calcium, cholesterol, fat and carbohydrate [5].

Yoghurt production is a means of preserving raw milk and making milk available in different varieties. It is the commonest form of fermented milk available [2].

The economic attractions of fermented milk are reflected in the enhanced shelf-life of milk resulting from the conversion of fluid milk to products which are more stable [3, 6]. The characteristic flavor of yoghurt is due to the lactic acid, trace of ethanol, dimethyl, propanol, ethanoic acid and other volatile aromatic substances including small quantities of acetic acid and acetaldehyde. [7, 8]. The present work was done to find out the possibility of using milk from plant sources as alternatives to cow milk in yoghurt production.

### MATERIALS AND METHODS

Coconut fruits, tigernut and soybean seeds were bought from local market while Fan milk yoghurt was bought from the fan milk depot in Ilorin, Kwara State Nigeria. Pure cultures of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* were obtained from the Microbiology laboratory of Institute of Agriculture, Research and Training (IART) in Ibadan, Oyo State while *Streptococcus lactis* was obtained from the Microbiology laboratory of Federal University of Technology, Minna, Niger State. Nutrient agar Oxoid was prepared according to manufacturers' specification and used for isolation and sub culturing of the pure cultures of microorganism from extracted milk.

#### Preparation of Samples

Fresh tigernut fruit (600g) was sorted out and cleaned. The corns were soaked in 700ml water for 5 hours, the water was decanted and the corns washed several times. It was blended with gradual addition of sterile water to a fine paste (1:2 w/v). The paste was sieved and the filtrate collected and kept as tigernut milk.

Coconut fruit was broken and the cotyledon cut into small pieces with sterile knife and washed with sterile water for several times. 600g was weighed and blended with gradual addition of sterile water to a fine paste (1:2w/v). The paste was sieved sterile with a muslin cloth, filtrate collected and kept as coconut milk.

Soybeans (600g) were sorted and soaked for 2 hours. Hulls were removed and washed with water. The soybeans were blended by gradually adding of 700ml sterile water in a blender to fine slurry. The paste was sieved with a clean muslin sieve and 500ml of sterile water was used during sieving (1:2 w/v). The filtrate was cooked on a hot plate for 15 minutes and then cooled as soybean milk. 7galactose and 5g sucrose sugar were dissolved in 93ml and 95ml of sterile distilled water each, to make 7% lactose and 5% sucrose sugar. The two sugars were added to each of the milk samples and homogenized. The freshly prepared milk

samples were pasteurized in a water bath at 65°C for 30 minutes and cooled to 43°C for inoculation [1].

To 200ml of each milk samples of tigernut, coconut and soybeans was added 2ml of 10<sup>-5</sup> dilution of

*L. bulgaricus*, *S. thermophilus* and *S. lactis* [9]. The organisms were inoculated in singles and combination into the milks in a 500ml plastic fermenter and held in a water bath at 43°C for 24 hours. The yoghurt produced was cooled immediately to about 5°C.

The standard method of AOAC (2000) was used to determine the proximate and mineral compositions as well as pH and titratable acidity of plant milk and yoghurt samples.

### Sensory Evaluation of Yoghurt

Ten panelists were used to determine and compare the organoleptic characteristic and the overall acceptability of yoghurt samples. Questionnaires were prepared for herdonic scale in which each of the panelists express their degrees of liking or disliking. The ratings for each yoghurt sample are given numerical values [11].

## II. RESULTS AND DISCUSSION

The highest microbial load of 1.8 x 10<sup>5</sup> cfu/ml and pH 4.80 was recorded in tigernut milk while the lowest of 0.8 x 10<sup>5</sup> cfu/ml and pH in soya beans. Coconut milk had 1.4 x 10<sup>5</sup> cfu/ml and pH 4.90. Tigernuts are usually exposed to various types of contaminations as they are displayed in open containers while the low count recorded in soya beans milk could be as a result of boiling during processing .

The organisms may have been introduced as contaminants during production though their usually affected by storage temperature. Tables 1a, 1b and 1c show the pH, titratable acidity, proximate and mineral compositions of milk samples fermented with the organisms singly. Milk and milk products like fermented milk and yoghurts are sources of different types of microorganisms some of which are pathogenic. The isolation of *Salmonella* sp and *Escherichia coli* in yoghurt has been reported [12, 13]. The dry matter of fan milk yoghurt was significantly different from those of the other samples. Moisture and fat content of yoghurts from plant sources were much higher than that from fan milk. Also the crude protein content of all the yoghurt samples are comparable and fall within the same range. The pH was observed to decrease as the titratable acidity increased. A similar trend was observed for yoghurt samples fermented with mixture of the organisms (Tables 2 a, b and c). It was observed that a there was significant difference in the microbial load and physicochemical properties of yoghurts prepared under traditional and modified methods [7]. There was a decrease in manufacturing time from 12 to 2 days though similarity in sensory qualities was recorded. It was also noted that several nutritional and health benefits are derived from consumption of yoghurt [6]. Yoghurts provides significant amount of minerals and vitamins in bio available form. There is also an improvement in lactose tolerance, loss of excess fat and body weight of consumers. The probiotic bacteria present in yoghurt are known to promote good health [15].

Table 1a: pH, TITRATABLE ACIDITY, PROXIMATE & MINERALS COMPOSITION OF YOGHURT SAMPLES FERMENTED WITH *Lactobacillus bulgaricus*

Samples	Dry Matter (%)	Moisture Content (%)	Fat (%)	Crude protein (%)	CHO (%)	pH	Titratable Acidity (%)	Ash (%)	Ca (%)	Mg (%)
Tigernut Yoghurt	8.22b	91.77c	4.87b	2.32b	15.51c	2.40d	0.67a	0.18c	0.03c	0.11b
Coconut Yoghurt	7.75c	92.50b	5.82a	2.07c	37.45a	2.50c	0.38c	0.26c	0.08b	0.13b
Soybean Yoghurt	3.36d	96.64a	2.49c	2.14c	21.21b	3.15b	0.64b	0.59b	0.08b	0.16a
Fan milk Yoghurt	16.68a	83.30d	1.60d	2.74a	12.09d	3.50a	0.37c	6.28a	0.34a	0.08c

Table 1b: pH, TITRATABLE ACIDITY, PROXIMATE & MINERALS COMPOSITION OF YOGHURT SAMPLES FERMENTED WITH *Streptococcus thermophilus*

<b>Tigernut Yoghurt</b>	5.16c	94.40b	4.65b	2.21c	1.3.25	2.35d	0.70a	0.19c	0.07c	0.04c
<b>Coconut Yoghurt</b>	7.07b	92.92c	5.82a	2.56b	37.71a	2.60c	0.42c	0.31c	0.16b	0.16a
<b>Soybeans Yoghurt</b>	3.21d	96.79a	2.38c	2.13c	17.91b	3.25b	0.65b	0.60b	0.08c	0.16a
<b>Fan milk Yoghurt</b>	16.68a	83.30d	1.50d	2.74a	12.09d	3.50a	0.37d	6.28a	0.34a	0.08b

Table 1c: pH TITRATABLE ACIDITY, PROXIMATE & MINERALS COMPOSITION OF YOGHURT SAMPLES FERMENTED WITH *Streptococcus lactis*

<b>Tigernut Yoghurt</b>	4.39C	95.61b	4.66b	2.19b	13.41c	2.20d	0.61a	0.21c	0.08c	0.10a
<b>Coconut Yoghurt</b>	7.69b	92.31c	4.97a	2.00c	37.95a	2.60c	0.57b	0.27c	0.10b	0.10a
<b>Soybeans Yoghurt</b>	4.09d	95.91a	2.91c	2.00c	20.8b	3.30b	0.61a	0.60b	0.07c	0.05c
<b>Fan milk Yoghurt</b>	16.68a	83.30d	1.60d	2.52a	12.09d	3.50a	0.37c	6.28a	0.34a	0.08b

Mean in a column having same alphabet letters are not significantly different at 0.05 (%)

Table 2a: pH TITRATABLE ACIDITY, PROXIMATE & MINERALS COMPOSITION OF YOGHURT SAMPLES FERMENTED WITH MIXTURE OF *Lactobacillus bulgaricus* and *Streptococcus thermophilus*

<b>Samples</b>	<b>Dry Matter (%)</b>	<b>Moisture Content (%)</b>	<b>Fat (%)</b>	<b>Crude Protein (%)</b>	<b>CHO (%)</b>	<b>pH</b>	<b>Titratable Acidity (%)</b>	<b>ASH (%)</b>	<b>Ca (%)</b>	<b>Mg (%)</b>
Tigernut Yoghurt	8.11b	91.39c	3.81b	2.33bc	25.14b	2.75c	0.56a	0.20c	0.08b	0.08b
Coconut Yoghurt	6.40c	93.60b	5.03a	2.49b	38.21a	2.45d	0.50c	0.27c	0.10b	0.08b
Soybeans Yoghurt	3.60d	96.40a	2.20c	2.32c	18.35c	3.25b	0.63a	0.33b	0.04c	0.17a
Fan milk Yoghurt	16.68a	83.30d	1.60d	2.74a	12.09d	3.50a	0.37d	6.28a	0.34a	0.08b

Table 2b: pH, TITRATABLE ACIDITY, PROXIMATE & MINERALS COMPOSITION OF YOGHURT SAMPLES FERMENTED WITH MIXTURE OF *Streptococcus thermophilus* and *Streptococcus lactis*

Tigernut Yoghurt	7.50c	92.25b	3.39b	2.28c	27.60a	2.60a	0.58c	0.29c	0.08b	0.40a
Coconut Yoghurt	8.50b	91.45c	4.70a	2.59b	38.23a	2.40a	0.54a	0.30c	0.08b	0.16b
Soybeans Yoghurt	3.30d	96.68a	2.83c	2.79a	12.97c	3.10a	0.71a	0.59b	0.04c	0.11b
Fan milk Yoghurt	16.61a	83.30d	1.60d	2.74ab	12.09d	3.5a	0.37a	6.28a	0.34a	0.08c

Table 2c: pH, TITRATABLE ACIDITY, PROXIMATE & MINERALS COMPOSITION OF YOGHURT SAMPLES FERMENTED WITH MIXTURE OF *Lactobacillus bulgaricus* and *Streptococcus lactis*

Tigernut Yoghurt	6.85c	93.15b	3.85b	2.70a	21.57b	2.90b	0.56b	0.27c	3.36a	0.11a
Coconut Yoghurt	9.35b	90.65c	4.72a	2.32b	38.20a	2.20c	0.49c	-0.24c	0.15c	0.07c
Soybeans Yoghurt	3.47d	96.52a	2.48c	2.29b	13.60c	3.30b	0.69a	0.55b	0.05c	0.11a
Fan milk Yoghurt	16.68a	83.30b	1.60d	2.74a	12.45d	3.5a	0.36d	6.28a	0.34b	0.08b

Mean in a column having same alphabets are not significantly different at 0.05 (%)

Table 3: SENSORY EVALUATION OF YOGHURT

Samples	Colour	Texture	Taste	Aroma	Overall Acceptance
Tigernut Yoghurt	14.9a	15.80a	15.20a	15.30a	15.20a
Coconut Yoghurt	14.00a	17.60a	16.50a	14.90a	14.50a
Soybeans Yoghurt	11.80b	20.60a	23.80a	22.40a	21.20a

Carbohydrate content of tigernut milk fermented with mixture of *S. thermophilus* and *S. lactis* has the highest values of 27.60% while those fermented with *S. thermophilus* alone and *S. lactis* alone has values of 13.25% and 13.41% respectively. Fan milk yoghurt has a value of 12.09%. pH values of samples were lower than that of fan milk. (tables 1 and 2) The titratable acidity of yoghurt samples are close in values in samples fermented with *L. bulgaricus* and *S. thermophilus* combined and *L. bulgaricus* and *S. lactis* combined with same value of 0.56% which are the lowest means values, while samples fermented with *S. thermophilus* has the highest value of 0.70% fanmilk yoghurt has a very low titratable acidity of 0.37%. The protein content of prepared yoghurt samples compare favourably with fan milk yogurts. This shows that the organisms employed in the fermentation can be utilized in the production of good quality yoghurts. Fermentation resulted in the hydrolysis of the carbohydrates present in the milk samples which amount to pH changes from acid production [3].

Yoghurts from plant milk compare favourably to fan milk yoghurt in sensory evaluation (Table 3). It has been reported that thickness and smoothness of yoghurt do not affect their consumer acceptability [16]. It was also observed that addition of folic acid, vitamins and minerals resulted in the lowering of flavour, texture and water holding capacity [17]. Findings revealed that milk from plant sources namely tigernut, coconut and soybeans can serve as substitute for cow milk in the manufacture of yoghurt. This will help in conserving cow milk for use in other areas

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***In vitro* effects of extracts of *Senna alata* (Cesalpiniaceae) on the polyamines produced by leukaemia cells (L1210) culture**

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**ABSTRACT**

The present study reports the effects of *Senna alata* (Cesalpiniaceae) extract on the metabolism of polyamines resulting from the proliferation of L1210 leukaemia cells. The results showed that the reduction of cell proliferation increased significantly from 28 to 32.80% after 72 hours of treatment. The percentage of viability of leukaemia cell varied significantly from 9.72 to 100% in the presence of extract alone, or in combination with DFMO or putrescine. The levels of the intracellular production of putrescine, spermidine and spermine were also inhibited by the extract. The DFMO-extract complex enhanced the inhibition of the production of intracellular polyamines up to 95% while the complex *S. alata*-putrescine significantly stimulated its biosynthesis. A significant reduction of the concentration of protein after 72 hours confirmed the reduction of polyamines resulting from inhibition cell proliferation.

**Keywords:** Polyamines; Inhibition; Leukaemia L1210; *Senna alata*.

**INTRODUCTION**

Natural polyamines; putrescine (NH<sub>2</sub>-(CH<sub>2</sub>)<sub>4</sub>-NH<sub>2</sub>), spermidine (NH<sub>2</sub>-(CH<sub>2</sub>)<sub>4</sub>-NH-(CH<sub>2</sub>)<sub>3</sub>-NH<sub>2</sub>), spermine (NH<sub>2</sub>-(CH<sub>2</sub>)<sub>3</sub>-NH-(CH<sub>2</sub>)<sub>4</sub>-NH-(CH<sub>2</sub>)<sub>3</sub>-NH<sub>2</sub>) are compounds formed in all living cells through specific biosynthetic pathways. Polyamines can be found in the free form, not complexed to

high molecular weight compounds, principally spermidine and spermine, which are transported by red blood cells (Moulinoux *et al.*, 1989). They can also be found in body fluids such as plasma, serum, call foetal serum (CFS) and urine (Quemener *et al.*, 1995). Polyamines are required for optimal growth in all known types of biological cells and they are essential for fundamental cellular processes such as growth, differentiation, transformation and apoptosis (Kahana *et al.*, 2002; Criss, 2003). Recent studies indicate molecular linkages between polyamines and apoptosis (Erez *et al.*, 2002; Criss, 2003). The range of cell polyamines is determined at the lower limit by their absolute requirement for cell proliferation, and at their upper limit by their toxicity (Kahana *et al.*, 2002). Due to the essential role of the polyamines in the cell functions, multiple pathways such as biosynthesis, catabolism, uptake, and excretion greatly regulate their intracellular concentration. It is widely accepted that under most circumstances the major sources for cell polyamines come from their synthesis from amino acid precursors (Kahana *et al.*, 2002; Criss, 2003). In this pathway, ornithine is decarboxylated to form putrescine through the action of ornithine decarboxylase. An aminopropyl group generated by the action of S-adenosylmethionine decarboxylase on S-adenosylmethionine is then attached to putrescine and spermidine to form spermidine and spermine respectively. These two enzymes are highly regulated and are subjected to feedback control by cellular polyamines (Moulinoux *et al.*, 1987). If these two highly regulated enzymes constituted the control points of biosynthesis, the catabolic pathway is controlled predominantly by the action of spermidine/spermine N1-acetyltransferase (SSAT) (Kahana *et al.*, 2002). The biological importance of polyamine metabolism stems mainly from the observation that this seems to be closely associated with cell proliferation. Polyamines and some of their derivatives, also various drugs which affect polyamine metabolism can influence cell division and sometimes also cell differentiation (Moulinoux *et al.*, 1987). From a clinical view point, the metabolism of polyamines has an obvious diagnostic especially in cancerology (Jänne *et al.*, 1978; Moulinoux *et al.*, 1991). The treatment of cells with  $\alpha$ -2-difluoromethylornithine (DFMO) and related ornithine decarboxylase (ODC) inhibitors causes the depletion of putrescine and spermidine concentrations in cells and tissues, the arrest of cell growth in culture as well as reduction of tumour growth (Sunkara *et al.*, 1987; Claverie and Mamont, 1989). Many polyamine studies now focus on reduction of total body polyamines for cancer prevention, or reduction of total body organ polyamines for organ cancer prevention (Criss, 2003). However a combination of

drugs to deplete cancer cells of polyamines and additional drugs to interfere with the “downstream” polyamine regulatory events will allow for more successful cancer therapy. This is why drugs interfering with polyamine biosynthesis possess considerable potential as therapeutic agents (Kahana *et al.*, 2002).

*Senna alata* (Caesalpiaceae) is found in different areas of Cameroon and Africa. The plant is used by traditional healers to treat cancers and anti-inflammatory pelvic diseases in West and Central African countries (Adjanahoun *et al.*, 1996; Morris, 1999). The antibacterial and antifungal activities of extract of the *S. alata* have been demonstrated. The antitumor activities of the leaves of this plant have been demonstrated using *Agrobacterium tumefaciens* in the potato disc tumor bioassay method (Pieme *et al.* 2005). The method based on the evaluation of an antimetabolic activity can help for the detection of a broad range of known and novel antitumor effects (McLaughlin and Rogers, 1998). Since the tumors produced by *A. tumefaciens* are histologically similar to those found in humans and animals (Agrios, 1997; Coker *et al.*, 2003), *S. alata* extract can inhibit the proliferation of human cancer cells. Hence, the objective of the present study was to evaluate the *in vitro* effects of extracts of *S. alata* on the proliferation of leukaemia L1210 cells.

## MATERIALS AND METHODS

### *Plant materials*

Fresh leaves of *S. alata* were collected near the Eloundem mountain in Yaoundé, the capital city of Cameroon. The sample was identified at the National Herbarium and voucher specimens were deposited there with the number 1871/YA.

### *Preparation of extracts*

The leaves of plant were dried at room temperature (30 ± 3°C), pulverized and finely sieved. The powder obtained (250g) was macerated in a 4:1 mixture (v/v) of ethanol/water for 72 hours. The extract solution was filtered using Whatman filter paper N° 1 and concentrated in an air circulating oven at 54°C until total dryness. The extraction was repeated twice and 30g of *S. alata* extract obtained and stored at 5°C. A range of concentrations were prepared (40-80 mg/ml) for the evaluation of biological activities.

### *Cell culture*

Leukaemia cells (L1210) were obtained from the Cell Biology Laboratory of the *Centre Hospitalier Universitaire* of Rennes (France). The cells were cultured and maintained in RPMI 1640 medium supplemented with 2 mM of L-glutamine, Penicillin (100 U/ml), Streptomycin (50 µg/ml) and 10% heat-

inactivated foetal calf serum (supplemented medium) at 37°C under a 5% CO<sub>2</sub> atmosphere. After growth, 10<sup>6</sup> cells/ml were inoculated in the presence of 10 µl of plant extract alone or combined with 20 µl of DFMO (165 mM) or 10 µl of putrescine (1 M). The mixture was evaluated for cell viability under the light microscope after 72 hours.

### *Evaluation of biological activities*

After 72 hours of culture, the cytotoxicity of the extracts was evaluated according to the method described by Mosmann (1983) and Nicks and Otto (1990). The cell viability was measured by evaluating the reduction of thiazonium salts catalysed by mitochondrial enzymes of the viable cells (Mosmann, 1983). The percentage of the viability of cells was then calculated assuming that this value is 100 % for the control using the formula:  $[1 - (OD_{\text{control}} - OD_{\text{test}})/OD_{\text{control}}] \times 100$ . The intracellular polyamine levels were determined using High Performance Liquid Chromatography according to the previously described method (Saeki *et al.*, 1978; Moulinoux *et al.*, 1987), while the protein concentration was assayed according to Lowry *et al.* (1951).

### *Phytochemical analysis*

The phytochemical analysis of the extracts was carried out (Harbone, 1976; Odebiyi and Sofowora, 1978; Treaves and Evans, 1989).

### *Statistical analysis*

The values were expressed as mean ± standard deviation (SD). Each value is a mean of a three replications test. One-way analysis of variance (ANOVA) was used to determine the significant differences between parameters and the Student-Newman Keuls test was used to locate these differences;  $p < 0.05$  was considered as the level of statistical significance and the statistical package used was SPSS 10.1.

## RESULTS

After 72 hours of treatment of the leukaemia cells (L1210) with the extract, the inhibition of the proliferation of cells increased from 28 to 38 %, while its viability remained around 80 % (Table 1). The viability of cells increased significantly ( $p < 0.05$ ) when the extract was combined with putrescine and decreased after treatment of cells with the complex extract-DFMO as compared to their control respectively (Tables 1). The results showed that the viability of the treated leukaemia



L1210 cells was lower than non treated cells. The effect of the extract of *S. alata* and DFMO on the intracellular concentration of polyamines illustrated in Table 2 showed that the levels of polyamines were significantly decreased after treatment of cells with extract alone. The presence of DFMO alone in the culture increased significantly the reduction of the levels of intracellular production of the polyamines compare both the control and the extract. The combination of the extract of *S. alata* with DFMO enhanced the reduction of the intracellular production of the polyamines from 52 to 95% (Table 3). In the presence of the exogenous putrescine (Table 3), the level of reduction of putrescine, cadaverine, spermidine and spermine increased from 9.84 to 73.28%. However, when the cells were treated with the complex extract-exogenous putrescine, the reduction of all the polyamines increased significantly ( $p < 0.05$ ) with the exception of spermine. The effect of extract of *S. alata*, DFMO and putrescine alone or in combination on the protein biosynthesis was also evaluated and represented in table 4. The results showed that the extract of *S. alata* alone inhibited the production of the protein. When this extract is combined with DFMO or exogenous putrescine, the inhibition of the synthesis of protein was potentialised.

#### DISCUSSION

Polyamines have been shown to play a role in cells proliferation and cancer. Because spermidine, spermine, and putrescine appear to be reliable indices of cells proliferation, all drugs and molecules which inhibit their metabolism are potential targets for cancer therapy (Pegg, 1998). Quemener *et al.* (1999) showed that DFMO drastically reduced the concentration of putrescine and significantly inhibited the proliferation of tumor cells *in vitro*. The first step of the production of polyamine is catalysed by the enzyme, ornithine decarboxylase, which leads to the production of putrescine. Hence, the inhibition of putrescine synthesis by the extract of *S. alata* can be explained either by the inactivation or the inhibition of the ornithine decarboxylase activity or the S-adenosylmethionine decarboxylase. The combination of putrescine and the extract affect on the production of the putrescine differently. The complex of *S. alata* extract – putrescine significantly reduced the production of polyamines. Similar observation was noted with the cells treated with the extract only (Table 2). The results indicated that the presence of exogenous putrescine in the culture promotes the production of putrescine through the action of several enzymes especially polyamine oxidase (or N-acetyltransferase) and ornithine decarboxylase

(Moulinoux *et al.*, 1991). It has become extremely difficult to deplete 100% of the polyamines from cancer tissue when that cancer tissue can obtain polyamines from the surrounding normal tissues. On the other hand, the combination of *S. alata* - putrescine in the culture contributes to the reduction of the intracellular putrescine by a feedback effect. Moulinoux *et al.* (1991) also showed that the putrescine plays an important role as a growth factor during embryogenesis and proliferation of normal and cancer cells. The reduction of the polyamines decreases the oncogenesis by most organic toxic chemicals when carcinogenesis studies were performed in tissue culture, intact animal or human studies (Kahana *et al.*, 2002). The extract of *S. alata*, DFMO or putrescine alone or in combination affects differently the synthesis of the protein involved in the leukaemia cells growth. The addition of the putrescine to the extract of *S. alata* significantly increased the production of protein confirming that the exogenous putrescine stimulates the proliferation of leukaemia cells via the production of polyamines. The phytochemical analysis of *S. alata* extract showed the presence of flavonoids, polyphenols, tannins, steroids and glycosides. A wide variety of natural compounds appear to possess significant cytotoxic, antiproliferative as well as chemopreventive activities. Extracts of plants used in traditional medicine also have similar properties. Flavonoids, flavone, flavonol, flavonone and isoflavonone classes possess antiproliferative effects in different cancer cell lines (Taraphdar *et al.*, 2001). Flavonoids varied significantly in their antiproliferative potential depending on the structural features (Taraphdar *et al.*, 2001). The presence of tannins, glycosides, polyphenols and steroids in the extracts contribute to enhance the antiproliferative effects of the extracts. Several studies have shown the cytotoxic effect and the highly inhibition of the proliferation of the different cell lines in different ways either through apoptosis or by induction of DNA fragmentation or cell cycle (Taraphdar *et al.*, 2001). Today, chemoprevention of cancers, using anti-polyamine drugs, can be used for high risk population groups in an attempt to decrease their cancer risk.

In conclusion, the extract of *S. alata* can potentially inhibit the proliferation of leukaemia cells and other blood cancers diseases. Further research needs to be done to elucidate the mechanism of the inhibition property of the extract of *S. alata* and identify different bioactive components involved in this activity.

### Acknowledgment

The authors acknowledge the technical support of the Chinese Cooperation, the Cameroon National Herbarium and all the members of “Le Groupe de Recherche en Thérapeutique Anticancéreuse, Laboratoire de Biologie Cellulaire, Histologie, Embryologie, et Cytogénétique, Faculté de Médecine, Université de Rennes I, France” and Dr. Achu Mercy of the Department of Biochemistry - University of Yaoundé I.

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**Table 1.** Effect of *S. alata* extract on the viability and the inhibition of the proliferation of the L1210 leukaemia cells.

Plant -*/-extracts	Treatment	% of Cells viability	Inhibition of proliferation (%)
<i>S. alata</i>	40 mg/ml	80,00 ± 0,00 <sup>d</sup>	28,00 ± 0,40 <sup>b</sup>
	80 mg/ml	80,00 ± 0,00 <sup>d</sup>	32,80 ± 0,47 <sup>c</sup>
	80 mg/ml + PUT (1 M)	68,14 ± 0,85 <sup>c</sup>	
	Témoin + PUT (1 M)	94,75 ± 0,35 <sup>e</sup>	
	80 mg/ml + DFMO (165 mM)	23,36 ± 0,36 <sup>b</sup>	
	Control + DFMO (165 mM)	9,72 ± 1,12 <sup>a</sup>	
	Control	100,00 ± 0,00 <sup>c</sup>	0,00

PUT: Putrescine; DFMO: alpha difluoromethylornithine; Values are expressed as mean ± SD (n = 3). Means with different letter superscript within each column are significantly different ( $p < 0.05$ ).

**Table 2.** Effect of extract and DFMO on the intracellular concentration of polyamines.

Plant extract	Treatment	PUT (µM)	CAD (µM)	SPM (µM)	SPD (µM)
<i>S. alata</i>	80 mg/ml	5,68 ± 0,02 <sup>d</sup>	1,25 ± 0,08 <sup>a</sup>	1,92 ± 0,01 <sup>c</sup>	3,67 ± 0,01 <sup>c</sup>
	80 mg/ml + DFMO (165 mM)	0,73 ± 0,01 <sup>a</sup>	2,81 ± 0,04 <sup>b</sup>	0,87 ± 0,02 <sup>b</sup>	1,91 ± 0,01 <sup>b</sup>
	Control + DFMO (165 mM)	1,92 ± 0,02 <sup>b</sup>	5,31 ± 0,02 <sup>c</sup>	0,56 ± 0,02 <sup>a</sup>	0,86 ± 0,01 <sup>a</sup>
	Control	6,31 ± 0,07 <sup>c</sup>	7,46 ± 0,01 <sup>d</sup>	6,45 ± 0,04 <sup>c</sup>	11,02 ± 0,00 <sup>c</sup>

DFMO: alpha difluoromethylornithine; PUT: Putrescine; CAD: Cadaverine; SPM: Spermine; SPD: Spermidine Values are expressed as mean ± SD (n = 3). Means with different superscript letter within each column are significantly different ( $P < 0.05$ ).

**Table 3.** Effect of extract and exogenous putrescine on the intracellular concentration of polyamines.

Plant extract	Treatment	PUT ( $\mu\text{M}$ )	CAD ( $\mu\text{M}$ )	SPM ( $\mu\text{M}$ )	SPD ( $\mu\text{M}$ )
<i>S. alata</i>	80 mg/ml	5,87 $\pm$ 0,04 <sup>d</sup>	1,66 $\pm$ 0,01 <sup>a</sup>	1,92 $\pm$ 0,01 <sup>b</sup>	3,66 $\pm$ 0,02 <sup>b</sup>
	80 mg/ml + PUT (1 M)	1,05 $\pm$ 0,02 <sup>a</sup>	4,04 $\pm$ 0,04 <sup>c</sup>	2,57 $\pm$ 0,02 <sup>c</sup>	7,19 $\pm$ 0,01 <sup>c</sup>
	Control + PUT (1 M)	4,57 $\pm$ 0,05 <sup>b</sup>	4,18 $\pm$ 0,04 <sup>b</sup>	1,80 $\pm$ 0,02 <sup>a</sup>	3,87 $\pm$ 0,00 <sup>a</sup>
	Control	6,24 $\pm$ 0,01 <sup>c</sup>	7,48 $\pm$ 0,02 <sup>d</sup>	18,29 $\pm$ 0,02 <sup>d</sup>	12,11 $\pm$ 1,02 <sup>d</sup>

PUT: Putrescine ; CAD: Cadeverine,; SPM: Spermine; SPD: Spermidine Values are expressed as mean  $\pm$  SD (n = 3). Means with different superscript letter within each column are significantly different (P <0.05).

**Table 4.** Effect of extract, DFMO and exogenous putrescine on the levels of protein.

Plant extract	Treatment	Protein (mg/ml)	PRC	PRC + DFMO	PRC + PUT
<i>S. alata</i>	80 mg/ml	0,452 $\pm$ 0,005 <sup>d</sup>	11	-	84
	80 mg/ml + DFMO (165 mM)	0,180 $\pm$ 0,006 <sup>a</sup>	64	58	93
	80 mg/ml + PUT (1 M)	0,580 $\pm$ 0,0115 <sup>e</sup>		-	79
Controls	Control	0,513 $\pm$ 0,007 <sup>ce</sup>			
	Control + DFMO (165 mM)	0,430 $\pm$ 0,010 <sup>bd</sup>			
	Control + PUT (1 M)	2,843 $\pm$ 0,005 <sup>f</sup>			

PUT: Putrescine; DFMO: alpha difluoromethylornithine; PRC: Percentage of reduction/Control; values are expressed as mean  $\pm$  SD (n = 3). Means with different superscript letter within each column are significantly different (P <0.05).

## **CONFERENCE DIVISION:**

General Symposium [for contributions not aligned to any division]

# NIGERIAN WEB JOURNALISM PROFILE: NEW PARADIGMS, NEW CHALLENGES.

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**ABSTRACT:** *Advancements in Information and Communication Technology (ICT) has led to the representation of different types of information in electronic formats. The consequent today is that text, pictures and voice can all be digitized. Along with these geometric changes in information presentation and distribution are tandem demands in user expectations for more rapid, open, and global access to information than has been available in the past. However, this migration from traditional print medium to digital format seem to constitute a threat to the existence of a number of traditional print institutions such as newspapers, publishing firms and libraries that are custodian of information dissemination, creation, and management. This paper looks at the evolution of the Internet for news dissemination in Nigeria. Socio-economic and political factors responsible for the growth as well as other factors militating against web journalism in Nigeria were also appraised.*

**Keywords:** ICT, Print, Publishing, Newspapers, News, Journalism, Digital, Web, Internet.

## I. INTRODUCTION

Few years back, the Internet was more applicable to research and other academic activities. Today however, there are numerous new entrants to the online revolution, newspapers not being exempted. With the volume of hard publications online and digital versions of virtually all newsprints in the advanced countries on the Internet one may be tempted to say that if stakeholders in traditional publishing in Africa and Nigeria in particular do not rise to save the industry from extinction, hardcopy newspapers may soon disappear from the newsstands. Williams (2003) informed that at the start of the twenty-first century the issue of the media and globalization is at the forefront of the debates in the field of media studies. Today, the print media is faced with the challenges of survival as online and digital services are touted to take its place this century.

Computers are increasingly more affordable and Internet connectivity is also becoming commonplace. The introduction and embracement of the Global System for Mobile Communication (GSM) in Nigeria and the influx of digital and online services such as the MP3 players, Ipod, cell phones with internet access, blogs (instant news reporting on personal and corporate web pages), online versions of newspapers, etc., has led news consumers to rely increasingly on obtaining

information from online and digital sources. Media executives attending the 2005 World Association of Newspapers Conference titled “*Beyond The Printed Word.*” in Madrid were advised that newspapers have no future without online and digital services (Yahoo news, 2006).

### *Electronic Versus Traditional Print Media*

Newspapers have the unique capacity of transmitting enormous amounts of information over long distances and are very responsive to cultural changes. Newspapers look to the future. They have over the centuries afforded consumers longevity, durability, historical evidence, and opportunity for record keeping and referencing. Unfortunately, they have been fraught with challenges; “one of the biggest challenges being its lack of accountability and transparency for claimed circulation” (Abplanalp, 2005 ).

New media technologies are, however, compressing time and space, shrinking the world. Marshall (2005) also lends his voice, arguably the most vocal and widely recognized, to this prediction, proposing that the global village was a reconstruction of the communal world of the ancient village torn asunder by the print media. “Online media,” as a label, is approximately a decade old, but the prediction of its sweeping influence predates it. Since the early 1980s there has been an unparalleled growth of global media.

### *Media Ownership in the New Dispensation*

The convergence of the media, computer and telecommunications markets and the deregulation and privatization of the media industries around the world are encouraging the further concentration of ownership (Edwards, 2005). The merger between Time Warner and America Online (AOL) in 2000 indicates that big time players in the media market are bent on remaining dominant in the industry. The quest for profit by media tycoons has shifted to electronic media. They see it as potentially large profit centers, especially among the younger target demographic groups. They do not really care if history is destroyed or if integrity is preserved once their bottom-line is sealed. Williams (2003), quoting Herman and McChesney, advised that “the future of new media is, according to political economists, ‘a subject to be

determined by politics, not technology". Therefore, Concentration of media ownership is one of the factors driving the exigency to replace hardcopy newspapers with digital versions.

#### *Advertising and the Survival of the Old Media*

Advertising is the backbone of the publishing industry in Nigeria. Experience in the advanced countries already showed that advanced media operations could hardly survive without advertising revenue. Products, services and political advertisements supposedly meant for the print media are being directed to the Internet. The insatiable appetite for profit by media entrepreneurs has already shifted resources, personnel, and attention to Internet news dissemination. Media Asia (2005) warned that for the future, it is only hopeful that print advertising rebounds, because budgets are being allocated to other media and competition for budget is tough". Bugeja (2005) erases doubts about whose interest is served as online and digital services overshadow traditional newspaper publishing. He observed that "lines blur in the new media world. The only line that doesn't is the bottom one: profit".

### II. WEB JOURNALISM IN NIGERIA

Since July, 1996 when *The Post Express* newspapers, blazed the trail in web journalism with its [www.postexpresswired.ng](http://www.postexpresswired.ng), so many other newspapers and magazines have followed suit. Although the paper faltered with its dream of ensuring that readers in different parts of the country are fed with the same edition because of the epileptic take off of the grand simultaneous printing process in Port Harcourt and Kaduna, the now rested *The Post Express* can be credited with laying the foundation for the digital age in newspaper production in Nigeria. *The Punch*, a leader in the popular genre and the country's highest circulating newspaper, which opted to stand aloof while others joined the fray, has also embraced the online culture. Although *The Punch* is one of the oldest private newspapers in Nigeria, it only went online in June 2003, exactly seven years after *The Post Express* blazed the trail.

While the combined daily print run of newspapers industry in Nigeria, now dogged by high cost of production, abysmally low readership and shrinking advert patronage is less than 300,000, the flow of information through the Internet is growing rapidly geometrically. According to the 2002 fact sheet of the National Information Technology Development Agency (NITDA), the number of computers connected to the Internet in Nigeria is 683,866. There are 530,720 in offices, 122,431 in homes and 32,060 in cybercafes. The share of Internet access in the South is 63 per cent while that of the North is put at 37 per cent. This meteoric rise of access to the Internet has brightened the prospect of Online Journalism and is expected to continue (NITDA, 2002). Where it took television and traditional print media decades to gain mass usage, in only four years, the Internet gained 50 million users (Brown, 2005). Apart from the draw back of the tele-visual world, Nigerian newspapers now have to compete with the growing online culture and information without borders. For

just N100 per hour, you can get connected to the Internet for one hour and read some of the best-published newspapers in the world.

### III. FACTORS MILITATING AGAINST THE SURVIVAL OF NEWSPRINTS.

The frontier of online business in Nigeria is being widened by the minute. Cybercafes are opening up virtually everywhere in our cities while more and more people are acquiring VSAT and phones with Internet facilities in their homes and offices. A casual observation of the total number of people connected online in the world daily which runs to several millions simply tells us that we are already confronted with a potential big market waiting to be harnessed. Even if allowance is made for the expansive free reading culture which swells the pockets of vendors in the country, the readership of life newspapers whose daily print run is less than 300,000 copies is still not anywhere near the patronage of online publications. The number of Internet users has continued to increase in a geometric progression.

Blogging is one phenomenon affecting the survival of hardcopy newspapers. Brady (2005) in examining blogging, says "the rise of easy-to-use software has put a printing press in the hand of every citizen. No longer can anyone be denied a seat at the table, and those of us in the mainstream press deny that at our own peril". In 2005, blogging's growth led news reporters and publications to source information from blogs and include it in their publications. News events can be accessed in the same instant that they occur. We must not forget also that a generation of youths that grew up using the web for virtually everything will better appreciate an interactive Internet new culture rather than carrying hardcopy all over the place. Reading a newspaper doesn't seem to hold value for this society anymore. The worth a reader gets from reading a newspaper, knowing the information was researched and proofread by trained professionals has been traded for instant gratification.

#### *Economic, socio-political, and cultural factors*

Politically and economically, the production of media products is constrained by economic and political factors. He who pays the piper dictates the tune. Newspapers have been used as machinery for political manipulations and selfish economic gains. Murdock and Golding believe "the mass media are first and foremost industrial and commercial organizations which produce and distribute commodities"(Williams, 2003). In Nigeria, media owners are striving to answer the call to uphold the tenets of journalism and preserve heritage in hardcopy newspaper publication.

### V. FACTORS INFLUENCING THE UPWARD CURVE IN WEB JOURNALISM

Participatory journalism that allows readers as well as trained professionals to make news available (through blogging) is a leading factor among others responsible for the steady embracement of the web journalism across the world. Participatory journalism is barely a year old, yet professional

journalists, media moguls, and industry experts alike embrace it.

Asian and European media are the leading markets for consumption of this new phenomenon which seem like a re-invention of journalism. These participatory journalism sites offer intense local coverage that big newspapers and broadcast stations do not always provide. As Nigeria move on in the new millennium the Internet remains a vital force for the propagation of unabridged information, healthy political campaign and an avenue for the free press. The web has the advantage of allowing people to distribute news without needing to buy printing presses or build television studios, thus requiring less revenue to be profitable. Not only that, it ensures in a democratic society, freedom of the press, hence it remains the most democratic system of publishing.

#### IV. DEVELOPMENTS IN WEB JOURNALISM

The revolution in web journalism has opened the readership space beyond our shores, making it possible for Nigerians living abroad and others seeking information about Nigeria anywhere in the world to have more than enough food for thought about happenings at home. What follows is a list of Nigerian Newspapers online

##### 1. Abuja Mirror

Weekly newspaper, includes past issues. Published by Today Communications Ltd.

<http://www.ndirect.co.uk/~n.today/mirror.htm>

##### 2. AllAfrica.com - Nigeria News

Wide variety of current news sources. Company formed from the former *Africa News* of Durham, NC.

<http://allafrica.com/nigeria/>

##### 3. Amana Online

Original news and commentary plus links to news from outside sources. "Gamji-USA Inc. the operators of AmanaOnline.Com brings you this resource to make sure that the voices of Arewa are made available on the Internet. We are a group of Northern Nigerians from various professional backgrounds residing in the Washington DC metropolitan area and other parts of the United States." <http://www.amanaonline.com/>

##### 4. BBC Africa News

The British Broadcasting Corp often has Nigerian news. <http://news.bbc.co.uk/hi/english/world/africa/>

##### 5. Business Day

Site for the daily print business newspaper. Includes information technology news.

<http://www.businessdayonline.com/>

##### 6. Daily Champion (Lagos)

Site of the print Lagos newspaper. Selected articles.

<http://www.champion-newspapers.com/>

##### 7. Daily Independent (Ikeja)

Daily "independent and liberal newspaper." Art and life, business, politics, sports, letters to the editor.

Published by Independent Newspapers Limited.  
<http://www.dailyindependentng.com/>

##### 8. Daily Sun (Lagos)

Site for the print newspaper targeted at young adults. Published by The Sun Publishing Ltd. "The Sun Publishing Limited was incorporated on March 29, 2001 to undertake the business of printing and publishing. The company's *The Sun* title joined the swelling ranks of the ever-vibrant Nigerian press on Saturday, January 18, 2003 as a weekly and June 16, 2003 as a daily. <http://www.sunnewsonline.com/>

##### 9. Daily Trust (Kaduna) and Weekly Trust

Site for the print newspaper. Published by Media Trust Nigeria Ltd. Began publication January 2001.

See also *Weekly Trust*. [KF] <http://www.gamji.com/>

##### 10. Financial Standard (Lagos)

Site for the print weekly business newspaper.

Published by Millennium Harvest Limited.

<http://www.financialstandardnews.com/>

##### 11. Gamji.com

Current news from the *Daily Trust* newspaper and political commentary. Links to news from other Nigerian newspapers; articles appear in frames. Links to the Hausa news from the BBC, Voice of America, Deutsche Welle. Maintained by Ismail Iro (Ph.D.), Hallmark Development, Corp., Bowie, Maryland.

[KF] <http://www.gamji.com>

##### 12. Global NewsBank

**Subscription only.** Some universities subscribe. Not the latest news but good for researching news from a week ago back to 1985. Selected reports from the BBC Monitoring Service (English translations of news), Agence France Presse, IPS, PANA, radio and/or TV stations <http://infoweb.newsbank.com/>

##### 13. Google News - Nigeria

Automatically retrieved news (from AllAfrica, BBC, African, U.S., and other news sources).

<http://news.google.com/news?hl=en&q=nigeria&btnG=Search+News>

##### 14. The Guardian

Electronic edition of the well-known independent

Lagos newspaper. <http://www.nguardiannews.com/>

##### 15. Hausa Bakwai

"News worthy events from Northern Nigeria collected from various Nigerian sources sent by e-mail. English and Hausa. Weekly. Subscription is free. To subscribe write to Ibrahim Kabiru. E-mail:

[bakwai\\_news@barutiwa.com](mailto:bakwai_news@barutiwa.com)

##### 16. Hotline (Kaduna)

Site for the print newspaper. Published by Hotline Publishing Company Ltd.

<http://www.gamji.com/hotline.htm>

##### 17. IndyMedia - Nigeria Independent Media Center

"a collective of independent media organizations and hundreds of journalists offering grassroots, non-



corporate coverage of major protests.

<http://nigeria.indymedia.org/>

Site for the print weekly news magazine.

<http://www.tellng.com/>

**18. Al-Mizan** (Zaria, Nigeria)

In Hausa. Online version of the print newspaper from Zaria, published since 1991.

<http://almizan.faithweb.com/>

**19. NaijaPost.com**

Mainly news from *This Day* newspaper and other sources. From Global Envision Technology, Charlotte, North Carolina. <http://www.naijapost.com/>

**20. New Age** (Lagos)

Print daily newspaper published by Century Media Limited. Political, business, sports news. Chat room.

<http://www.newage-online.com/>

**21. Newswatch** (Lagos)

Current and past articles from the print weekly news magazine. Published by Newswatch Communications Limited. <http://www.newswatchngr.com/>

**22. Nigeria News Now**

Current Nigerian news on politics, business, states' news, the economy, health, education, the judiciary, environment, sports, religion, technology, **official statements**, press conferences, arts and culture, **essays and commentary** on topics of the day. Based in East Orange, New Jersey. <http://nigeriannewsnow.com/>

**23. Nigeria World**

Has pop-up ads. Current news from Nigerian newspapers gathered from other Nigeria-related web sites (mainly from odili.net). Political commentary, letters from Nigerians world-wide. Maintained by Chuck Odili, based in Charlotte, North Carolina.

<http://www.nigeriaworld.com/>

**24. Nigerian News du Jour**

A news only email list. To subscribe to NNDJ, send a message to: [majordomo@sfu.ca](mailto:majordomo@sfu.ca)

Leave the Subject line blank. In the Message are put: **subscribe n-news**

**25. Nigerian Tribune** (Ibadan)

Site for the print daily newspaper. Published by African Newspapers of Nigeria PLC.

<http://www.tribune.com.ng/>

**26. NIPOFO, Nigerian Political Forum**

Currents news links to AllAfrica.com, BBC, Nigerian online newspapers (*This Day*, *Vanguard*), publications of the **New Democrats** <http://www.nipofo.com>

**27. Punch** (Lagos)

Web edition of the Nigerian print newspaper. Political, business, stock market, cartoons, sports news. On-line polls. Promotes democracy and free enterprise. Published by Punch (Nigeria) Ltd.

<http://www.punchng.com/>

**28. Sun News Online - Daily Sun** (Ikeja)

Published by the Sun Publishing Ltd. Based in Ikeja, Lagos State. <http://www.sunnewsonline.com>

**29. Tell** (Lagos)

**30. This Day** (Lagos)

Online edition of the print newspaper. Selected articles, e-business news, etc.

<http://www.thisdayonline.com/>

**31. Tide**

Online edition of the print newspaper. Published by Rivers State Newspaper Corporation. News, especially on the Niger Delta, business, the environment. <http://www.thetidenews.com>

**32. Today**

Site has not been updated since 2000. Weekly newspaper. Has current and past issues. Published by Today Communications who also publish *Abuja Mirror*. <http://www.ndirect.co.uk/today/today.htm>

**33. Topix.net - Nigeria News**

News aggregated from different sources (Nigerian newspapers, Nigeria web sites, North American and European newspapers, etc.). (RSS feed: <http://rss.topix.net/rss/world/nigeria.xml>)

<http://www.topix.net/world/nigeria>

**34. Triumph (Daily)** (Kano)

Daily print newspaper published by the Triumph Publishing Company, Ltd., Kano, Nigeria. Also publishes, *Weekend Triumph*, *Sunday Triumph*, *Albshir & Alfjir*.

<http://www.triumphnewspapers.com>

**35. USAfrica Online** (Houston, Texas)

Many articles on Nigeria-related topics and U.S.-Africa relations. Profiles of prominent people. Web site of a Houston, Texas newspaper published by Chido Nwangwu. A subscription is \$30 a year.

<http://www.usafricaonline.com>

**36. Vanguard**

Electronic edition of the independent daily Lagos newspaper established in 1984.

<http://www.vanguardngr.com/>

**37. Weekly Trust** (Kaduna)

"The Weekly Trust and Daily Trust are... published by Media Trust Nigeria, Limited, an Abuja-based integrated marketing and communications outfit." The *Weekly Trust* began publication March 1998. [KF]

<http://www.weeklytrust.com/>

**38. Weekly Trust** (Kaduna) and *Daily Trust*

Site for the print newspapers. Published by Media Trust Nigeria Ltd. See also *Daily Trust*.

<http://www.gamji.com/>

**39. Yahoo - Nigeria News**

[http://headlines.yahoo.com/Full\\_Coverage/World/Nigeria/](http://headlines.yahoo.com/Full_Coverage/World/Nigeria/)

<http://library.stanford.edu/>

## VI. FACTORS MILITATING AGAINST WEB JOURNALISM IN NIGERIA

Of serious concern is a journalism that makes reporters sit at home trading objectivity and authenticity for ease of publishing. Whether this is true web journalism remains a question to be answered by the advocates of web journalism. Bugeja (2005) advises that “advances in news technology are meant to keep reporters indoors, enhancing productivity often at the expense of authenticity”. Other factors that bias the mind of the populace against this form of journalism include:

- (a) **Internet Infrastructures:** The issue of infrastructures remains a concern in a country where power supply is epileptic and connectivity in rural areas remains elusive. Of course, roads exist to transport hardcopy newspapers to the rural areas, at least using motorbikes, but the information highway powered by electricity and Internet connectivity and computers are yet to be “constructed” to reach rural dwellers.
- (b) **Accessibility:** Accessibility is a primary concern. If most of the world’s population can’t access hardcopy newspapers (arguably inexpensive) because they are illiterate or impoverished, how will they access digital and online services? Varian (2005) estimates that over 90% of information currently produced is created in a digital format, and there’s a possibility this percentage will increase substantially in the future. Much existing content currently available only in physical formats will soon be digitized.
- (c) **Community:** Localized identity and community may suffer with new media. Skilled reporters are absent in most developing countries’ local communities. The majority of the news available online through blogging services and participatory journalism is gathered by neophytes whose long-term interest may be self-serving.
- (d) **Exposure to Dominant Culture:** Williams (2003) exposes the biggest obstacle of new media to our communities. “The spread of global media as well as their increasing centrality in most people’s lives is seen as a problem for local communities. The debate about the impact of global media revolves around the question of identity – cultural, national and individual. Everybody needs a sense of who they are, a sense of belonging. The global media pose a threat to the nation, promising to erode those imaginary boundaries that distinguish one group of people from another”. News consumers’ interest in new media opens them to the risk of loss of local community identity through exposure to dominant cultures.
- (e) **Objectivity and Reliability:** A prevailing and binding tenet of journalism is the reflection of objectivity in news reports. Publications relying on information gathered through blogging or participatory journalism risk a lack of objectivity. These publications may expose their readers to unconfirmed reports, unverified claims, and amateur

writers reporting fabrications. One can argue that this happens with trained professionals too; and the media has had its fair share of scandals resulting from this, but it is apt to note that the culprits can be made accountable because they are in mainstream media and can be identified.

## VII. CONCLUSION

Could Hipp have been accurate when he said “digital revenue is serious business... online business is a growth business, while newspapers are not” (YahooNews 2006) Could that statement be a reflection of the drive that lifted the printed word off tablets and stones (which were reserved for elites in the 15<sup>th</sup> century) and placed it on newsprints (which became widely accepted and made information more widely available)? Online and digital news dissemination is truly catching on and replacing hardcopy newspapers. If a disaster should befall the technological field, such as a dotcom bust, the history of generations of people and nations may be completely lost. We must bear it in mind that information and communication technology (ICT) is producing a paperless society – it has its merits and demerits.

On the other hand, attempts to resist the changes that are coming as hardcopy newspapers bow to their online and digital versions may not be favorable for the print industry. Responsible entrepreneurship requires that publishers come to grips with history by striking a balance between electronic and print technology. Our government will do well to make provision for ICT infrastructure that will ensure IT penetration into the rural areas so dwellers can take advantage of the current evolution.

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# Assessment of Poultry Slaughterhouse Wastewater Treatment Plant: A Case Study of Zartech Limited, Ibadan, Nigeria

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**Abstract** - The efficiency of the poultry wastewater treatment plant of Zartech limited, Ibadan, Nigeria, was assessed based on percentage reduction of the various water contaminants while the unit cost of treated water was compared with that supplied through tankers. Wastewater and treated water samples were respectively collected from the points of generation and release after treatment for laboratory analysis for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Oil and Grease, Nitrate, Phosphate and Hydrogen Potential (pH). The values obtained for the wastewater were 1680, 5199, 7125, 1266, 70.0 and 6.8mg/l, as against 22.8, 15.6, 0, 15.2, 0 and 0 mg/l for the treated water. This translates to treatment efficiencies in percentages of 98.7, 99.7, 100.0, 98.8, 100.0 and 100.0 for BOD, COD, TSS, Oil and grease, Nitrate and Phosphate respectively. The pH of the wastewater was 6.7 as against 7.2 for the treated water. Based on the results obtained, the plant was adjudged efficient for the treatment of poultry wastewater. The cost of treated water was ₦0.18/l compared with ₦0.50/l for that supplied through tankers, resulting in a daily savings of about ₦120,506.95. Further cost reduction can be achieved through adjustment of dosing pumps.

**Keywords** - Pollution, poultry, slaughterhouse, treatment, wastewater.

## 1. INTRODUCTION

The desired qualities of water depend on the purpose for which it is to be used. These water qualities are measured by a number of parameters which include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Oil and grease, Nitrate, Phosphate and Hydrogen Potential (pH).

The term wastewater is defined as the spent or used water of a community or industry which contains dissolved and suspended matter, and about 99% of which is liquid while the remaining 1% is solid waste [1]. The composition of wastewater depends on the source of generation [2]. Poultry slaughterhouses produce substantial amounts of wastewater containing high amounts of biodegradable organic matter, suspended and colloidal matter such as fats, proteins and cellulose [3]. The wastewater is generated from various operations such as chicken cutting, scalding, defeathering, eviscerating,

chilling, packaging and plant cleanup. Slaughterhouse wastewater has a complex composition and is very harmful to the environment [4]. It has high organic concentration compared to domestic wastewater. After the initial screening of coarse solids, slaughterhouse wastewater is mainly composed of diluted blood, fat, and suspended solids. It may also contain some manure [5] while pathogens, including salmonella and shigella bacterial, parasite eggs and anaerobic cysts may also be present. Typical characteristics of slaughterhouse wastewater in Ibadan, Nigeria, is detailed in [6].

Wastewater must be treated before it is either discharged onto water courses or open field in order to reduce its potential environmental hazards. Where there is a need for it to be reused, the treatment becomes even more essential. The clean water act prohibits the discharge of toxic pollutants in large amounts into water courses or open lands [7].

The biological method of treatment involves the use of bio-organisms either in the presence (aerobic) or otherwise (anaerobic) of oxygen to reduce the pathogenic loads. The chemical method involves the use of chemicals in different forms and means in the treatment of the wastewater. The choice of an appropriate biological treatment system is influenced by a number of factors, including wastewater load and the need to minimize odors.

The removal efficiencies of the various wastewater components depend on the method used and amounts of SS that can be removed in the primary treatment phase. Sand filtration system has been reported to achieve over 95% removal of BOD and COD [8]. Reference [9] investigated the use of the coagulation/flocculation process to remove organic matter from slaughterhouse wastewater by adding aluminum salts and polymer compounds. The COD removal efficiency was reported to be in the range of 45-75%.

The objective of the work reported here was undertaken to access the efficiency of the Zartech Limited, Ibadan, Nigeria, poultry wastewater treatment plant on the basis of percentage reduction of the various water contaminants, and to compare the cost of treated water with that supplied through water tankers.

## 2. MATERIALS AND METHODS

### 2.1 Study Location and Treatment Plant

Zartech Limited, whose wastewater treatment plant was used for this study is one of the leading agricultural establishments in Southwestern Nigeria. The headquarters is located in Ibadan, while other farms owned by the establishment are located in various parts of Nigeria. Its primary activities are animal and plant production especially poultry, fisheries, livestock, horticulture and animal feeds. The poultry slaughterhouse plant located in Ibadan, has a design capacity of 24,000 chickens per day and produces approximately 0.38ML of wastewater daily.

A schematic diagram of the wastewater treatment plant (Fig. 1) indicates the following components: screens, flow equalization tanks, skimming spades, chemical dosing systems, sedimentation tanks, carbon filter, sand filters, bag filters, and UV light. The treatment process consists of about nine stages the sequence of which is as follows:

*Screening:* Screens are placed at the wastewater outlet and at various points along the water channel to remove the suspended solids which include feathers, some intestinal content, some fats, oils and grease from the wastewater.

*Skimming:* This is done with the use of long spades to remove fat and grease that may still be present at the free surface of the wastewater.

*Primary Clarification:* Separation of the sludge from the inflowing liquid.

*Chemical Coagulation:* The addition of aluminum sulphate. This precipitates the organic materials from the wastewater stream. Flow equalization tanks equipped with mechanical agitators and chemical dosing pumps are used at this stage.

*Chlorination :* Disinfection of the water stream so that bacteria and other pathogens are eliminated.

*Neutralization:* Correction of treated water pH by the injection of milk lime or citric acid depending on the resulting pH of water.

*Sedimentation:* Four sedimentation tanks connected in series are used to remove settled material. The sludge is then driven to an outlet where it is removed using scrapers.

*Carbon, sand and bag filtration:* These are used to control odors, remove nutrients such as phosphorus, sulphide suspended solids, remaining BOD as well as pathogens.

*UV light purification:* The final treatment stage after which the treated water is transferred to storage tanks or for

immediate reuse. It is done to kill resistant bacteria and pathogens.

### 2.2 Sampling and Analysis

The distance between the point of discharge of the wastewater from the slaughterhouse and its entry to the treatment plant is about 700m. Wastewater samples were collected at three points along the flow line. Operation shift takes place at 2.00pm during which the plant is washed and the water in the chiller is changed. In order to ensure that the wastewater tested was devoid of any washwater which might dilute the level of contamination, the wastewater samples were collected between 11.00 am and 12.30pm daily for five consecutive slaughtering days using 50ml round bottom flasks. The detention time within the treatment plant is about 8 hours and in order to ensure that the treated sample obtained was a product of the wastewater from which samples were collected, treated water samples were collected between 7.00 pm and 9.00pm on same days that the wastewater samples were collected.

The samples were taken to the Zartech Water laboratory for analysis. Tests were carried out for BOD, COD, TSS, Oil and grease, Nitrate, Phosphate and Hydrogen potential for both the wastewater and treated water samples. Experimental procedures were in accordance with Reference [10]

## 3. RESULTS AND DISCUSSION

### 3.1 Plant efficiency

The mean values of the results obtained from the laboratory analysis for the raw wastewater and treated water are presented in Table 1. The efficiency of the plant in removing each of the contaminants is also indicated.

The treatment process completely removed the suspended solids, nitrate and phosphate in the wastewater while for the BOD, COD and the Oil & grease, removal were constantly above 95%.

A pH value of 7.2 was obtained for the treated water sample as against a value of 6.7 for the untreated wastewater sample. The implication of this is that the slightly acidic wastewater has achieved a near neutral value following treatment thus enabling its discharge into nearest watercourse without serious disturbance or impact on the environment.

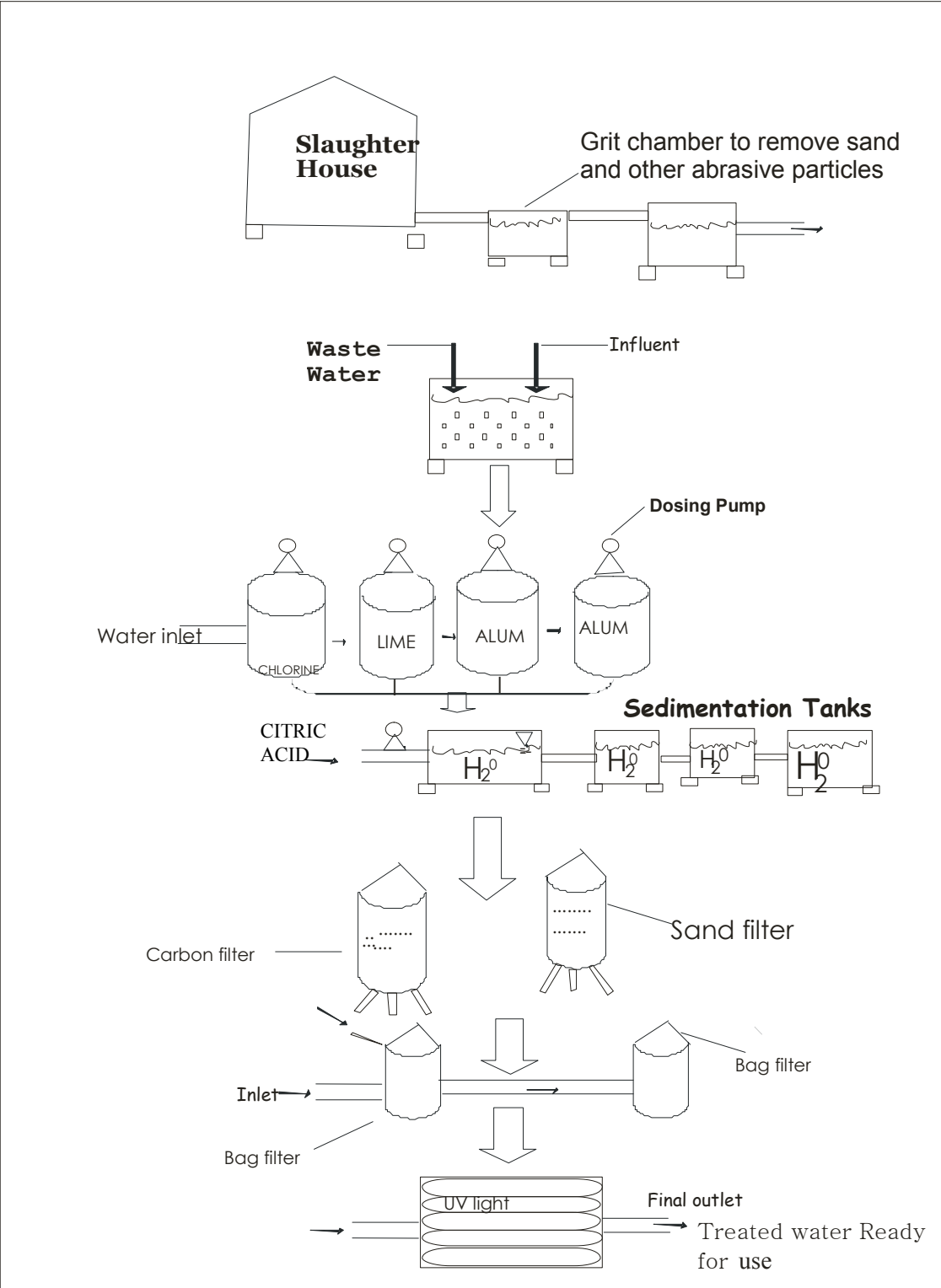


Figure 1. Wastewater Treatment Operations

TABLE 1  
TREATMENT EFFICIENCY OF THE ZARTECH  
LIMITED WASTEWATER TREATMENT PLANT\*.

Parameter	Wastewater	Treated Water	Treatment Efficiency
BOD	1680	22.8	98.7
COD	5199	15.6	99.7
TSS	7125	-	100.0
Oil/Grease	1266	15.2	98.8
Nitrate	70.0	-	100.0
Phosphate	6.8	-	100.0
pH	6.7	7.2	-

\*all values expressed in mg/l except pH

The physical examination of the treated water indicated that it was colourless but with a mild taste and odour associated with overdose of chlorine. Relatively high level of chlorine makes the water unsuitable for live vaccine administration to poultry birds as it renders the vaccine inefficient.

### 3.2 Cost Implication

Saving in the cost of water supply is a major consideration for in-house treatment and reuse of wastewater. It was therefore considered necessary to compare the unit cost of treated water with the cost of procurement through water tankers from sources such as the Eleyele dam which is about 20km away from the poultry slaughter house, being the nearest guaranteed source of water. The commercial and accounts departments provided relevant data for the preparation of Table 2. From Table 2, the unit cost of treated water was ₦0.18/litre compared to ₦0.50/litre for water purchased. With the use of treated wastewater, the daily water requirement of the slaughter house was provided at a cost of ₦69,493.63 which would have risen to ₦190,000.00 if supplied through tankers. By the use of the plant, there was a daily savings of ₦120,506.37. The choice of in-house treatment and water reuse is therefore justified.

By adopting a number of measures, it is possible to further reduce the cost of running the treatment plant. For example, the use of appropriate amount of chlorine will eliminate overdosing and reduce the amount expended on this chemical.

TABLE 2  
RUNNING COST OF THE ZARTECH LIMITED WASTEWATER TREATMENT PLANT\*

S/N	Description	Cost in Naira (₦)
1	Labour	
	a) Monthly salary of one Biochemist	29,650.00
	b) Monthly salary of one Chemical Engineer	32,866.00
	c) Monthly salaries of three Technicians @ N18,600.00	55,800.00
	d) Monthly salary of one Plumber	14,860.00
		<b>133,176.00</b>
2	Chemical and Test kits	
	a) Chlorine: 42.75kg/day @ N400.00/kg	17,100.00
	b) Hydrated lime: 47.5kg/day @ N65.00/kg	3,087.50
	c) Alum: 31.35kg/day @ N65.00/kg	2,037.75
	d) Sodium Thiosulphate : 11.4kg/day @ N3,000.00/kg	34,200.00
	e) Citric Acid : 1.66kg/day @ 250/kg	415.00
	f) Chlorine Test kit (Cost/day)	2,080.00
		<b>58,920.25</b>
3	Daily cost of fuel for generator	3,680.00
4	Cost of annual plant maintenance including dredging of reservoirs, pipe maintenance and pump repair and maintenance	56,300.00

\*At an average of 240 working days per annum, the running cost of the plant treating 0.38ML of wastewater is about ₦69,493.63/day.

## 4 CONCLUSIONS AND RECOMMENDATIONS

The poultry slaughterhouse wastewater treatment showed over 90% removal of BOD, COD, TSS, Oil grease, Nitrate and Phosphate. The pH was changed from acidic to neutral value. These high efficiency values are indicators of a satisfactory performance of the treatment plant.

The cost of treated water was ₦0.18/litre compared with ₦0.50/litre for purchased water. This cost of water treatment

can further be reduced and the plant efficiency improved upon by adopting the following measures:

a) Reducing the chlorine used through dosage monitoring which can be achieved through regular adjustment of the dosing pumps to supply the amount of chlorine that is just enough for the organic load of the wastewater. A preliminary laboratory study to establish the level of overdosing should be carried out.

b) Reducing the liquid waste load by preventing all solid wastes and all concentrated liquids from entering the wastewater stream.

c) Equip the wastewater outlet channels with screens and fat traps to recover and reduce the concentration of coarse material and fat in the combined wastewater stream.

#### ACKNOWLEDGMENT

The authors are grateful to the following people: Mr. Sani M. Salako, the General Manager of Zartech Limited Maya Branch, Mrs. Abimbola Lawal and other staff of Zartech Analysis Laboratory for permission to use the laboratory and assistance in the sample analysis. The useful criticisms of Professor A.Y. Sangodoyin of the University of Ibadan while preparing this paper are acknowledged.

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# Determination of the Moduli of Elasticity and Rupture, and Impact Energy of Oil Palm Trunk

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**Abstract-**The moduli of elasticity and rupture, and the energy to cause failure under impact load of oil palm trunk were determined. Samples for testing were obtained from the base, middle and top of the tree trunk. They were taken from both the core and outer regions of the trunk and tested under wet and dry conditions. The samples obtained from the outer layer of the base and tested under dry condition, gave the highest modulus of elasticity of 4,943 N/mm<sup>2</sup> and a modulus of rupture of 42.8 N/mm<sup>2</sup>. The sample obtained from the inner section of the top and tested under wet condition gave the lowest values of 369.7 N/mm<sup>2</sup> for modulus of elasticity and 0.4 N/mm<sup>2</sup> for modulus of rupture. The maximum value of energy consumption of 12.86 joules was recorded for the outer base section tested under wet condition as against the minimum value of 0.45joules recorded for the samples from the inner portion of the top and tested under dry condition. There was a general decrease from the base to the top for the three parameters and from inside to the outer section.

**Key words** - Oil palm, trunk, elasticity, rupture, energy consumption.

## 1. INTRODUCTION

The ever increasing human population which demands more housing has put pressure on the conventional materials of construction and the escalating prices has made most of them unaffordable especially by the poor rural communities. It has been established that about 60% of the cost of construction projects is accounted for by the cost of materials and an appropriate method of reducing building costs is a reduction in cost of materials. The materials of construction which are locally available and for which local technology may be available to effectively utilize, provide a viable option in this respect. The use of local materials has the potential of reducing the total project cost by between 30 and 80% compared with when conventional materials are used [1]. Palm wood is a hard timber from palm trees and it offers an alternative to rainforest timber [2]. The oil palm wood presents a suitable option where and when available and its utilization may be better exploited if its engineering properties are known. There is dearth of this information in Nigeria at present.

The oil palm, (*Elaeis guineensis*, Jacquin) is an upright growing tree commonly found in the tropical rainforest of West Africa where it is believed to have originated [3, 4, 5, 6, 7, 8, 9]. The oil palm belongs to the warm, high rainfall tropical forest area. It is equally found in various parts of the world between latitudes 44°S and 44°N wherever the required conditions of at least 1500 mm evenly distributed annual rainfall and temperatures of between 24°C and 32°C are available. Major producers include Malaysia, Indonesia, Nigeria, China, Republic of Congo and Ivory Coast. In Nigeria, the oil palm is found mainly in the south where it grows wildly as well as in established plantations.

The oil palm wood is made up of two distinct sections from the base to the top (Plate 1). These regions are the high and low density portions. The high density outer portion is usually darker in colour than the low density inner core and it is very predominant at the base section. The high density portion is next to the cambium and the inner wood tissue is bounded by this strong portion of the tree which is composed of densely packed fibers. Reference [10] reported that this outer region, made up of densely packed fibers, is much stronger than most hardwoods and that is why the oil palm tree is able to withstand the winds that break other trees.

In Nigeria, the main attraction for the oil palm tree is the fruit, which provides the palm and kernel oils, and palm wine from the trunk for human consumption and industrial raw material. This provides a source of employment for a good number of the rural populace. The trunk as a material is of little significance and when it either falls naturally or removed during operations on construction sites, it is left to rot or burnt to give way for other activities. In very rare cases, it is used as a fuel and truss members for roofs of rural buildings. Generally, the trunks of several million palms felled throughout the tropics are usually wasted and it is now being suggested that the oil palm trunk should be considered as a suitable alternative to endangered hardwoods [2, 11]. Reference [12] reported that in Thailand and Malaysia, the increasing demand for furniture items and



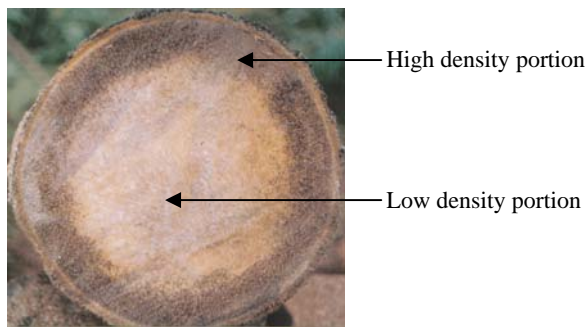


Plate 1. Transverse section of oil palm trunk

the declining supply of the traditional timber for construction motivated the search for alternative materials, and the oil palm trunk which is abundant but under-utilized was considered as an alternative

The mechanical properties of a material give an indication of its response to external loading. For wood related materials, this is known to be affected by density and moisture content especially below the fiber saturation point. Reference [13] reported that these strength properties are further influenced by the rate and direction of load application. The moduli of elasticity and rupture are two of the engineering properties that determine the potentials of a material for structural use. The modulus of elasticity which expresses the relationship between the stress and strain when the material is under load allows the prediction of its behaviour while in service. The modulus of rupture on the other hand, provides information on the amount of force required to break the material. The primary objective of the work reported here was to determine the moduli of elasticity and rupture as well as energy consumption of oil palm trunk and their variations along the longitudinal and transverse sections of the trunk, under wet and dry conditions.

## 2. MATERIALS AND METHODS

### 2.1 Collection of Samples

The samples used for this study were obtained from *dura* species growing naturally in swampy areas within the University of Ibadan campus, Nigeria where a cluster of the tree is found. In selecting a tree to be felled, the physical conditions of the tree such as straightness of trunk, good girth and minimum observable natural defects and physically inflicted injuries were taken into account. This was to minimize the possible effect of growth defects in reducing the mechanical properties of the trunk. Five trees were felled using chain saw with the cutting done at an average height of 30cm above the natural ground level. The average length of the trunk between the point of cut and the crown was 20.3 meters while the average diameter varied

from 30cm at the base to 24cm at the top. The trunk length was cut into 120cm bolts. Two bolts each were taken from the base, middle and top of the five trunks for samples production. From each bolt, four samples each of low (core) and high-density (outside) were collected for test making 240 samples. The samples were labeled for ease of identification as B, M and T indicating the base, middle and top of the trunk respectively.

### 2.2 Pre-test Treatment

The tests were to be carried out under wet and dry conditions and for this reason, the samples collected from all sections were divided into two equal parts. The set for the dry test was oven dried to a constant weight after which they were left in an air conditioned room for two days to stabilize and attain an average moisture content of 12%. The second set for wet test was soaked in water for seven days to bring the sample to fiber saturation point after which they were removed and drained before being tested.

### 2.3 Experimental Procedure

Two tests, impact and static bending were conducted:

#### a) Impact Bending Test

The impact bending test provides information on the shock resistance of the specimen tested. This was carried out using the Hatt-Turner impact testing machine and in accordance with [14]. The impact load was provided by a 1.5 kg metal weight hammer hung by means of a cable between two metal pipes with a clearance that was just enough for free movement of the hammer. The specimen was adequately secured at the bottom of the pipes such that there was no displacement when the impact load hit it at the centre. The initial height of the impact load was 25cm. This was increased at intervals of 5.08cm until the specimens gave signs of failure and had to be reduced to 2.54cm. The height of the impact load which caused the sample to fail was recorded. Some of these specimens are shown in plates 2 and 3.



Plate 2. Cross section of samples before testing



Plate 3. Cross section of samples after testing

### b) Static bending test

Static bending provides information on the tensile strength of the specimen as expressed by the modulus of rigidity (MOR) and modulus of elasticity (MOE), and was carried out using the Hounsefield tensiometer in accordance with [14]. After loading the specimen, pressure was gradually applied while the movement of the mercury was observed. An extensometer was attached to produce a load deflection graph. The application of pressure was stopped when the mercury was observed to decline. The point on the scale at which the mercury started to decline indicated the maximum load that was sustainable by the specimen and was used in calculating the MOR using the following equation

$$MOR = \frac{3PL}{2bd^2} (N/mm^2) \quad (1)$$

The load deflection curve obtained with the extensometer was used to compute the MOE using the following equation

$$MOE = \frac{PL^3}{4Dbd^3} (N/mm^2) \quad (2)$$

Where P is the maximum load sustained at failure,

L is the span of specimen;

D is the deflection at point of failure in mm and it is obtained as the slope of the graph plotted by the extensometer at point of failure,

b and d are the width and thickness of specimen respectively.

Calculations were made for each of the ten replicates in a group from which an average value was obtained

## 3.0 RESULTS AND DISCUSSIONS

### 3.1 Energy absorbed

The energy required to cause failure under impact loads are presented in Fig. 1 for all conditions of test. The energy decreases from the bottom to the top but increases from the core to the outside. The values for dry conditions were generally lower than for wet conditions. This may be attributed to the fact that when a wooden material dries, it becomes more brittle and less resistant to impact load.

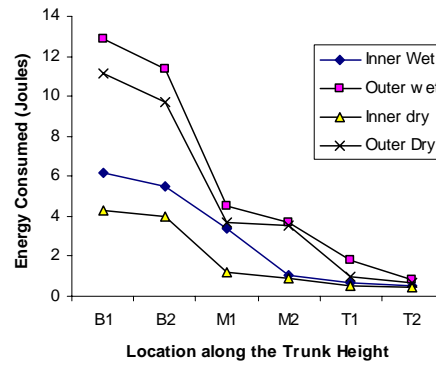


Figure 1. Energy Consumption

### 3.2 Static bending

Data collected from these tests were used in the calculation of MOE and MOR which are presented in Fig. 2 and 3. Both parameters were observed to decrease from the base towards the top of the tree and also decreased from the pith to the cambium. The pattern of variation of the MOE and MOR from the base to the top is similar to what other workers such as [12] have observed.

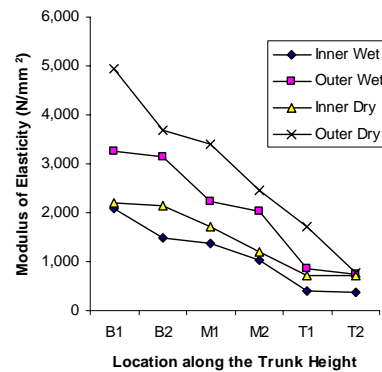


Figure 2. Modulus of Elasticity

While MOR is an indication of the ultimate strength of the sample, the stiffness is indicated by the MOE. The observations made in this study imply that the outer base section of the palm wood tree is the strongest and expectedly stiffest while the inner top is the weakest. When this material is to be used for load bearing structures, preference should be given to materials obtained from the

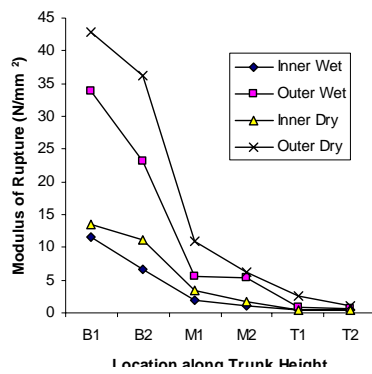


Figure 3. Modulus of Rupture

base. The values for dry conditions were generally higher than for wet conditions for all the cases investigated. This is attributable to the fact that when a wooden material is dry, the gaps in-between the cell – wall material reduces. The fibers are able to reinforce one another thereby strengthening the wood more but in wet samples, the wood fibers are farther apart as the water comes in-between them and this reduces the effective strength under gradual loading. In general and below the fiber saturation point, the strength of wood including the oil palm wood is increased as the moisture content reduces [15].

#### 4.0 CONCLUSIONS

1. For samples obtained from the core and tested under wet condition, the energy consumption varied from 6.2 joules at the base to 0.52 joules at the top; the MOE and MOR varied respectively from 2,075 N/mm<sup>2</sup> to 369.7 N/mm<sup>2</sup>, and 11.5 N/mm<sup>2</sup> to 0.4 N/mm<sup>2</sup>.

2. For samples obtained from the core and tested under dry condition, the energy consumption varied from 4.26 joules at the base to 0.45 joules at the top. MOE and MOR varied from 2,209 N/mm<sup>2</sup> to 700.3 N/mm<sup>2</sup>; and 13.4 N/mm<sup>2</sup> to 0.5 N/mm<sup>2</sup> respectively.

3. For samples obtained from the outer section and tested under wet condition, the energy consumption varied from 12.86 joules at the base to 0.82 joules at the top, and the MOE and MOR varied respectively from 3,251.5 N/mm<sup>2</sup> to 774.5 N/mm<sup>2</sup>, and 33.9 N/mm<sup>2</sup> to 0.6 N/mm<sup>2</sup>.

4. For samples obtained from the outer section and tested under dry condition, the energy consumption varied from 11.14 joules at the base to 0.67 joules at the top. MOE and MOR varied from 4,943 N/mm<sup>2</sup> and 42.8 N/mm<sup>2</sup> at the base to 771.8 N/mm<sup>2</sup> and 1.0 N/mm<sup>2</sup> at the top respectively

5. The properties investigated decreased from the base towards the top of the trunk but increased from the pith towards the cambium. Moisture content was found to influence the properties investigated. While dry samples were less resistant to impact load, they were more resistant to gradual loading as exhibited by higher stiffness and ultimate strength than the wet samples.

#### ACKNOWLEDGMENT

The authors are grateful to the Department of Forestry and Wildlife, University of Ibadan for the use of their laboratory for the tests carried out in this study.

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# The Design for Lifespan Approach for Constructions

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**Abstract-**This paper describes the design philosophy "Design for Lifespan", which has been developed and tested at the Technische Universiteit Eindhoven, the Netherlands. The lifespan concept addresses issues like environmental impact, depletion of resources and optimization of material utilization, labour and capital during the design, construction and use of buildings. The relation between the lifespan and the design of both new buildings as well as of interventions in existing buildings is discussed. The appropriateness of this conceptual approach in developing countries will be highlighted as well.

**Keywords-**Lifespan, design, ldc's, re-use, environment

## I. INTRODUCTION INTO THE LIFESPAN PHILOSOPHY

The Green Agenda '21 Ref. [1] was formulated in order to address issues of building and construction in relation to the increasing problems with the environment and global warming. The Agenda '21 covers amongst others the optimization of use of materials with regards to, depletion of resources, minimization of energy use from "cradle to cave".

The lifespan of a building was the new aspect that was introduced to be taken into account whilst designing and constructing a building.. The question that was raised was: "Why should a building be created with a lifespan that is longer than the period during which it really will be used?" Building for a predetermined lifespan may also influence the use of materials, energy and capital. This counts for the design of new buildings but also for the adaptation or renovation of existing buildings.

The concept of design for lifespan is a research area under responsibility of the group BCC of the TU/e,

Faculty of Architecture, Building and Planning Ref. [4]. In practice we see many buildings, which are not functioning optimally. So many adaptations are made during the lifespan to create a certain acceptable level, which is not always an optimum from financial point of view. Thus, why then should you make a building, which will last longer than can be foreseen? Offices in the Netherlands have an approximate lifespan of 15 years after which the interior and sometimes exterior is replaced for reasons of more comfort and adaptation to the altered corporate identity (for example: bank buildings). Houses have a longer lifespan, although the fast changing technologies such as ICT make it possible to adapt in buildings comfort more adequately to people's wishes.

So, from a technical point of view, different lifespans can be distinguished. For example, the main structure of a building may remain and satisfy longer than the infill or parts there of. In order to reduce the need for demolition, etc. it is possible to introduce (design for) flexibility. By doing so, changes may be made both in the building structure and of the infill without really affecting the whole building.

The reuse of parts of the building can be taken into consideration, already during the design phase. The basic thoughts in this direction were initiated by Habraken Ref. [6], who developed the "frame-infill" principle whereby the infill may be replaced/changed after a certain period without affecting the frame.

More precisely, when thinking along these lines, one can also adapt parts of the frame to a different use such as a different location of a column (within a certain margin) Ref. [5]; or, to enable changes on the location of a staircase, because of an altered use of a building. This has consequences for the floors structure, which have to be constructed, allowing these changes. The (Dutch) "Live Like You Want" Concept for dwellings also provided the option for reallocating

the façade openings and to adapt them for a different use Ref. [7].

A more general option is to design buildings, which are functionally neutral. This means that a building is designed and built, independent of its future usage. This option allows for more changes than design for flexibility. As this topic is just under development, it cannot yet be confirmed if the envisaged effects are indeed achievable.

Whatever type of built-in flexibility has been chosen, the lifespan of the building is an aspect, which requires further explanation in the following paragraphs.

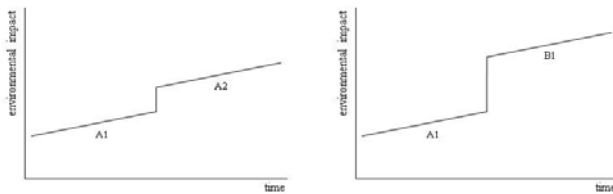


Fig. 1. Environmental Impact vs lifespan (Ref. 3)

Reuse of either a whole building or parts thereof has an Environmental Impact. Figure 1 shows that the erection of two buildings A1 later replaced by B1 on the same spot has a totally different environmental impact, then when replacing just parts of the building A1, changing into building A2 and by doing so, extending the lifespan of the building.

## II. DESIGN FOR LIFESPAN IN GENERAL

### A. New buildings

In general a set of design rules can be followed to create a sustainable building, that meets the requirements of a predetermined lifespan. There are a number of good examples of such lifespan designs for buildings such as emergency shelters as well as for office buildings such as the XX building. These will be described in the following paragraph.

### B. Existing buildings

For existing buildings it is some times necessary to judge if the lifespan of the building, or parts thereof, has to be extended or to be ended. The Re-architecture concept - under development - Ref. [8], that is based on the lifespan concept, gives a way to judge from an ecological and a cultural point of view, whether the building, or parts thereof, are worthwhile to be kept. In case of interventions in these existing buildings, we

have to deal with materials already put in place. Moreover also the energy consumption of these buildings is already fixed through the energy consumption during the construction of the building as well as during the use of it.

In developing countries, in particular there is a lack of resources. So, any design concept, which may save the usage of resources, should be welcome.

## III. DESCRIPTION OF DIFFERENT LIFESPAN DESIGNS

The following elaborates in more detail the various options for lifespan design.

### A. 20 years XX office building

In Delft, an office building with the name 'XX office', for XX Architects was built (see Fig. 2). The basic idea is the office building will last for just 20 years after which it will be deconstructed and decomposed Ref. [9].

In order to satisfy Environmental Impact Regulations, the materials applied should not 'last' longer than those 20 years or should be applied and detailed in such a way, that re-use and de-construction for reuse or recycling would be possible, when reaching the twenty years time.

This requires special knowledge of the lifespan of components and materials and also knowledge of methods of connections of joints. Specific materials were used such as carton board tubes for air-co ducts.

An Environmental Impact analysis was made of the materials used and this was compared with a building made in a conventional way. It turned out that the Impact of XX is just 50% of the latter one, see Fig. 3.



Fig. 2. The XX office building lasting for 20 years only. (Ref. 9)



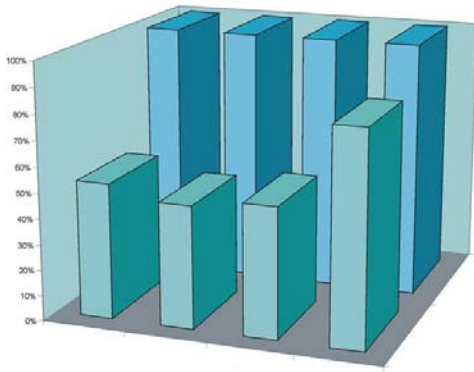


Fig. 3 Comparison of E.I. of XX office and a conventional office (Ref. 9)

### B. 5 years Children Art's Gallery

Following the same lifespan principles, the 'Kinderkunsthal' was built in Rotterdam. This building was intended to show children a collection of art work Ref. [9].

A number of sea-freight containers were positioned in such way that an attractive area has been created. The containers were used as a basic framework, put together and dressed in a minimalist way, with panels finishing both inside and outside.

After the planned period of 5 years, the containers were reused, materials recycled and nothing is left in place, as is the foundation as well, which is just inserted on the top soil.

### C. 1-5 years transitional shelter

In disaster areas, people have to be provided with facilities for (re)building their own housing units. For political reasons, transitional shelter can not look like "permanent" buildings, designed and built for lifespans longer than encountered. So also in this case the required lifespan of both materials and components should be taken into account very carefully.

After this period people may decide to upgrade their units to more permanent ones: various examples are available, such as the steel frame as being developed by the Red Cross International and being used in Vietnam and Aceh, Ref. [2], see Fig. 4.

### D. 0-1 year emergency shelter

Design for life span for a period of just a few days – to a month/ year refers to short term use of structures. Well known are the tents being set-up by Red Cross International and UNCHR in case of emergencies. A lot of expertise has already been put into new developments.



Fig. 4 Transitional shelter (Ref. 2)

New materials and technologies enable designers to develop more comfortable shelters for the short period. These shelters have to satisfy many requirements such as being appropriate storage of good quality, weather/climate resistance, producing its own electric energy. Furthermore they shall be easily transported and easily put in place.

Afterwards, the materials and the components can be re-used. After all, there are not so many materials that last for just a short period of time. So, some parts of the emergency shelter could also be designed to cater for a longer period, (=the transitional) period Ref. [10].

## IV. DESIGN FOR LIFESPAN EXISTING BUILDINGS: RE-ARCHITECTURE

When redesigning existing buildings we have to think of materials, components, infrastructure and structures already put in place for a number of years.

When it comes to design for life span one can think of improving these buildings for the function they are now providing. Maintenance and renovations are the options available with an increasing number of execution /building site activities to be undertaken.

Pereira Roders has developed (for her PhD research) a so-called design process support system, called Re-Architecture, which sustains architects to developing renovation designs of existing buildings, conscious about the building's lifespan: past, present and future Ref. [8]. This design process has two phases: the pre-design stage, undertaking an accurate judgement of the building; and the design stage, to design the renovation proposal, see Fig. 5. One can also judge the consequences of his design decisions with regards to changes in the existing building.

This system is under development but can be studied from [www.re-architecture.eu](http://www.re-architecture.eu). Although the concept has been developed for assisting the designer in renovation designs (reuse and conversion) in an existing heritage building (defined as any building older than one generation), it is also useful for other scales of intervention, such as maintenance, restoration, etc.

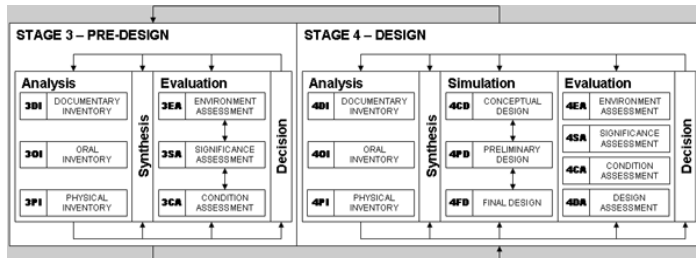


Fig. 5. The design process: pre-design and design stages (Ref. 8)

## V. DISCUSSION: WHAT IS THE INTEREST FOR LESS DEVELOPED COUNTRIES

In this paragraph the aspects will be discussed that need to be taken into consideration when applying the above developed concepts on designs for life span in Less Developed Countries (LDC's).

Thinking in terms of design for lifespan may seem contradicting to the contemporary design practice in LDC's, as 'we' are already 'happy' when the quantity of buildings – offices, houses etc. – that is realized annually is far below the actual needs. So bothering about constructing buildings, just lasting 20 years or even shorter does not seem to be justified. (e.g. the one million houses project in the RSA).

However, taking into account the reasons behind the new design concept this broader perspective, may have its specific advantages for LDC's. Just mentioning a few:

- one may use simpler materials, less import. As it does not have to last too long there is no need for very good materials
- maintenance may not be necessary, which is not a strong issue there.
- simpler construction methods
- options for reuse of the materials and components
- as labour is cheap and materials are expensive, so why not after a period of time adapt/change your building or even construct a new one with the use of the out coming materials!
- as land rights are not often known one may decide to construct a temporary building which may be

changed/ extended for the future when the rights have been settled.

- you can adapt or demolish existing buildings for new buildings to satisfy the new developments/requirements.
- lower requirements – building by laws
- in vulnerable areas damage may be less as we use lighter materials / simpler materials
- it may work out cheaper
- move from low cost to higher cost as opportunities improve (this requires possibilities for deconstruction and selling) this reduces waste of invested capital
- it stimulates people to start construction sooner with the simpler materials (so earlier investments and staff) as they know improvements can be made without suffering capital waste.
- when we involve a form of self help building, people know/understand better how their house is constructed, they know the details, so they may be able to improve their construction easier themselves.

## VI. CONCLUSIONS

The following conclusions can be drawn.

Apart from the already developed buildings, which are based on the ideas on design for lifespan design, more research is needed.

1. Research into physical/technical lifespan of materials and components; as we still have insufficient knowledge on those issues;
2. It is of interest to learn from existing buildings. What has been changed in buildings over time, which means was the building already flexible e.g. in built flexibility through extra height? (this involves case studies of realized buildings).
3. Study of expected developments in future, so that we can already take them into account, as far as, is possible during the design phase (think of teleworking, domotica for the elderly, miniaturization of installations, more security, change of climate, energy efficiency, solar energy).
4. With regards to developing countries, this design philosophy is worth to be experimented and monitored for specific cases.

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# **An Econometric Analysis on the Effects of Intersectoral Labor Mobility on Deforestation in Ghana**

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**International Conference on Adaptive Science & Technology (ICAST')**  
**10 – 12 December 2007, Accra, Ghana, West AFRICA**  
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### **Abstract**

*The link between population pressure, poverty, non-availability of non-agricultural employment, intersectoral labour mobility and deforestation are thought to be strong in developing economies. While one mostly observes migration from rural to urban employment, periodic interruptions marked by reverse migration from the non-agricultural sector to the agricultural sector due to sharp economic downturns has occurred during Ghana's adjustment period in the 1980s. This paper investigates the effects of this reverse labour mobility on area cleared for agriculture between the periods of 1970-1999. An empirical model relating to the effects of the determinants of labour mobility as well as the effects of labour mobility on deforestation is analyzed using cointegration and error correction modelling approach. The empirical results show that while rural population pressure and the rate of unemployment in the non-agricultural sector exerts positive and negative effects respectively on labour mobility in the short-run, intersectoral labour mobility exerts a positive effect on deforestation in the short-run.*

**Keywords:** *Intersectoral labor mobility, deforestation, cointegration analysis, Ghana.*

### **1. Introduction**

The relationship between people and the environment has changed over time. In particular, environment and development are interlinked. Excessive deforestation and reduction in soil quality induced by rapid population growth contributes to low rural income. The process of economic development involves resource reallocation, inter alia. One such economic phenomenon of resource transfer which has been accelerating over the years in developing countries is the mobility of labor between the agricultural and non-agricultural sectors. In Ghana, the transfer of labor from the agricultural sector to non-agricultural sector has occurred in relative terms. The total labor force still remains predominantly agricultural. The share of agriculture in total employment has declined; but in absolute terms, employment in the agricultural sector has increased (Ewusi *et al*, 1983). While there was a decline in the proportionate share of agriculture in total employment from 63 percent to 53 percent between 1960 and 1970; in absolute terms, there was an increase in the number of persons employed in the agricultural sector.

Policy reforms under the Economic Recovery Program (ERP) and Structural Adjustment Program (SAP) initiated in April 1983 have encouraged reversed migration in Ghana as urban dwellers have returned to the farm (Jaegar, 1992; Abdulai, 1999) thus coinciding with the growth in the agricultural sector especially the production of cocoa as targeted by the ERP (Fosu, 1989; Beaudry and Sowa, 1994). The primary goal of the adjustment programme was to liberalize the price system in order to stimulate production in sectors where Ghana possesses a comparative advantage. The links between population pressure, non-availability of non-agricultural employment, intersectoral labor mobility and deforestation are thought to be strong. The process of environmental degradation is associated with frontier expansion and about 70 percent of original closed forests in Ghana have been destroyed due to the demand for agricultural lands (Ampadu-Agyei *et al*, 1994)<sup>1</sup>. If there is shortage of land, the degradation is exacerbated as farm workers are forced to overexploit the land.

Although conversion of forestland has conferred substantial economic benefits, a point has been reached where it is necessary to balance economic growth with rational management of resources to ensure that the resource base is not entirely eroded in the process of development<sup>2</sup>. The effort by Knerr (1992) to analyze the socio-economic effects on deforestation in less developed countries was analytical in nature. Ehui and Hertel (1989) and Lopez (1997) who looked at deforestation in general did not consider the potential linkages between intersectoral labor migration and depletion of forest.

The main objective of this paper is to analyze the effect of intersectoral migration of labor on deforestation in Ghana both in the short-run and in the long-run. Two important questions are raised: What are the determinants of intersectoral labor mobility in Ghana during the 1970 to 1999 period? To what extent has the transfer of labor between the agricultural and non-agricultural sectors contributed to deforestation in Ghana? The paper is structured into seven sections. In Section 2, a review of the relevant literature is undertaken. A theoretical model on optimal forest use is formulated in Section 3. Section 4 presents the empirical analysis.

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<sup>1</sup> Agricultural policies pursued in an attempt to achieve economic development in Ghana seem to have stimulated deforestation through increases in land area cultivated.

<sup>2</sup> Ghana's Environmental Action Plan enacted by the Environmental Protection Agency emphasizes this.

In Section 5, the description of variables and the sources of data employed are indicated. The empirical results are discussed in Section 6. Conclusions and recommendations are distilled in Section 7.

## 2. Survey of Literature

This Section reviews the relevant literature. More light is shed on the empirical work on labor mobility and deforestation. The basic determinant of intersectoral labor mobility is the existence of income differences between sectors (Mundlak and Larson, 1997). The influential Todaro (1969) model postulated that migration is an increasing function of expected differential between sectors and the probability of obtaining a job. A migratory movement in sub-Saharan Africa, apart from rural to urban, takes the form of rural to rural which has had implications for agricultural development in the region (Abdulai, 1999). In Ghana, intersectoral labor mobility is seen as an internal migration where domestic labor supply is reallocated between rural (agriculture) and urban (non-agricultural) sectors. While one mostly observes migration from rural to urban employment, there has been periodic brief interruptions marked by episodes of reverse migration from industry back to agriculture due to sharp economic downturns as it happened during the 1920-21 recessions in the United States (Hatton and Williamson, 1994), and during Ghana's adjustment periods in the 1980s (Ewusi, 1987; Abdulai, 1999).

The Todaro (1969) study based on a cross-country data verified that the rate of migration is positively related to the ratio of income in non-agriculture to agriculture and that labor supply from agriculture to non agriculture is upward sloping. As labor leaves agriculture, labor productivity increases, leading to a decline in both income differential and migration respectively<sup>3</sup>. These results are consistent with what Banerjee and Kanbur (1981) obtained for Indian data. Beals *et al.*, (1967) used income in their Ghanaian study but limited their estimates to regional averages while Mundlak and Larson (1997) preferred GDP as a proxy for national income due to unavailability of good quality wage data. With Indian data, Banerjee and Bucci (1994) found out that low income workers, the landless, and the better educated are the most likely to engage in on-the-job search; thus, invalidating Todaro's job-lottery and high

unemployment view of urban labor markets in the developing world. Banerjee and Kanbur (1981) found inequality of land holdings to be positively related to higher rates of migration from the rural sector.

Regression models by Angelsen and Kaimowitz (1998) on Tanzania and by Panayotou and Sungsuwan (1994) on Thailand found a positive correlation between higher agricultural prices and deforestation. The effect of changes in agricultural input prices on forest clearing leads to indeterminate conclusion and mixed empirical evidence especially in the case of fertilizer. Regression models used on South Africa suggest a positive relationship between fertilizer prices and deforestation due to intensification (Holden, 1997). A study on Latin America by Babier and Burgess (1996) indicates a reduced deforestation as fertilizer prices increase, the reasons being that agriculture becomes less profitable when there is higher cost associated with the acquisition of fertilizer. Higher prices of inputs such as seeds, pesticides and hand tools also reduce forest clearing (Monela, 1995). Although empirical studies on Africa and Asia have ignored the issue of credit availability, Monela (*ibid.*) found a positive relationship between credit availability and deforestation in Tanzania.

Greater access to forest and markets accelerates deforestation (Mertens and Lambin, 1997) and that higher rural wages and greater off-farm employment opportunities reduce deforestation by making agricultural and forestry activities more costly (Ruben *et al.*, 1994; Bluffstone, 1995). Although empirical evidence on the relation between population growth and deforestation has been weaker, Rock (1996) obtained a positive relationship between them while Cropper and Griffiths (1994) found no effect. Mainardi, (1996) found higher deforestation as national per capita income increases.

## 3. Modeling Optimal Forest Use

The impact of intersectoral labor migration on the rate of forest decline is analyzed in the context of aggregate demand for forestland for agricultural production and aggregate supply of agricultural labor. The aggregate demand for forestland for conversion is formulated following Lopez (1997) and Barbier (2000). The rural household is assumed to be a price-taker in all markets for commodities and services it buys, consumes and produces. The profit maximizing decision of households is determined under the assumption that optimal

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<sup>3</sup> Migration stops when the income is roughly equal across sectors.

production function is independent of consumption and leisure choices. Let the household's agricultural production function,  $Y$ , be expressed as the product of the stock of arable land,  $A$  (in ha) and agricultural productivity per hectare,  $s$ . If the agricultural productivity is determined by the amount of purchased inputs,  $X$ , and agricultural labor,  $L^*$ , then the production function is stated as  $Y = A \cdot s(X, L^*)$ ,

$$s_x > 0, s_{xx} < 0, s_{L^*} > 0, s_{L^*L^*} < 0 \quad (1)$$

where  $s_x$  denotes the first order partial derivative of  $s(\cdot)$  with respect to  $X$ ,  $s_{xx}$  denotes the second order partial derivative of  $s(\cdot)$  with respect to  $X$  and so on.

The stock of agricultural land grows by new forestland,  $n(L)$  converted to agriculture by allocating some household labor  $L$ . Assuming that a proportion of agricultural land taken out of production at each time period  $t$  occurs at constant rate,  $k$ , then the rate agricultural land expansion is expressed as

$$\dot{A}/\dot{\partial t} = \dot{A}_t = n(L_t) - kA_t \quad (2)$$

where  $n_L > 0$ ,  $n_{LL} < 0$  and  $A(0) = A_0$  and  $k \neq 0$

Maximising aggregate profits  $\Pi$  of the agricultural sector over an infinite time horizon, the relevant optimization problem can be stated as

$$\text{Maximise } J = \int_0^{\infty} \Pi_t e^{-rt} dt \quad (3)$$

subject to  $\dot{A}_t = n(L_t) - kA_t$ , where  $r$  is the discount rate.

Given aggregate output price,  $p$ , input price,  $w$ , and cost function associated with forest conversion,  $c(L)$ , the aggregate profit  $\Pi$  for the households is computed as

$$\Pi = pY - wX - c(L) \quad (4)$$

where  $c_L > 0$  and  $c_{LL} < 0$  the time subscript  $t$  is suppressed for ease of exposition.

The total labor endowment of the household  $D$  is used for agricultural production  $L^*$  and land conversion,  $L$ , so that

$$L^* = D - L \quad (5)$$

The household's production function becomes

$$Y = A \cdot s(X, D - L) \quad (6)$$

The aggregate profit function becomes

$$\Pi = pAs(X, D - L) - wX - c(L) \quad (7)$$

The Hamiltonian for the solution of the intertemporal maximisation problem is

$$\begin{aligned} \Pi = pAs(X, D - L) - wX - c(L) \\ + \phi(n(L) - kA) \end{aligned} \quad (8)$$

where  $X$  and  $L$  are control variables,  $A$  is the state variable and  $\phi$  is the corresponding co-state variable representing the shadow value of land in terms of additional agricultural profits.

The optimal path to steady-state equilibrium is solved by deriving the first order conditions as follows

$$\partial H / \partial X = pAs_x - w = 0 \Rightarrow w = pAs_x \quad (9)$$

$$\partial H / \partial L = -pAs_L - c_L + \phi n_L = 0 \quad (10)$$

$$\Rightarrow \phi n_L = c_L + pAs_L$$

$$\partial H / \partial A = ps(X, D - L) + \phi(-k) = -\dot{\phi} \quad (11)$$

$$\Rightarrow ps(X, D - L) - \phi k = -\dot{\phi}$$

$$\partial H / \partial \phi = n(L) - kA = \dot{A} \quad (12)$$

Rearranging equation (9) as  $A = w/p s_x$  and substituting it into equation (12) gives

$$\dot{A} = n(L) - kw/p s_x. \text{ Differentiating the resultant}$$

equation with respect to  $w$ ,  $p$  and  $w/p$  gives

$$\partial \dot{A} / \partial w = -k/p s_x < 0, \quad \partial \dot{A} / \partial p = kw/p^2 s_x > 0$$

and  $\partial \dot{A} / \partial (w/p) = -k/s_x < 0$  respectively. The

optimal land use in each period  $A(t)$  is derived by differentiating equation (9) with respect to time

$$A(t) = 1/k (n(L) + w s_{xx} / p (s_x)^2 \dot{X}) \quad (13)$$

Notably,

$$\partial A / \partial (w/p) = -s_{xx} / (s_x)^2 \dot{X} < 0$$

or  $= 0$  or  $> 0$  if  $\dot{X} > 0$  or  $= 0$  or  $< 0$ . (14)

Demand for agricultural land as indicated in equation (13) depends not only on the rate of land conversion,  $n(L)$ , and the proportion of land under fallow,  $k$ , but also on agricultural returns ( $p/w$ ), the rate of marginal productivity of purchased inputs  $s_{xx}/s_x$ , and the rate of input use over time  $\partial X / \partial t$ . The impact of an increase in agricultural returns on land use  $\partial A / \partial (p/w)$  is determined by equation (14). If input use is growing overtime,

then agricultural land use will increase with rise in agricultural returns and vice versa. If  $\partial X/\partial t > 0$  then  $\partial A/\partial(p/w) > 0$  or if  $\partial X/\partial t < 0$  then  $\partial A/\partial(p/w) < 0$ . As noted by Barbier (2000), equation (13) provides useful insights into how input use and prices influence demand for land<sup>4</sup>.

The indirect effects of agriculture on forestland cleared for agriculture is captured through the increased profitability of frontier farming which, inter alia, stimulates labor displacement through migration to the agricultural sector. On-farm migration could lead to increased population pressure on land resulting in increased production and deforestation (Boserup, 1965; Rothenberg, 1980). Increase in availability of off-farm employment and income will unambiguously reduce deforestation.

Land area demanded for agriculture is a function of output and input prices, rural population pressure and a labor migration variable expressed as

$$A_c = A(O^p, I^p, P^R, M^A) \quad (15)$$

Notably,

$$\partial A_c/\partial I^p > 0, \partial A_c/\partial O^p > 0, \partial A_c/\partial P^R > 0 \quad \text{and} \\ \partial A_c/\partial M^A < 0.$$

where  $A_c$  is the area cleared for agriculture or area deforested,  $O^p$  is vector of output prices,  $I^p$  is vector of input prices,  $P^R$  is population pressure and  $M^A$  is labor migration from agricultural sector to non-agricultural sector.

Supply of agricultural labor is formulated by employing Harris and Todaro (1970) framework where intersectoral labor mobility occurs when a change in out-migration in response to short-run increases in income differential depends on the unemployment rate in the non-agriculture sector. Malthusian effect also postulates that higher wages, higher fertility and lower mortality rates as a result of natural population growth rate could stimulate migration. The effect of Structural Adjustment Programme on labor mobility rates is captured with the inclusion of its dummy (Barbier, 2000). Endogenizing labor input as suggested by Angelsen (1999), the labor mobility model is specified as

$$M^A = M(W^A, P^R, U^R, S^D) \quad (16)$$

Notably,

$$\partial M^A/\partial W^A < 0, \partial M^A/\partial P^R < 0, \partial M^A/\partial U^R < 0 \quad \text{and} \\ \partial M^A/\partial S^D < 0.$$

where  $M^A$  is migration of labor from the agricultural sector to the non-agricultural sector,  $W^A$  is the expected income in agriculture relative to that in the non-agricultural sector,  $P^R$  is population pressure,  $U^R$  is rate of unemployment in non-agricultural sector and  $S^D$  is structural adjustment dummy ( $S^D = 1$  for 1983 – 99 and zero otherwise)

#### 4. Empirical Analysis

The empirical model is specified, followed by cointegration and error correction modelling procedures in this section. The Dynamic Generalized Least Squares Estimator (DGLS) is used to specify a system of simultaneous equations involving labor mobility and its determinants and area deforested and its determinants. Having checked the identifiability status of the two equations and found them to be over identified, the Iterative Three Stage Least Squares approach is used to estimate the model. With the presence of cointegration established, the relevant Error Correction Models which incorporate the long-run equilibrium and short-run dynamics are estimated.

##### 4.1 Empirical Model

The empirical model is specified as a system of simultaneous equations in two endogenous variables, *MAN* and *DAREA*.

$$MAN_t = a_0 + a_1 WAN_t + a_2 RPOPD_t + a_3 UREM_t \\ \quad \quad \quad (-) \quad \quad (+) \quad \quad (-) \quad (17)$$

$$+ a_4 SAP_t + e_{1t}$$

(-)

$$DAREA_t = b_0 + b_1 MAN_t + b_2 RPOPD_t \\ \quad \quad \quad (-) \quad \quad (+) \\ + b_3 PCOC_t + b_4 PMZE_t \quad (18)$$

(+) (+)

$$+ b_5 PINST_t + e_{2t}$$

(-)

<sup>4</sup> The direct increase in the relative prices of agricultural products and decrease in the relative price of agricultural inputs stimulate farmers to increase output resulting in increasing demand of land for conversion to agriculture.

where *MAN* denotes labor mobility from agricultural sector to non-agricultural sector, *WAN* denotes income in agriculture relative to non-agriculture, *RPOPD* denotes rural population pressure, *UREM* denotes unemployment rate in non-agricultural sector, *DAREA* denotes area deforested, *PINST* denotes the price index of insecticides, *PCOC* is real producer price of cocoa, *PMZE* denotes real producer price of maize, *SAP* is adjustment dummy (*SAP* = 1 for 1983 - 99, 0 = otherwise), *t* denotes current time period and *e* denotes error term. The intercept terms capture factors which affect the rates of migration and deforestation and which change slowly overtime. The error terms account for possible omitted variables and errors associated with measurement and aggregation of the variables.

#### 4.2. Cointegration and Equilibrium Correction Modelling

Cointegration analysis begins with the determination of order of integration of each of the relevant time series because of the non-stationary stochastic processes of most economic time series. The time series is stationary if its mean, variance and autocovariances are independent of time. The necessary conditions for variables to be cointegrated are that they should be of the same order of integration and that linear regression involving the levels of the series must be stationary<sup>5</sup>. The order of integration is the number of unit roots the series contains or the number of differencing operations required to make it stationary. A stationary series is therefore

integrated of order zero,  $I(0)$ <sup>6</sup>.

To identify the order of integration, the Augmented Dickey-Fuller (ADF) unit root test is employed. Given a time series,  $Z_t$ , the Dickey-

<sup>5</sup> Many series are non-stationary in their levels but becomes stationary after their first differences.

<sup>6</sup>Time series  $X_t$  and  $Z_t$  are cointegrated of order  $(d, b)$ , where  $(0 \leq d \leq b)$  and  $X_t$  and  $Z_t \sim CI(d, b)$ , if  $X_t \sim I(d)$  and  $Z_t \sim I(d)$ , and  $(X_t - \beta Z_t) \sim I(d - b)$ . The two series are cointegrated if the residual  $\mu_t$  from the cointegration regression is stationary.

Fuller procedure involves the estimation of the regression

$$\Delta Z_t = \alpha + \gamma Z_{t-1} + \mu_t \quad (19)$$

where  $\alpha$  is a constant drift,  $\gamma = \delta - 1$  and  $\delta$  is the coefficient to be tested and  $\mu_t$  is a stationary random disturbance term. The ADF test ensures that a lag length  $k$  is chosen which makes  $\mu_{2t}$  a white noise term

$$\Delta Z_t = \alpha + \gamma Z_{t-1} + \sum_{i=1}^k \beta_i \Delta Z_{t-i} + \mu_{2t} \quad (20)$$

The ADF test statistic is the *t*-value for  $\gamma = \delta - 1$  in equation (20) under a null hypothesis  $H_0 : \gamma = 0$  implying non-stationarity against  $H_A : \gamma < 0$  implying stationarity,  $I(0)$ . When  $\gamma = 0$ , implying non-rejection of  $H_0$ , a unit root test on  $\Delta Z_t$  is run to verify whether  $Z_t$  is integrated of order one. When

$H_0$  is rejected for  $\Delta Z_t$ , then  $Z_t$  is  $I(0)$ . The null hypothesis of non-stationarity is rejected if ADF statistic exceeds the Mackinnon critical value at the 5 percent level of significance. Since lagged dependent variables are used in the ADF specifications, the Breusch-Godfrey (BG) test is employed to test for higher order autocorrelation (Maddalla, 2001). Once the stationarity properties of the individual series are established, linear combinations of the integrated series are tested for cointegration<sup>7</sup>.

If two series are cointegrated, then there exists an error correction representation which captures the short-run dynamics while making them consistent with long-run dynamics (Holden and Permon, 1994). Various authors have applied the classical Engle-Granger (1987) approach in analyzing the existence of long-run and short-run relationships between economic variables but the Dynamic Generalised Least-Square (DGLS) estimator proposed by Stock and Watson (1993) is employed in this paper. The DGLS estimator provides efficient estimates of long-run parameters and also eliminates the serial correlation in the model (Burger, Smit and Vogelvang, 2001). The simultaneous equation models explaining the long-run relationships between intersectoral labor mobility and deforestation are specified as

<sup>7</sup> If there is a long-run relationship between two non-stationary time series, then the cointegration test verifies whether deviations from the long-run path are stationary.

$$MAN_t = \phi_{10} + \phi'_1 Z_{t1} + \sum_{i=0}^k \phi'_{i1} \Delta Z_{t-i,1} + \mu_{t1} \quad (21)$$

$$DAREA_t = \phi_{20} + \phi'_2 Z_{t2} + \sum_{i=0}^p \phi'_{i2} \Delta Z_{t-i,2} + \mu_{t2} \quad (22)$$

where  $\phi_{10}$  and  $\phi_{20}$  are intercepts and  $Z_{t1}$  is the vector  $(l_t WAN_t RPOPD_t UREM_t)'$ ,  $Z_{t2}$  is the vector  $(l_t MAN_t RPOPD_t PINST_t PCOC_t PMZE_t)'$  with  $l_t = 1 \forall t$  in equations (21) and (22) respectively.  $\phi'_1$  and  $\phi'_2$  are vectors of long-run coefficients,  $\phi'_{i1}$  and  $\phi'_{i2}$  are vectors of short-run effects<sup>8</sup>.

The error correction terms that converge to the equilibrium relationships in equations (21) and (22) are estimated as

$$ect_{t1} = MAN_t - \hat{a}_0 - \sum_{j=1}^n \hat{a}_j Z_{tj,1} \quad (23)$$

$$ect_{t2} = DAREA_t - \hat{b}_0 - \sum_{j=1}^n \hat{b}_j Z_{tj,2} \quad (24)$$

where  $\hat{a}_0$  and  $\hat{b}_0$  are estimated constant terms and  $\hat{a}_j$  and  $\hat{b}_j$  are vector of estimated coefficients.  $Z_{tj,1}$  and  $Z_{tj,2}$  are vectors of explanatory variables and  $n$  is number of explanatory variables. The error correction models are specified as:

$$\Delta MAN_t = \delta_0 + \sum_{i=0}^k \delta'_{i1} \Delta Z_{t-i,1} + \gamma_1 ect_{t-1,1} + u_{4t} \quad (25)$$

$$\Delta DAREA_t = \delta_1 + \sum_{i=0}^k \delta'_{i2} \Delta Z_{t-i,2} + \gamma_2 ect_{t-1,2} + u_{5t} \quad (26)$$

where  $k$  is the chosen lag lengths,  $\delta_0$  and  $\delta_1$  are constant terms,  $\delta'_{i1}$  and  $\delta'_{i2}$  are vectors of estimated coefficients,  $\Delta Z_{t-i,1}$  and  $\Delta Z_{t-i,2}$  are vectors of explanatory variables,  $ect_{t-1,1}$  and  $ect_{t-1,2}$  are the error correction terms and  $\gamma_1$  and  $\gamma_2$  are their coefficients..

## 5. Description of Variables and Sources of Data

The data employed cover the period from 1970 to 1999. They are annual time series data on Ghana. In what follows, the definition and measurement of each variable are provided and the sources of all the data are also indicated.

### Labor Mobility

Assuming that agriculture is the largest sector and the residual employer, labor mobility rate is measured as the magnitude of labor contributed by the agricultural sector to the rest of the economy. As noted by Johnston and Kilby (1975), the absolute increase in the non-agriculture labor force per annum is computed

$$M(t) = (\dot{L}_t^N - \dot{L}_t)(L_{t-1}^N / L_t) \quad (27)$$

where  $M(t)$  is the labor mobility rate in period  $t$

and  $(\dot{L}_t^N - \dot{L}_t)$ ,  $\dot{L}_t^N$  and  $\dot{L}_t$  are the coefficient of differential growth, the growth rate of labor force in non-agricultural sector in period  $t$  and the growth rate of total labor force respectively<sup>9</sup>. Total labor force represents all persons aged 15 years and above engaged in or seeking employment in the agricultural sector or the non-agricultural sector. The time series data on labor employed in agriculture and the whole economy were obtained from various issues of the *UN Food and Agriculture Organisation (FAO) Production Yearbook* and the *Quarterly Digest of Statistics* published by Ghana Statistical Service.

### Deforestation Rate

Various authors have relied on the availability of time series data on forest stock in the measurement of deforestation rate<sup>10</sup>. The deforestation rate used represents deforestation due to agricultural expansion. The variable was computed as the difference between the area under agricultural cultivation and other industrial activities like logging and mining for consecutive years. Data on deforestation were obtained from various issues of the *FAO Production Yearbook*, the data files of the Ghana Forestry Department in Kumasi and the Ministry of Food and Agriculture, Ghana.

### Income

Total Gross Domestic Product (GDP) is used to proxy national income. Total GDP is made up of GDP in agriculture and GDP in non-agriculture. Non-agricultural GDP is the difference between total GDP and GDP in agriculture. These are used to proxy agricultural and non-agricultural incomes respectively. The income variables used in the estimations are income per capita. Agricultural

<sup>8</sup> Sufficient lags of  $\Delta Z_{t-i,1}$  and  $\Delta Z_{t-i,2}$  are chosen to enhance the efficiency of the estimation.

<sup>9</sup> The coefficient is also known as the Folke Doving coefficient of differential growth (Doving, 1959).

<sup>10</sup> Ehui and Hertel computed deforestation rate as the difference between the remaining forest stocks for consecutive years



income per capita is the ratio of agricultural income to agricultural population. Non-agricultural income per capita is the ratio of non-agricultural income to non-agricultural population. The income in agriculture relative to that in non-agriculture was derived as the ratio of agricultural income per capita to non-agricultural income per capita. Both GDP in current and constant 1985 prices were obtained. Dividing the nominal GDP (current) by the real GDP (constant) gave the GDP deflators (indexed to 1985=100). The agricultural population and non-agricultural population data were obtained from the various issues of *FAO Production Yearbook*. The time series data on gross domestic product (GDP) in constant 1985 prices originating in the agricultural and non-agricultural sectors were obtained from the Ghana Statistical Service and the various issues of the *International Financial Statistics (IFS)* published by the *International Monetary Fund (IMF)*.

#### *Rural Population Density*

Rural population pressure is derived as the ratio of rural population (millions) to area cultivated (ha). The deflator is area under cultivation in forest regions. Reliable time series data on area cultivated were not available so area under maize cultivation was used as a proxy since maize is one of the major staple foods cultivated by rural farmers in Ghana. Data on rural and urban populations were taken from the various issues of the *FAO Production Yearbook* and *International Financial Statistics (IFS)* of the *IMF*. Time series data on annual cultivated land for various crops are obtained from the various issues of the *FAO Production Yearbook*.

#### *Rate of Unemployment in Non-agricultural Sector*

The rate of non-agricultural unemployment is defined as the ratio of the difference between total employment and agricultural employment to the difference between the economically active population and agricultural employment. This assumes that economically active population in agriculture is equal to the number employed in that sector. The sources of the employment data were the *ILO Yearbook of Labor Statistics* and the *FAO Production Yearbook*.

#### *Price of Insecticides*

Annual time series data on the price of insecticides measured in ¢ / litres of Gammalin 20 are employed. The relevant data were obtained from the Cocoa Services Division of Ghana COCOBOD.

#### *Real Producer Price of Cocoa*

Real producer price of cocoa is used. The real producer prices of cocoa are obtained by deflating the nominal price of cocoa to 1985 prices using the CPI. Annual time series data on producer price of cocoa in ¢ / bag were obtained from various issues of *Quarterly Digest of Statistics (QDS)* published by the Ghana Statistical Service and Ghana COCOBOD.

#### *Real Producer Price of Maize*

The real producer price of maize was obtained by deflating the producer price of maize to 1985 prices with the rural CPI. Data on nominal producer price of maize were obtained from the Ministry of Food and Agriculture, Ghana.

## **6. Empirical Results**

The empirical results are presented in this section. Results of the relevant stationarity tests are discussed followed by the results of the error correction modelling.

### *6.1. Stationarity Tests*

Table 1 presents the empirical results on ADF test. While the levels of each of the series are non-stationary, the first differences are stationary. All the series became stationary when deterministic trend and drift term were included. The hypothesis of unit root could not be rejected at the levels for all the series because none of the ADF *t*-statistics exceeded its asymptotic critical value at the levels (Mackinnon, 1991). However, after first differencing, the hypothesis of a unit root was rejected at the 5 percent significance level for all the series. The Breusch Godfrey Lagrange Multiplier test for second order autocorrelation shows no autocorrelation in the residuals of the error term.

Table 1. Results of Unit Root Test.

Series	Level			Difference			Conclusion
	ADF	MCV	Lag-Length	ADF	MCV	Lag-Length	
<i>MAN</i>	-3.5218	-3.5867	2	-4.5320	-3.5943	2	<i>MAN</i> ~ I(1)
<i>DAREA</i>	-2.2342	-2.9750	1	-4.2993	-2.9798	1	<i>DAREA</i> ~ I(1)
<i>RPOPD</i>	-2.4108	-3.5867	2	-4.7865	-3.5943	2	<i>RPOPD</i> ~ I(1)
<i>WAN</i>	-3.2657	-3.5796	1	-4.1351	-3.5943	2	<i>WAN</i> ~ I(1)
<i>UREM</i>	-2.2075	-3.5943	3	-6.6206	-3.5867	1	<i>UREM</i> ~ I(1)
<i>PINST</i>	-0.7624	-3.5796	1	-4.3885	-3.5867	1	<i>PINST</i> ~ I(1)
<i>PCOC</i>	-3.0828	-3.5796	2	-3.8110	-3.5943	2	<i>PCOC</i> ~ I(1)
<i>PMZE</i>	-3.4228	-3.5867	2	-4.8609	-3.5943	2	<i>PMZE</i> ~ I(1)

Note: All variables are in their raw form. The ADF technique tests  $H_0: X_t \sim I(1)$  against  $H_1: X_t \sim I(0)$ . MCV are the asymptotic critical values or the Mackinnon critical values for rejection of hypothesis of a unit root and they are at the 5 percent level of significance. The ADF critical values are obtained from Mackinnon (1991). An ADF equation includes a drift and a trend term. *MAN* denotes labor mobility from agricultural to non-agricultural sector, *DAREA* denotes area deforested, *RPOPD* denotes population pressure in rural area *WAN* denotes income in agricultural sector relative to the non-agricultural sector, *UREM* denotes unemployment rate in non-agricultural sector, *PINST* denotes price of insecticides, *PCOC* denotes real producer price of cocoa and *PMZE* denotes real producer price of maize.

Source: Author's computations.

### 6.2. Long-Run Relationship

The results from the Iterative Three Stage Least-Squares estimation of the long-run relationship are shown in Table 2. Convergence was achieved after 26 iterations. The estimated coefficient of determination indicates that about 70 percent of the variation in intersectoral labor mobility from agricultural to non-agricultural sector is explained by the independent variables. The independent variables also explain about 60 percent of the variation in the area deforested. The *Q*-statistics from the correlogram of the residual of the labor mobility model are not significant even at 10 percent. Further serial correlation test with the *Breusch-Godfrey LM* test gave a BG (2) value of 1.472 and probability of 47.9 percent indicating a non-rejection of the null hypothesis of no autocorrelation in the model. Similarly, a BG (2) value of 1.472 with a probability of 47.9 percent shows no autocorrelation in the deforestation model.

The estimated coefficient of income in agriculture relative to non-agriculture in the labor mobility model does not exhibit the postulated sign but is significantly different from zero at the 10 percent level. This result runs counter to the Todaro (1969) hypothesis indicating perhaps that non-agricultural opportunities have come to dominate mobility decisions (Booth and Sundrum, 1984). The coefficients of rural population density and unemployment rate in non-agricultural sector have the expected signs and are significant at 5 percent

and 1 percent levels respectively. The results suggest that in the long-run, intersectoral labor mobility increases by 0.13 units and declines by 0.07 units when rural population density increases by 1 unit and unemployment rate in the non-agricultural sector increases by 1 unit, ceteris paribus. The negative insignificant coefficient of the structural adjustment dummy reveals minimal effect on intersectoral labour mobility in the long-run.

The coefficient of intersectoral labor mobility variable in the deforestation model bears the postulated sign but it is not significantly different from zero even at the 10 percent level. The rural population pressure, producer price of cocoa and insecticide price variables all carried the hypothesized signs and are significantly different from zero at the 5 percent, 1 percent and 1 percent levels. The producer price of maize has the expected positive sign but it is not significantly different from zero even at the 10 percent level. The negative coefficient of intersectoral labor mobility supports the observation by Jaegar (1992) and Abdulai (1999) that intersectoral flow of workers into the agricultural sector for cocoa production has occurred in Ghana. A unit increase in rural population density leads to a 19.5 unit increase in the area deforested in the long-run confirming the theoretical underpinnings of the neo-Malthusian belief about the effect of growing human populations on natural resource use (Sunderlin and Resosudarmo, 1999). With increasing population

pressure on land, the natural tendency is for people to clear more land.

The positive cointegration coefficient of 0.0002 of producer price of cocoa indicates that in the long-run, a unit increase in the producer price of cocoa results in about 0.0002 unit increase in the area deforested. This profit to margin of farmers

might have encouraged them increase output even though pesticides and fertiliser subsidies were curtailed during the stabilisation period of Ghana's ERP (Abdulai and Rieder, 1995). The estimated coefficient of price of insecticides has the postulated negative

Table 2. Results of Long-Run Relationships

Dependent Variable = <i>MAN</i>				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
<i>CONSTANT</i>	-0.0484	0.0308	-1.5715	0.1246
<i>WAN</i>	0.0138	0.0073	1.8827	0.0676
<i>RPODN</i>	0.1274	0.0579	2.2017	0.0340
<i>UREM</i>	-0.0653	0.0225	-2.8975	0.0063
<i>SAP</i>	-0.0073	0.0088	-0.8252	0.4146
$\Delta(UREM)$	-0.1749	0.0265	-6.5950	0.0000
$\Delta(UREM)_{t-1}$	0.0463	0.0242	1.9168	0.0630
$\Delta(RPOPD)_{t-1}$	-0.4548	0.2631	-1.7288	0.0922
$\Delta(WAN)_{t-1}$	0.0027	0.0063	0.4351	0.6661
$R^2 = 0.6995$			Mean = -0.0016	
Adj. $R^2 = 0.5729$			S.D. = 0.0254	
S.E. of regression = 0.0166			RSS = 0.0052	
DW Stat. = 2.0474			BG (2) = 1.4721 (0.4791)	
Dependent Variable = <i>DAREA</i>				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
<i>CONSTANT</i>	-11.9107	7.0664	-1.6855	0.1003
<i>MAN</i>	-26.2866	33.5285	-0.7840	0.4380
<i>RPODN</i>	19.5032	9.6099	2.0295	0.0496
<i>PCOC</i>	0.0002	0.0001	2.5409	0.0154
<i>PMZE</i>	0.0012	0.0035	0.3505	0.7280
<i>PINST</i>	-0.0011	0.0004	-3.0840	0.0038
$\Delta(MAN)_{t-1}$	-10.5366	16.6539	-0.6327	0.5308
$\Delta(PCOC)_{t-1}$	0.0002	0.0001	1.4227	0.1632
$\Delta(PMZE)_{t-1}$	-0.0051	0.0030	-1.6834	0.1007
$\Delta(PINST)$	0.0003	0.0002	1.5303	0.1345
$R^2 = 0.6017$			Mean = 4.0231	
Adj. $R^2 = 0.4026$			S.D. = 5.6992	
S.E. of regression = 4.4052			RSS = 349.2977	
DW Stat. = 1.2001			BG(2) = 1.7934 (0.1810)	

Note: \*\*\* Significant at 1 percent, \*\* significant at 5 percent, \* significant at 10 percent. The variables are in their raw form. *MAN* denotes labor mobility from agricultural to non-agricultural sector, *DAREA* denotes area deforested, *RPOPD* denotes population pressure in rural areas, *WAN* denotes income in agricultural sector relative to that in non-agricultural sector, *UREM* denotes unemployment rate in non-agricultural sector, *PINST* denotes price of insecticides, *PCOC* denotes real producer price of cocoa and *PMZE* denotes real producer price of maize, *SAP* denotes structural adjustment programme. The instruments used in the relevant equations are *WAN*, *UREM*, *SAP*,  $\Delta(UREM)$ ,  $\Delta(UREM)_{t-1}$ ,  $\Delta(RPOPD)_{t-1}$ ,  $\Delta(WAN)_{t-1}$ , *PCOC*, *PMZE*, *PINST*,  $\Delta(PINST)$ ,  $\Delta(MAN)_{t-1}$ ,  $\Delta(PCOC)_{t-1}$ ,  $\Delta(PMZE)_{t-1}$ .

Source: Author's computations.

Table 3. Results of Short-Run Relationships

Dependent Variable = $\Delta(MAN)$				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
<i>CONSTANT</i>	0.0106	0.0103	1.0320	0.3106
$\Delta(WAN)$	0.0021	0.0129	0.1659	0.8693
$\Delta(RPOPD)$	0.1136	0.5067	0.2242	0.8242
$\Delta(UREM)$	-0.2373	0.0489	-4.8542	0.0000
$\Delta(SAP)$	0.0073	0.0249	0.2945	0.7702
$\Delta(WAN)_{t-1}$	0.0115	0.0129	0.8911	0.3802
$\Delta(RPOPD)_{t-1}$	-0.6641	0.4940	-1.3443	0.1893
<i>ect</i> <sub>1,t-1</sub>	-1.1051	0.3718	-2.9719	0.0059
$R^2 = 0.5641$				Mean = 0.0002
Adjusted $R^2 = 0.3945$				S.D = 0.0388
S.E. of regression = 0.0302				RSS. = 0.0164
DW Stat. = 2.138634				BG (2) = 1.7194 (0.1898)
Dependent Variable = $\Delta(DAREA)$				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
<i>CONSTANT</i>	2.2429	1.4445	1.5528	0.1313
$\Delta(MAN)$	-28.4015	14.2044	-1.9995	0.0550
$\Delta(RPOPD)$	-33.0634	85.9614	-0.3846	0.7033
$\Delta(PCOC)$	0.0003	0.0001	2.1738	0.0380
$\Delta(PMZE)$	0.0005	0.0019	0.2674	0.7911
$\Delta(PINST)$	-0.0007	0.0004	-1.9875	0.0564
$\Delta(MAN)_{t-1}$	43.3786	14.8311	2.9248	0.0066
$\Delta(RPOPD)_{t-1}$	-138.6542	89.3393	-1.5519	0.1315
$\Delta(PINST)_{t-1}$	-0.0002	0.0003	-0.4737	0.6392
$\Delta(PMZE)_{t-1}$	0.0009	0.0021	0.4154	0.6809
<i>ect</i> <sub>2,t-1</sub>	-0.8304	0.2445	-3.3958	0.0020
$\Delta(DAREA)_{t-1}$	0.6653	0.2763	2.4078	0.0226
$\Delta(MAN)_{t-2}$	53.8683	12.3348	4.3672	0.0001
$\Delta(DAREA)_{t-2}$	0.0284	0.1597	0.1778	0.8602
$\Delta(PCOC)_{t-2}$	-0.0002	0.0001	-1.9071	0.0665
$R^2 = 0.7763$				Mean = 0.2215
Adj. $R^2 = 0.4915$				S.D = 3.7097
S.E of Regression = 2.6454				RSS = 76.9783
DW Stat. = 2.0125				BG (2) = 1.6987 (0.4267)

Note: \*\*\* significant at 1 percent level, \*\* significant at 5 percent level, \* significant at 10 percent level. All values are in their raw form.  $\Delta MAN$  denotes difference of labor mobility from agricultural to non-agricultural sector,  $\Delta DAREA$  denotes difference of area deforested,  $\Delta RPOPD$  denotes difference of population pressure in rural areas,  $\Delta WAN$  denotes difference of income in agricultural sector relative to non-agricultural sector,  $\Delta UREM$  denotes difference of unemployment rate in non-agricultural sector,  $\Delta PINST$  denotes difference of price of insecticides,  $\Delta PCOC$  denotes difference of real producer price of cocoa,  $\Delta PMZE$  denotes difference of real producer price of maize,  $\Delta SAP$  denotes difference of structural adjustment programme and *ect* denotes error correction term. The instruments used in the equations are  $\Delta(WAN)$ ,  $\Delta(RPOPD)$ ,  $\Delta(UREM)$ ,  $\Delta(SAP)$ ,  $\Delta(WAN)_{t-1}$ ,  $\Delta(RPOPD)_{t-1}$ , *ect*<sub>1,t-1</sub>, *ect*<sub>2,t-1</sub>,  $\Delta(PCOC)$ ,  $\Delta(PMZE)$ ,  $\Delta(PINST)$ ,  $\Delta(MAN)_{t-1}$ ,  $\Delta(DAREA)_{t-1}$ ,  $\Delta(DAREA)_{t-2}$ ,  $\Delta(MAN)_{t-2}$ ,  $\Delta(PCOC)_{t-2}$ .

Source: Author's computations.

sign and is significantly different from zero at the 1 percent level. This agrees with the empirical studies by Ruben *et al.*, (1994) for Costa Rica and Monela (1995) for South Africa that reduced prices of inputs increase forest clearing in the long-run.

#### 6.4. Short-Run Effects

The empirical results on the short-run relationship between intersectoral labor mobility and its determinants and short-run relationship between area deforested and its determinants are discussed in this Section. Table 3 presents results of the short-run relationships after application of Iterative Three Stage-Least Squares. Convergence was achieved after 36 iterations. The *Breusch-Godfrey LM* test with *BG (2)* value of 1.7194 and a *p-value* of 0.1898 suggest no autocorrelation in the labor mobility model and a *BG (2)* value of 1.6987 with a *p-value* of 0.4267 indicates the absence of serial autocorrelation in the residuals of the deforestation model.

The short-run effects are captured by the estimated coefficients. Unlike the long-run relationships, the income in agriculture relative to non-agriculture is not statistically significant. The rural population density variable in the intersectoral labor mobility model has the expected positive sign but not significantly different from zero in the short-run. The coefficient of unemployment rate in the non-agricultural sector is significant at the 1 percent level and has the apriori negative sign, lending credence to the proposition that as unemployment rate in a sector increases, labor migration to that sector decreases (Bencivenga and Rosenweig, 1997). Similar to the long-run effects, the SAP dummy is statistically insignificant. The reverse labor migration to the agricultural sector during the structural adjustment period may be attributed to the expansion of cocoa production as asserted by Beaudry and Sowa (1994).

In terms of postulated signs, the short-run dynamics did not differ very much from the long-run dynamics in the deforestation model. As expected, the intersectoral labor mobility variable has the hypothesised negative sign and it is significantly different from zero at the 10 percent level. The producer prices of maize and cocoa carried the correct signs but only the producer price of cocoa is statistically significant at the 5 percent level as it happened in the long-run estimation. The negative coefficient of 0.0007 of insecticide prices at the 10 percent significant level implies that in the short-run, a proportionate decline in the price of

insecticides leads to 0.0007 percent increase in the area deforested. The coefficients of the error correction terms have the expected negative signs and are statistically significant at 1 percent respectively indicating that last periods equilibrium error of intersectoral labor mobility from agricultural to non agricultural sectors has a significant impact on subsequent changes in the amount of area deforested through agricultural expansion.

## 7. Conclusions and Recommendations

The long-run and short-run relationships between intersectoral labor mobility and area deforested in Ghana over the period 1970–99 have been analyzed in this paper. In the long-run, intersectoral labor mobility from agricultural to non-agricultural sector increases with rural population pressure but decrease with the rate of unemployment in the non-agricultural sector. Policies which tend to increase rural income would encourage more people to stay in the rural sector but in the long-run, if rural population density continues to increase, this benefit would be neutralized. Policies which suppress urban incomes and lead to high unemployment rate where the bulk of non-agricultural work is concentrated would discourage labor from staying in that sector, as it happened in the late 1980s and early 1990s in Ghana. When bottlenecks in the rural and urban markets are removed, pressure on land would be reduced.

In the short-run, we observe deforestation due to intersectoral labor mobility from the agricultural sector to the non-agricultural sector. Exodus of labor to the agricultural sector due to non-existence of off-farm job opportunities would encourage people to clear more land which inadvertently leads to adverse environmental effects. Hence establishment of cottage industry and small-scale industries and other rural development policies which encourage job creation in the rural sector, must be pursued. Small-scale and affordable irrigation projects must be given a boost to absorb the surplus agricultural labor from the rural sector. There is the need to slow down the increasing pressure on land by promoting productivity increasing technologies in both the cocoa and maize sectors of the economy.

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# Screening of Intercellular Adhesion Molecule-1 Mutation In Children With Cerebral Malaria In Central Sudan

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**Keywords:** ICAM-1; cerebral malaria, children, Sudan

**Abstract:**

Malaria remains a major health problem in many countries; cerebral malaria is one of the complications of malaria. Intercellular adhesion molecule-1 (ICAM-1) act as a receptor for *Plasmodium falciparum* infected erythrocytes (PRBCs), located in the endothelial tissue including brain. Together with many others, adhesion of this receptor to (PRBCs) in the brain leads to accumulation of this complex in the cerebral vessel and obstructs blood flow, so development of cerebral malaria.

The study was conducted in 50 children confirmed to have cerebral malaria in central Sudan. The genetic analysis of ICAM-1 gene was compared with 50 children from school pupils with no history for cerebral malaria.

The incidence of cerebral malaria in this study is influenced by geographic, age, and ethnic factors with no gender variation. Ages from 4 – 8 years showed the highest incidence for cerebral malaria, about 68% of study group belong to four tribal stocks, [(28%) belong to Johayna tribal stock.

Four (8%) of study subjects died, 42(84%) were discharged alive and healthy, while 4(8%) survived with neurological sequelae (Hemiparesis, Hemiplegia, Aphasia, and Quadriplegia and Blindness).

The use of allele specific PCR (ASP) for genetic analysis in this study, indicated that the heterozygous (K29/M29) was 26% in CM patients and 12% in the control group, while only one (2%) mutant homozygous (M29/M29) was detected in CM patients group, but was not found in the control group. The distribution of alleles between subjects and control has shown significant difference, and all subjects who carried mutant allele (heterozygous and homozygous mutant) had 3 times susceptibility to CM than the other group, ( $P$ -value= 0.038, Odd Ratio = 2.5; 95% CI 1.011 - 6.181). The incidence of ICAM-1kilifi allele frequency in the study group was 11%, and this might increase the risk for susceptibility to cerebral malaria.

**Introduction:**

Malaria continues to be a major health problem in many parts of the world, with over 2400 million people at the risk of infection [1]. Mortality from malaria in African children under 5 years is 36/1000 per year [2]. Malaria results in up to 2.5 million deaths annually, with young children and pregnant women at greatest risk [3]. The patterns of pathology differ with changes in the degree of endemicity (Miller *et al.*, 1994). Cerebral malaria (CM) causes death in children and non immune adults [4].

In Sudan, malaria is the leading cause of morbidity and mortality, with an annual estimated 7.5 million clinical cases and 35,000 deaths. *P. falciparum* is the dominant parasite and the principal mosquito vectors are *Anopheles arabiensis*, *A. gambiae* and *A. funestus* [5]. Ninety percent (90%) of all malarial attacks are caused by *P.falciparum*, which causes the most severe form of disease and deaths attributable to malaria in Sudan [6]. High seasonal rainfall, variation in temperature and humidity which is observed during the rainy season in Sudan can favor mosquito breeding resulting in strong seasonal transmission. Malaria risk is present all over the country although too different degrees. In the northern, eastern, and western states, malaria is mainly low to moderate with predominately seasonal transmission and epidemic outbreaks. In southern Sudan, malaria is moderate to high or highly intense generally with perennial transmission. Although, in Sudan, whole population may be at risk to contracting the disease when they travel to the high risk areas, the following special groups are at higher risk to malarial infection; travelers from malaria free areas (visitors), pregnant women (specially during their first pregnancy), children in steroid or immunosuppressive drugs, expatriates and Sudanese returning from non- malarious areas [7]. As well as being receptor for parasite adhesion, ICAM-1 (CD54) also play a major role in normal immunofunction [8]. The various host



functions are mediated by specific interaction with a number of ligands, principally leukocyte function associated antigen 1 (LFA-1) [8], the plasma protein fibrinogen also binds to ICAM-1, [9;10], through its role in promoting cell-cell contacted and the resulting intercellular signaling, ICAM-1 facilitates leukocyte proliferation and transmigration across activated endothelium. ICAM-1 also has a role in diverse spectrum of disease including pathogen adhesion, for example *P. falciparum*- infected erythrocyte [11; 12]. Moreover, a number of inflammatory disorders such as septic shock [13], and autoimmunity [14] are involved.

*Methods:*

The study was carried out in an endemic area. Patients with *falciparum* malaria who had unrousable coma, not attributed to any other causes, this coma persisted for more than 1 hour after the convulsion; with asexual malaria parasites demonstrated on a peripheral blood were recruited from hospitals located in central Sudan cities (Wad Medani, Sinnar, and Singa). Fifty children with age and sex match were selected as a control from different schools in the three cities, or from patients from the three hospitals who were admitted for other diseases than CM and have no history for CM.

*Allele specific PCR (ASP):*

Also called the amplification refractory mutation system (ARMS). Is a simple method for the detection of any known point mutation or small deletion or insertion [15; 16].

In this method, we used two separate and complementary PCR amplifications for each sample; one was specific for ICAM-1Kilifi allele and the other for ICAM-1 ref allele, using three primers. One was common for the two reactions, and other two, one for each reaction, which differs from each other at their 3' ends, specific for the particular variant base (A/T).

*PCR reactions:*

The total volume of the PCR reactions was 30µl, containing 4µl genomic DNA, 10 picomoles for each primer of the two allele, 1picomole for internal control primers, 200µM dNTPs (dATP, dGTP, dCTP, and dTTP), 2.5µl from 10 x Taq Gold Buffer (100mM Tris HCl, pH 8.3, 500 mM KCl, 15 mM MgCl<sub>2</sub> and 0.01 % (w/v) gelatin (Perkin Elmer Cetus), 2 U AmpliTaq Gold™ polymerase (Perkin Elmer Cetus), and completed to the total volume with deionized water. 150bps of DNA fragment was PCR amplified using designed primers; primer1 common for both

reactions, primer2 for ICAM-1<sup>Kilifi</sup> reaction only, and primer3 for ICAM-1<sup>ref</sup> reaction only, also 330bps of internal control was amplified. The PCR condition was; 94°C as initial denaturation for 3 minutes, followed by 35 cycles of 94°C as melting temperature for 45 minutes, 64°C annealing for 45 minutes, and 72 as extension for 45 minutes. Then a final step in 72°C for 3 minutes as a final prolongation.

Table 1 Primers used for PCR amplification

Primer name	Primer sequences
Primer1	5'TGCCTGTCGCCTCTTCCCT3'
Primer2	GGTCTCTATGCCCAACAAC▼A
Primer3	GGTCTCTATGCCCAACAAC▼T

10µl of PCR product electrophoresed at 100v for 15 minutes in 2% agarose gel in 0.5xTBE (Tris base boric acid EDTA) buffer (running buffer), loaded with 5µl bromo phenol blue (loading buffer).The gel and running buffer contained ethidium bromide (0.5µg/ml), which stained the DNA before placed the gel on a UV light for visualization and finally photographed.

ICAM-1<sup>ref</sup> homozygous (Wild type- K29/K29) characterized by the amplification produced only in the ICAM-1<sup>ref</sup> reaction, a heterozygote (K29/M29) characterized by the amplification produced in the both reactions and ICAM-1<sup>Kilifi</sup> homozygous (Homozygous Mutant- M29/M29) characterized by the amplification produced only in the ICAM-1<sup>Kilifi</sup> reaction.

*Results:*

Fifty children were diagnosed as having cerebral malaria. Eighteen (36%) from Wad Medani Pediatric Teaching Hospital, 27 (54%) from Sinnar hospital, 5 (10%) from Singa hospital. All patients with blood film negative for asexual stages or having other diseases that may had contributed to the same complication of CM were excluded from the study. The highest incidence of disease was shown between the ages from 4 - 8years. 56% were males, 44% were females, and there is no significant difference between them ( $P=0.71$ ). The study subjects extended along 10 different tribal stocks, 68% of them belong to four tribal stocks, [(28%) belong to Johayna tribal stock, (16%) to Gaalian tribal stock, while (12%) belong to Nuba and Nigerian tribal stocks]. Four (8%) of the children were died, 42(84%) were discharged alive and

healthy, while 4 (8%) survived with neurological sequelae (Hemiparesis, Hemiplegia, Aphasia, and Quadriparesis and Blindness). ICAM-1 genotype was screened by ASP method. The wild type (K29/K29) was 72% in CM patients and 88% in their control, the heterozygous (K29/M29) was 26% in CM patients and 12% in the control group, while only one (2%) mutant homozygous (M29/M29) was detected in CM patients group, but was not found in the control group. There was no significant difference in the distribution of ICAM-1 genotypes, but the difference was found between the wild type and the carrier to mutant allele (heterozygous and homozygous mutant) with  $P$ -value= 0.046. The allele frequencies in the control group (n=50) were 0.94 for (K29), and 0.06 for (M29), and in CM subjects (n=50) were 0.85 for (K29), and 0.15 for (M29). The distribution of alleles between subjects and control has shown significant difference, and all subjects who carried mutant allele had 3 times susceptibility to CM than the other group ( $P$ -value= 0.038, Odd Ratio = 2.5; 95% CI 1.011 - 6.181) (Table 2 and 3).

Table 2 The genotype frequencies of ICAM-1 in CM patients and control

ICAM-1 Group	Genotypes		
	K29/K29	K29/M29	M29/M29
CM Patients	36(72%)	13(26%)	1(2%)
Control	44(88%)	6(12%)	0(0%)

Table 3 The allele frequencies of ICAM-1 in CM patients and control

ICAM-1 Group	Genotypes		Alleles	
	K29/K29	K29/M29+ M29/M29	K29	M29
CM Patients	36(72%)	14(28%)	0.85	0.15
Control	44(88%)	6(12%)	0.94	0.06
$P$	0.046		.038	

#### Discussion:

The distribution of study subjects shown that Sinnar was the highest incidence with CM compared to other two hospitals 54% (n=27). The highest age exposed to the disease was from 4 – 8 years in these children without any difference observed between sex and this may be attributed to the low immunity of these children most tribal stock had CM clustering (28%), while Beja, Nilotic, and Moroccan and Egyptian

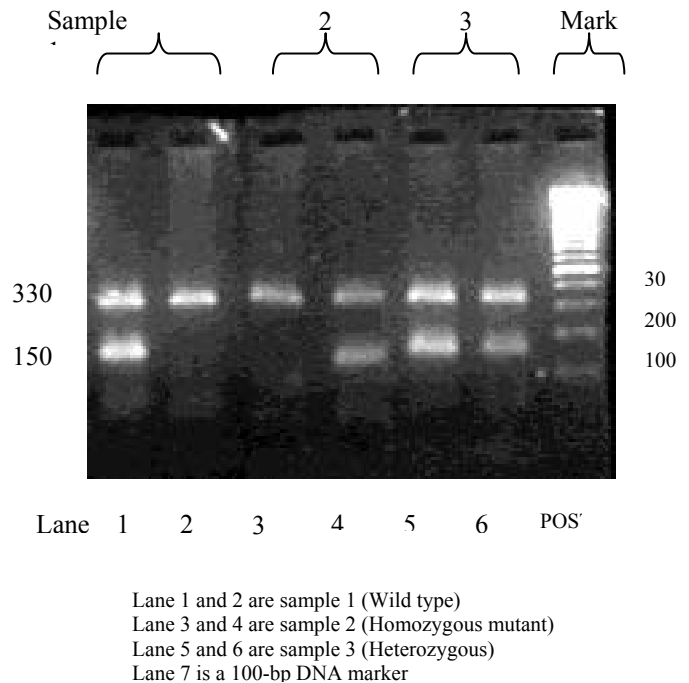


Fig 1 Detection of ICAM-1 polymorphism using ASP method

had the less clustering (2%). Confirming the distribution of the disease influences by geographic, age, and ethnic factors. Recently a mutation that caused A to T transversion in the ICAM-1 gene, causing a Lys to Met change in the amino acid sequence was recorded [17]. The distribution of this mutation was found in different populations in Africa and North America. In the North American population, it was found predominantly in African-Americans (41%), (n=41) [18]. No Caucasian was found to carry the ICAM-1 gene mutation [17]. In a two Asian populations studied in Papa New Guinea and Thailand, only in the Papa New Guinea was the ICAM-1 gene mutation found. No Thai had the mutation.

In contrast this mutation was found in Sudanese populations as shown in our study in frequency of (20%), 19% (n=13) were heterozygous, 1% (n=1) were homozygous. This agrees with the data from the study in Kenya, Nigeria, Gabone, and Papa New Guinea, indicated this mutation is predominant in the African populations at a high frequency comparable with the other populations. The results obtained from our study suggest that group carrier to this mutation is highly susceptible to CM than the other group ( $P$ = 0.046), this is an agreement with a recent study in Kenyan children which found this mutation had a high susceptibility to cerebral malaria. In a

study carried in the Gambian children, no correlation between ICAM-1 gene polymorphism and disease severity was found. Other study in Gabonese children, found this mutation protect against severe malaria. The exact causes for these discrepancies in these studies is return to geographic differences of *P. falciparum* strains that bind with different affinities to endothelial cells with this mutation. In the Gabon study compared patients had severe malaria with patients had mild malaria, the incidence of CM was rather low (n = 9), three were heterozygous and six were wild type, the influence of ICAM-1 may be by other genetic factors in other group of severe malaria than CM. It has been hypothesized that the intercellular adhesion receptors used by normal cells could also be operative in the spreading of circulating malignant cells to target organs; carriers to this mutation is resistant to the development of lymphoid malignancy compared with wild-type control.[19].

The presence of this mutation at a high frequency in populations in the malarious regions of Africa is explained by a protective effect to pathogens other than *P. falciparum*, such as bacterial infections, etc...

#### Conclusion:

The African mutation (ICAM-1kilifi) is predominant in Sudanese population as 20% for carriers and 0.11 for allele frequency. This allele increases the risk for susceptibility to cerebral malaria three times than the other allele (P= 0.038, Odd Ratio = 2.5; 95% CI 1.011, so we recommend the encouragement of experiences exploring vaccine, that may weaken the binding between ICAM-1 and infected erythrocytes. Since this mutation is present at a high frequency in populations in the malarious regions of Africa including Sudan, we think that it has a protective effect to pathogens other than *P. falciparum*, so we strongly recommend study of this mutation with other pathogens.

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