ROLE OF ECONOMIC DIVERSIFICATION IN SUSTAINABLE WATER MANAGEMENT: A SOCIO-HYDROLOGICAL ANALYSIS

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CERTIFICATE OF AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for any degree nor has it been submitted as part of requirements for a degree except as fully acknowledge within the text. I also certify that this report has been written by me. Any help that I have received in my research work and the preparation of the report itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Mahendran Roobavannan

August 2017.

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DEDICATION

To my lovely parents

Mahendran & Thanaluxmy

RESEARCH OUTCOMES

Journal publications.

- Roobavannan, M., Kandasamy, J., Pande, S., Vigneswaran, S., Sivapalan, M. 2017. Allocating environmental water and impact on basin unemployment: Role of a diversified economy. *Ecological Economics*, 136, 178-188, http://dx.doi.org/10.10 16/j.ecolecon.2017.02.006.
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- Mahendran Roobavannan, Jaya Kandasamy, Saket Pande, Saravanamuthu Vigneswaran, Murugesu Sivapalan, Allocating environmental water and impact on basin unemployment: Role of a diversified economy, Joint meeting of Japan Geoscience Union and American Geophysical Union, Chiba, Japan, May 2017.
- Mahendran Roobavannan, Jaya Kandasamy, Saket Pande, Saravanamuthu Vigneswaran, Murugesu Sivapalan, Finding a Sustainable Balance in the Water Food Nexus – Socio-economic Transformation in an Agricultural Catchment,10th World Congress on water resources and environment "Panta Rhei", European Water Resource Association, Athens, Greece, July 2017.
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Workshop attended

- Participated the Socio-hydrology workshop conducted at National Socio-Environmental Synthesis Center (SESYNC), Annapolis, Maryland, USA, August 4-7, 2014
- Participated the Socio-hydrology workshop conducted at National Socio-Environmental Synthesis Center (SESYNC), Annapolis, Maryland, USA, May 11-13, 2015

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NOMENCLATURE /ABBREVIATION

ABM	Agent based models
ABS	Australian Bureau of Statistics
ACF	Auto correlation function
AIC	Akaike information criterion
ARMA	Auto regressive moving average
BCC	Basin community committees
BIC	Bayesian information criterion
BSDI	Basin sustainable development index
CCM	Coupled-component modelling
CHANS	Coupled human and natural systems
CIA	Coleambally irrigation area
CPI	Commodity price index
CSR	Community sensitivity and response
EKC	Environmental kuznets curve
EWH	Environmental water holder
FPE	Final prediction error
FSR	Fish species richness
GDPc	Gross domestic product per capita for Australia
HDI	Human development index
HQIC	Hannan-Quinn information criterion
HSDI	Human sustainable development index
IWRM	Integrated water resource management
MBDA	Murry darling basin authority
MBDC	Murry darling basin commission
MDB	Murry darling basin
MHI	Median household income
MIA	Murrumbidgee irrigation area
MRB	Murrumbidgee river basin
NSE	Nash-Sutcliffe efficiency
NSW	New south wales
R^2	Coefficient of determination

RMSE	Root mean squared error
SD	System dynamics
SDL	Sustainable diversion limits
TFP	Total factor of productivity
UNDP	United nations development program
VAR	Vector auto regressive
WSP	Water-sharing plans
WSR	Water storage resilience

ABSTRACT

Water-human systems are closely linked and display co-evolutionary dynamics influenced by society's values and preferences. This has been observed in the Murrumbidgee River Basin, Australia where water usage initially focused on agriculture. After more than 100 years of agricultural development the Murrumbidgee Basin experienced a "pendulum swing" in terms of water allocation, initially exclusively for agriculture but changed in recent times to being reallocated to the environment. People became more concerned about the degradation of ecosystems, the amount of water left in the system and how much should be returned to the natural environment. However, water diversion for environmental purposes threatens many agricultural communities and their livelihoods. This thesis focuses on the human-water-environment nexus in the Murrumbidgee River Basin, and attempts to explain how and why changes in the management of water have impacted on the local economy and the community, but also with wider ramifications.

Predictably reduced water allocation to agriculture saw declines in that agricultural employment levels. Despite this, paradoxically, the basin unemployment rate declined and basin median household income increased. To understand and interpret this, in Chapter 3 we first analyze available labor, economic and hydrology data, and then develop a simple dynamic model to interpret the observed patterns of basin employment and unemployment. Data analysis revealed the likely causes behind the paradox as: (a) migration of people from the basin; and (b) absorption of the labor force in the fast-growing non-agricultural sectors of the basin's diversified economy. The model simulations reinforced this interpretation. Further model simulations under alternative scenarios of out-migration and sectoral transformation indicated that *basins embedded in faster growing national economies*, and are *more diversified* to begin with, are likely to be more conducive to agriculture industry reform (e.g., reduced water allocation) and environmental regeneration. This is a sobering message for other regions experiencing environmental degradation due to extensive agricultural development.

Chapter 4 hypothesizes that in the competition for water between economic livelihood and environmental wellbeing, economic diversification is the key to changing community sentiment in favor of environmental protection, and triggering policy actions that resulted in more water allocation to the environment. To test this hypothesis, we develop a socio-hydrological model to link the dynamics of the whole economy (both

agriculture and manufacturing and services industries) to the community's sensitivity regarding the environment. Changing community sensitivity influenced how water was allocated and governed and how the agricultural sector declined relative to manufacturing and services. In this way, we show that *economic diversification played a key role* in influencing the community's values and preferences with respect to the environment and economic growth. Without economic diversification, model simulations show that the community would not have been sufficiently sensitive and willing enough to act to restore the environment, highlighting the key role of sectoral transformation in achieving sustainable agricultural development.

Chapter 5 attempts to foresee future developments in the basin with a focus on how water managers could be informed and prepare for un-foreseen issues arising from climate change and the economy. The study uses a coupled socio-hydrological dynamical system model with endogenous social values and preferences. The exogenous drivers were economic and climatic-based. The dynamical system is represented by a suite of differential equations that can evolve over time. The study revealed possible basin development and exogeneous forcing conditions which could lead to sustainable basin development. In terms of sustainability the modelling and analysis revealed the importance of a diversified basin economy and how this is enhanced by moderate growth (or near current observed levels) of the national economy. An analysis was also carried out on the reliability of the system to meet water demand. Apart from an obvious relationship with available basin inflows, the reliability of meeting water demands from communities in the basin is low when the national economy is weak. The reverse was also found to be true.

Even though the changes in water management adversely impacted on the agriculture sector and created economic stress in the basin, its communities were able to adapt to and cope with water allocations favoring the environment through industry changes facilitated by movement of capital in a free economy, supported by appropriate strategies and government funding. This was helped by the adaptive capacity of people through reemployment in other economic sectors of the basin economy, experiencing unemployment for a period of time, migrating from the basin, and engaging in crop diversification. It is found that for given climate conditions, a higher level of diversification in the basin's economy increases its sustainability. Therefore, policy-makers and resource managers need to focus on measures to diversify the economy when

it is thriving, but also recognize capacity of society to adapt to unpredictable shocks in the system.