Exploring the seasonal dynamics of Australian temperate grasslands through phenocam imagery, remote sensing and field data

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A thesis submitted for the degree
Doctor of Philosophy (Science)

Climate Change Cluster
School of Life Sciences
University of Technology Sydney
2017

Certificate of Original Authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This research is supported by an Australian Government Research Training Program Scholarship.

Signature of Student:

Date: 19/5/2017

Acknowledgements

I would like to express my sincere thanks to my supervisor, Professor Alfredo Huete. He has taught me a great deal about the research process and I am indebted to him for being willing to share his time, wisdom and knowledge of remote sensing.

I also thank Rainer Rehwinkel (NSW OEH) for sharing his time and transmitting his enthusiasm for grassland ecology. His mentorship, training and help in obtaining field sites was invaluable.

Acknowledgement is due to the following organisations for financial support: the UTS Climate Change Cluster, and Australian Wildlife Conservancy grant. Travel funds were granted by the UTS Faculty of Science. This research was supported by an Australian Government Research Training Program Scholarship.

The use of field sites would not have been possible without the permission and ongoing assistance of several people: Dr Sally Power for access to the DRI-GRASS facility, Michael Mulvaney, Greg Baines and Don Fletcher; Peter Saunders and Brett Peden; Tobias and Lawrence Koenig; and David and Judith Watson.

Technical and moral support was provided by past and present post-docs and students of the Huete lab, particularly Zunyi Xie who has set the pace throughout this journey. I also thank members of the Forbes lab 'Shut Up and Write' team, fellow students of the School of Life Sciences, and Dr Andy Leigh, Professor Derek Eamus and Dr Brad Murray for their constructive feedback at various stages. This research would not have been possible without the assistance of the excellent UTS technical and administrative staff and undergrad volunteer, Nicole Laurie.

Sincere thanks are due to my OEH team leaders Terry Brill and Lucian McElwain for continuing to support my studies throughout a period of organisational change.

Finally, thanks to Shari and Izzy for their unwavering support and waggly tail, respectively.

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Abbreviations

ACT	Australian Capital Territory
ANPP	Aboveground Net Primary Productivity
BOM	Bureau of Meteorology
BRDF	Bidirectional Reflectance Distribution Function
C_3	photosynthetic system that uses three carbon molecules; cool season active
C_4	photosynthetic system that uses four carbon molecules; warm season active
CAI	Cellulose Absorption Index
CO_2	Carbon dioxide
ETM+	Enhanced Thematic Mapper plus
EVI	Enhanced Vegetation Index
fAPAR	fraction of Absorbed Photosynthetically Active Radiation
FOV	Field Of View
(f)BG	(fraction of) background substrate
(f)NPV	(fraction of) Non Photosynthetic Vegetation
(f)PV	(fraction of) Photosynthetic Vegetation
Gcc	Green Chromatic Coordinate
LAI	Leaf Area Index
MODIS	Moderate resolution Imaging Spectroradiometer
MSS	Multiscanner System
NDVI	Normalized Difference Vegetation Index
$NDVI_{705}$	Red-edge Normalized Difference Vegetation Index
NIR	Near Infra-Red
NSW	New South Wales
OLI	Operational Land Imager
Phenocam	Time-lapse camera used for monitoring land surface phenology
RGB	(of images, or image capture systems) Red, Green, Blue
ROI	Region of Interest
SWIR	Short-Wave Infra-Red
UTS	University of Technology Sydney
VI	Vegetation Index
WSU	Western Sydney University

Abstract

Management of temperate grasslands in south-eastern Australia is critical to support biodiversity conservation and agriculture under altered rainfall and warming conditions of future climates. Remote sensing is a common tool for monitoring vegetation but the dynamics of temperate grasslands present some unique challenges to conventional remote sensing methods. Land surface phenology—changes in large-scale vegetation dynamics—can improve the characterisation of temperate grasslands but the bulk of research in this field occurs in deciduous systems that show predictable vegetation changes. This research aims to explore drivers of grassland phenology and quantify the vegetation response by using field measurements, spectral instruments, time-lapse 'phenocams' and satellite data.

A series of controlled experiments explored the fundamental expression of grassland characteristics. Spectral ($NDVI_{705}$ vegetation index) and biophysical (fractional cover) response of grassland mesocosms was investigated through manipulation of species, density and disturbance. C_3 and C_4 species showed distinctive phenology profiles, density treatments demonstrated a logical increase in $NDVI_{705}$ from low- to high-density, and recovery of grasslands from disturbance was quantified. Standing litter, a common feature of Australian grasslands, strongly suppressed reflectance-based vegetation indices.

To investigate grassland response to changes in rainfall quantity and timing, phenocams collected sub-daily imagery from rainfall exclusion plots. Five treatments were assessed: ambient rainfall, increased rainfall, decreased rainfall, summer drought and extreme events. The Green Chromatic Coordinate index (g_{CC}) showed dynamic response to rainfall in all treatments. Increasing quantities of rainfall resulted in significantly higher productivity throughout the year. Grassland productivity increased during cooler months from extreme events, but was equivalent to ambient rainfall during summer months. Summer drought unexpectedly drove higher g_{CC} during non-drought periods, which was attributed to exotic forb invasions following disturbance.

Field research was conducted on native and exotic C_3- and C_4-dominated grasslands in the South Eastern Highlands bioregion. Floristic surveys showed high variation in species richness and condition throughout the year, with highest detection of native

species during summer months. Sites comprising multiple dominant species with overlapping phenophases showed a complex relationship with land surface phenology. Comparison of satellite NDVI (MODIS Terra, Landsat ETM+/OLI), phenocam and field variables showed that satellites and phenocams were equivalent at estimating green cover but the higher temporal capacity of phenocams allowed more precise definition of greening/browning trends.

Dynamic knowledge of field conditions is essential for validating remote sensing phenology studies. This research develops a greater understanding of non-conventional phenology and provides practical tools to improve management of temperate grasslands.