Satellite remote sensing to monitor land condition and dynamics in arid Australia

Letting the landscape speak for itself

Thesis submitted for the degree of

Doctor of Philosophy

by

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Title page image: Landscape in the northwestern Alinytjara Wilurara Natural Resources Management region near Pipalytjara. Photo by E F Lawley, February 15, 2012.

ABSTRACT

The natural arid regions of Australia hold special value because their ecosystems are relatively intact. They play an important role in carbon cycling, provide ecosystem services, deliver benchmark information about ecosystem structure and function in unmodified landscapes, and are often the last stronghold of threatened species. Many of these regions are also homelands for Aboriginal traditional owners. These regions are under increasing external pressures from mining, tourism, localised grazing and invasive species. Careful management is needed to maintain their ecological values.

Monitoring land condition is vital for management, but in extensive remote regions collecting field data to adequately represent land systems and processes is time consuming and costly. The high spatio-temporal variability of the arid landscape further confounds data interpretation. Long-term patterns of variability in vegetation response need to be understood to interpret management effects as distinct from natural variability. These long-term patterns cannot be understood from field data alone. In contrast, satellite-based monitoring offers potential monitoring solutions, with spatially comprehensive and consistent coverage over wide regions at relatively low cost.

This overall aim of the research was to improve arid land condition monitoring through use of satellite remote sensing. Vegetation cover and soil exposure were used as indicators of land condition throughout the study.

The study focused on the Alinytjara Wilurara (AW) Natural Resources Management (NRM) region in the far west of South Australia. This region is 261,180 km^2 in extent, much of it in near-pristine or wilderness condition, and is co-managed by the South Australian Government and the Aboriginal traditional owners. The landscape is extremely varied, incorporating calcarenite cliffs and dunes along the southern coast, the flat limestone Nullarbor Plain, red dune fields of the Great Victoria Desert, and the granitic Central Ranges and associated alluvial fans and plains in the north.

The research comprised three components to address the overall aim. Specific objectives were to characterize and better understand the patterns of long term spatio-temporal variability in vegetation growth over the Australian arid zone; to interpret these patterns, their significance and implications for monitoring and management across the AW study region; and to evaluate the potential of high-temporal frequency

low-spatial resolution fractional cover imagery for rapid land condition monitoring in the region. To address the difficulties of field validation, a further objective was to develop the use of high-spatial resolution satellite data as a tool for evaluation of low-spatial resolution fractional cover products.

To detect long-term patterns of variability in vegetation growth, 25 years of twice-monthly AVHRR NDVI data were analysed with principal components analysis. The main components that underlie Australia-wide arid zone variability were revealed as total vegetation growth, seasonal response, and erratic east-west response driven by cyclonic activity. These factors were used as the basis to classify the Australian arid region into 24 classes. The new spatio-temporal classes, which represent long-term vegetation function, were compared to the existing Interim Biogeographic Regionalisation for Australia (IBRA), which describes vegetation in terms of structure and composition. Some classes showed close correspondence with IBRA regions, but in other areas the classes revealed variation in functional response within and between IBRA regions.

Subsequently, focusing on the AW region, the four dominant classes in this region showed distinct characteristics in relation to average amount and temporal variability of vegetation growth, timing of growth cycles, and vegetation type. These distinctions can improve interpretation of on-ground data and have important implications for site selection and monitoring protocols such as timing and frequency of monitoring.

Lastly, a MODIS fractional cover product, designated for Australia-wide usage, was tested for suitability over the AW region for ongoing monitoring of land condition. In the absence of field data, remotely-sensed surrogates were created, which classified high-spatial resolution (2.5m) ALOS PRISM data into fractions of bare soil and vegetation cover. These were up-scaled to MODIS resolution. Weak correlation was found between the surrogate and the MODIS fractional cover product, implying that the MODIS product is not suitable in its current form for use in the AW region. The finding of a slightly stronger correlation with increased vegetation cover suggests that the lack of relationship may be due to the generally low NDVI response of the arid perennial vegetation in this region. The novel method employed to create the soil exposure surrogate for this evaluation warrants further development and application for validating low spatial resolution image products in arid regions worldwide.

This research shows how remote sensing can be used to define the high spatio-temporal variability of the Australian arid zone and provide new spatio-temporal information to improve regional environmental monitoring and management. We recommend that satellite remote sensing, because of its temporal capacity and comprehensive nature, be included as an essential component for monitoring remote arid environments.

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DECLARATION

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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DEDICATION

For Steven

29-12-1975 – 29-03-1995

ACKNOWLEDGEMENTS

Well here we are, and what a journey it has been. There seems to be a certain madness in going to university after 30 years of filling in “occupation – home duties” on the census forms. When asked why I am studying, with the “at your age?” implied, my reply has been: curiosity drove me! But truth-be-told, the wish to write a scientific report on our findings as environmental volunteers, and my inability to do so, was the driver.

This adventure would however never have happened without the encouragement of many people along the way. From Ben Pavy, who infected me with the joy of recognising plants, to Sue Kenny and Lee Heard who showed how to preserve and record the information, and most of all to Brad Page and Annelise Wiebkin, who on distant islands, under starry skies while waiting silently for Little penguins to come home, swayed my mind into believing that studying for a university degree was a realistic option; I may have surprised them as much as myself, when it became a PhD. Thanks goes to Dr. Scoresby Shepherd, whose example I admire, not spending time on obstacles, but navigating around them and keeping on course. He showed me, in his role as editor, how to “omit needless words”, though I confess that has remained a struggle. To these and many others I owe gratitude for their belief in me that set me on this journey.

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LIST OF PUBLICATIONS

Publications included in this thesis

Lawley, E.F., Lewis, M.M., & Ostendorf, B. (2011). Environmental zonation across the Australian arid region based on long-term vegetation dynamics. *Journal of Arid Environments*, 75, 576-585

Lawley, E.F., Lewis, M.M., & Ostendorf, B. (2014). Using spatio-temporal vegetation imagery for arid lands monitoring. *Ecological Indicators* (Submitted)

Lawley, E.F., Lewis, M.M., & Ostendorf, B. (2014). Evaluating MODIS soil fractional cover for arid regions, using albedo from high-spatial resolution satellite imagery. *International Journal of Remote Sensing*, 35, 2028-2046

ACRONYMS

ALOS	Advanced Land Observing Satellite
AW region	Alinytjara Wilurara region
AWNRM	Alinytjara Wilurara Natural Resources Management
AVHRR	Advanced Very High Resolution Radiometer
BRDF	Bidirectional Reflectance Distribution Function
IBRA	Interim Biogeographic Regionalisation for Australia
MODIS	MODerate resolution Imaging Spectroradiometer
MODIS Fract-G	The MODIS Fractional cover product created by Guerschman et al (2009) – abbreviation coined for this thesis.
NBAR	Nadir BRDF-Adjusted Reflectance
NOAA	National Oceanic and Atmospheric Administration
PRISM	Panchromatic Remote-sensing Instrument Stereo Mapping
GVD	Great Victoria Desert