Faculty of Health, Engineering and Sciences

SCALING EFFECTS ON LANDSCAPE FUNCTION ANALYSIS OF RANGELANDS USING REMOTELY SENSED IMAGERY

A thesis submitted by

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In fulfilment of the requirements of

Doctor of Philosophy

2015
ABSTRACT

The declining productivity and loss of ecosystem condition of arid and semi-arid lands is a worldwide concern and a major problem in Australia. Ecosystem condition can be assessed with the help of satellite imagery to measure the loss of basic resources (leakiness) from these areas. Leakiness has been shown to depend on the amount, type and position of vegetation cover in the landscape. It is well established that image scale (the observation scale) strongly affects the detection of landscape patterns and that rescaling changes these observed patterns through change in the structure of image features. Determining the relationship between leakiness calculated from images at different scales may assist in comparing results from the newer satellites with data from older long-duration time-series satellites such as Landsat and MODIS.

This research investigated the effect of different image resolutions on the calculation of leakiness (CSIRO Leakiness Calculator) from a savannah grazing catchment in North Queensland, Australia. Temporally and spatially coincident images from SPOT, Landsat and MODIS satellites were analysed for 11 vegetation indices. These were used in the Leakiness Calculator (LC) to calculate catchment leakiness.

Catchment and sub-catchments were defined from DEMs at scales matching the imagery. A high resolution DEM matching the SPOT resolution was extracted from an aerial photograph stereo model. The SRTM 1s DEM and the GEODATA 9s DEM were each rescaled to match the Landsat and MODIS image scales. Rescaling was by cubic convolution in ArcGIS and other image adjustments were done using ERDAS Imagine, SAGA and ERMapper software. Image structure was analysed by variogram analysis using FETEX 2 software in an ENVI IDL environment.

This study found that the amount of vegetation cover varied with the type of analysis method and the spatial resolution. There was no clear pattern of cover values, except that the 25m Ground Cover Index (GCI) had the highest values. The usual measure of catchment leakiness, Calculated Leakiness (Lcalc) was nominally higher at higher resolutions. This is because it is influenced by the number of cells in the analysis area. A new measure of leakiness, the Adjusted Average Leakiness (AAL) was formulated to be insensitive to cell number and to cell size.

AAL responded inversely to amount of vegetation cover for a given vegetation index but there was no consistent relationship between AAL and type of vegetation index. AAL from Perpendicular Distance Indices (PDI) correlated negatively with cover (as expected) but AAL from the Soil Adjusted Vegetation Index (SAVI) and the Normalised Difference Vegetation Index (NDVI) correlated positively with amount
of cover (unexpected). Other vegetation indices had irregular correlations between amount of cover and AAL.

Leakiness scaling functions for calculating both types of leakiness between 10 – 250m resolutions were developed (Resolution Scalograms). Lcalc scalograms took the form of linear reciprocal squared relationships for leakiness from SAVI and the Stress Related Vegetation Index (STVI) and a cubic reciprocal squared relationship for leakiness from the Perpendicular Distance of red-over-green band index (PDrg). AAL scalograms were simpler and took the form of simple linear relationships for leakiness from SAVI and STVI, but cubic for leakiness from PDrg. The high correlation between sill variance and resolution allowed the development of Variance Leakiness Scalograms (VLS). VLS for SAVI and STVI were positive logarithmic relationships and the PDrg VLS was a positive linear relationship.

Analysis of the structure (variance) of observation scale images of the catchment showed they had bounded natural logarithmic variograms. This structure decayed with progressive upscaling. Both observation scale and upscaled images had higher variances at lower a resolution. This is substantially different from previously reported findings. Three-dimensional (3D) models of the variance surfaces showed the effect of upscaling on image structure for different vegetation indices. The PDrg image variance response was the most complex. These models identified the optimal image resolution at which SAVI, STVI and PDrg features are expressed. Correlation between leakiness and conventional variogram indices and indices developed by the Universidad Politecnica de Valencia (UPV) was used to analyse for relationships between image structure and resolution. DEM variograms behaved differently. They had unbounded quadratic variograms and retained their form when upscaled.

The effect of vegetation cover in different areas of the catchment was tested by increasing SAVI and PDrg vegetation cover at different locations relative to major catchment features such as streamlines, elevation, slope, aspect, topographic feature and amount of pre-existing cover. Leakiness decreased the most when cover was added to zones distant from streams, at higher elevations, on lower slopes, on the crest of rises, on the top of ridge lines and in areas with the lowest amount of pre-existing cover. It is acknowledged that these findings are not entirely consistent with each other. There is mixed support for them in the literature. Smaller amounts of cover reduced leakiness more per unit of added cover than larger amounts of cover in all situations.
CERTIFICATION OF DISSERTATION

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own efforts, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

__________________________________________  ____________________________
Signature of Candidate                        Date

ENDORSEMENT

__________________________________________  ____________________________
Signature of Principal Supervisor             Date

__________________________________________  ____________________________
Signature of Associate Supervisor             Date
ACKNOWLEDGEMENTS

A thesis is not possible without the help of many people but most of all I would like to express my sincere appreciation to my supervisors. First and foremost to Associate Professor Armando Apan who both introduced me to GIS and Remote Sensing in the beginning through his very capable teaching skills and who has stood by me, ever ready to assist me throughout this thesis. He helped me realise a design that was only a vague idea in the beginning, helped me formulate the approach, the analysis methods and finally the interpretation of the findings. His forbearance with the idiosyncrasies of a senior student is acknowledged and very much appreciated. Dr Xiaoye Liu, my co-supervisor, has been quietly involved in all aspects of this work as she was with my Master's Thesis. She has been someone I could always depend on for ideas or whenever a difficult processing step was encountered. Individually and collectively, I thank both my supervisors.

This work required access to many resources without which it would not have been possible. Firstly, I acknowledge the USQ resources that were made available including computing resources of the ICT Department and the field mapping equipment provided by the Department of Civil Engineering and Surveying. I especially appreciate the help of Mr Clinton Caudell in overcoming many practical problems associated with fieldwork. A financial travel grant from the National Climate Change Adaptation Research Facility (NCCARF) was particularly helpful with costs associated with conferring with established researchers at CSIRO and the Queensland Department of Agriculture, Fisheries and Forestry (QDAFF).

Mr Lee Blacklock of the Queensland Natural Resources Management Groups Cooperative was very helpful in making SPOT imagery available along with Mr Doug Willis of the North Queensland Dry Tropics Natural Resources Management Group. The Government of the USA also deserves credit for continuing to make GPS data signals and Landsat and MODIS imagery available free of cost to the user.

Many people gave freely of their time and technical advice, especially Queensland State Government agency staff. Special acknowledgement is given to Mr Adrian Neal, Mr Mehedi Etemadi, Ms Jasmine Muir, Dr Peter Scarth and Dr Robert Karfs for their counsel and advice. No work of this type could be done without the pioneering work of CSIRO investigators and special acknowledgement is given to Mr David Tongway, Dr Adam Liedloff, Mr John Ludwig, Dr Brett Abbott, Mrs Vanessa Chewings and Dr Gary Bastin each of whom gave very useful and helpful advice. I also acknowledge the patient and helpful processing advice of two fellow students, Mr Govinda Baral and Mr Rodolfo Espada.
All fieldwork has a “home in the bush” somewhere and it fell to the lot of four friendly graziers to let me tramp throughout their properties collecting data. Without release of confidentiality, I am very thankful for the goodwill of Brian and Molly Christensen of Jesmond Station, Jennifer and Robert Laurie of Powlathanga station, Ian and Pam Berryman of Fifteen Mile Station and David Berryman and Rita Parker of Mt Windsor Station for allowing me open access for collecting a suite of field records. These were essential for correctly georegistering the imagery and ground-truthing image values.
PUBLICATIONS RELATED TO THIS THESIS


5. Dunwoody, E., A. Apan, and X. Liu (in preparation). Not all bare spots are the same: Use of the Leakiness Calculator to rank revegetation areas in a watershed. To be submitted to journal of Applied Geography, Elsevier Pty. Ltd. Cambridge MA.
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<tr>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAL</td>
<td>Adjusted Average Leakiness</td>
</tr>
<tr>
<td>ABCD</td>
<td>Natural pasture condition categories</td>
</tr>
<tr>
<td>AFM</td>
<td>Area between the First lag and the First Maximum</td>
</tr>
<tr>
<td>APS</td>
<td>Aerial Photographs</td>
</tr>
<tr>
<td>ARVI</td>
<td>Atmospherically Resistance Vegetation Index</td>
</tr>
<tr>
<td>ASTER</td>
<td>Advanced Spaceborne Thermal Emission and Reflectiuon Radiometer</td>
</tr>
<tr>
<td>ATE</td>
<td>Advanced Terrain Extraction</td>
</tr>
<tr>
<td>AVG</td>
<td>Non-overlapping Averaging interpolation resampling</td>
</tr>
<tr>
<td>BIL</td>
<td>Bilinear interpolation resampling</td>
</tr>
<tr>
<td>BOTANAL</td>
<td>Pasture yield estimating procedure</td>
</tr>
<tr>
<td>CAI</td>
<td>Cellulose Absorption Index</td>
</tr>
<tr>
<td>CASI</td>
<td>Canadian AeroSpace Institute</td>
</tr>
<tr>
<td>CC</td>
<td>Cubic Convolution resampling</td>
</tr>
<tr>
<td>CDLI</td>
<td>Cover based Directional Leakiness Index</td>
</tr>
<tr>
<td>CEC</td>
<td>Cation Exchange Capacity</td>
</tr>
<tr>
<td>CoD</td>
<td>Coefficient of Determination ($R^2$)</td>
</tr>
<tr>
<td>CORVI</td>
<td>Corrected Vegetation Index</td>
</tr>
<tr>
<td>CSI</td>
<td>Cross Scale Interaction</td>
</tr>
<tr>
<td>DEM</td>
<td>Digital Elevation Model</td>
</tr>
<tr>
<td>DLI</td>
<td>Directional Leakiness Index</td>
</tr>
<tr>
<td>DN</td>
<td>Digital Number</td>
</tr>
<tr>
<td>DTM</td>
<td>Digital Terrain Model</td>
</tr>
<tr>
<td>EO-1</td>
<td>Observer 1 satellite</td>
</tr>
<tr>
<td>EROS</td>
<td>Earth Resources Observation Center</td>
</tr>
<tr>
<td>ETM+</td>
<td>Enhanced Thematic Mapper plus</td>
</tr>
<tr>
<td>FCI</td>
<td>Fractional Cover Index</td>
</tr>
<tr>
<td>FDO</td>
<td>First Derivative near the Origin</td>
</tr>
<tr>
<td>FETEX</td>
<td>Feature Extraction software</td>
</tr>
<tr>
<td>FML</td>
<td>First Maximum Lag</td>
</tr>
<tr>
<td>FPC</td>
<td>Foliage Projective Cover</td>
</tr>
<tr>
<td>FR</td>
<td>First Range</td>
</tr>
<tr>
<td>FSV</td>
<td>First Sill semi-Variance</td>
</tr>
<tr>
<td>GC</td>
<td>Ground Cover</td>
</tr>
<tr>
<td>GCI</td>
<td>Ground Cover Index</td>
</tr>
<tr>
<td>GCPs</td>
<td>Ground Control Points</td>
</tr>
<tr>
<td>GloVis</td>
<td>USGS Global Visualisation Viewer</td>
</tr>
</tbody>
</table>
GPS............ Global Positioning System
GRPs........... Ground Reference Points
GRS............ Geodetic Reference Spheroid
HJ-1............ Name of Chinese satellite
HRVIR.......... High Resolution Visible Infra-Red
HIS............ Hyper Spectral Imager
IR............. Infra-Red
LC............... Leakiness calculator
Lcalc.......... Leakiness calculated
LFI............. Landscape Function Index
LI............... Leakiness Index
LISEM......... Limburg Soil Erosion Model
LPS............. Leica Photogrammetry Suite
M............. Majority resampling
MAE........... Mean Average Error
MAUP......... Modifiable Areal Unit Problem
MCSMA........ Monte Carlo Spectral Mixture Analysis
MDLI........... Modified Directional Leakiness Index
MERIS......... Medium Resolution Imaging Spectrometer
MFM.......... Mean of the semivariogram up to the First Maximum
MGA........... Map Grid of Australia
MODIS......... Moderate Resolution Imaging Spectrometer
MRBGI......... Multiple Regression Bare Ground Index
MSDI......... Moving Standard Deviation Index
MSS......... Multi Spectral Scanner
MTF........... Multi-Scale Transfer Function
NDVI......... Normalised Difference Vegetation Index
NIR........ Near Infra-Red
NLWRA......... National Land and Water Resources Audit
NN......... Nearest Neighbour interpolation Resampling
NPV......... Non-Photosynthetic Vegetation
NQ DTNRMB.. North Queensland Dry Tropics Natural Resources Management Body
NSCVR....... Nugget to Spatially Correlated Variance Ratio
NSVR....... Nugget to Sill Variance Ratio
NV......... Nugget Variance
ORIMA......... Leica Orientation Management software
PATCHKEY..... A native pasture analysis procedure
PD54......... Perpendicular Distance of band 5 over band 4
PD57......... Perpendicular Distance of band 5 over band 7
PDI........ Perpendicular Distance Indices
PD$_{rg}$  Perpendicular Distance of red band over green band
PD$_{rn}$  Perpendicular Distance of the red band over the NIR band
PD$_{rs}$  Perpendicular Distance of the red band over the SWIR band
PMF  Pixel Modular Transfer Function
ProXH  A brand of Trimble GNSS antennae
PS  Point Support
PSF  Point Spread Function
PSMs  Permanent Survey Marker
PV  Photosynthetic Vegetation
PVI-3  Perpendicular Vegetation Index number
QDERM  Queensland Department of Environment and Resource Management
Q-GRAZE  A proprietary pasture quality assessment software
QNRGC  Queensland Natural Resources Groups Cooperative
R  Range
RGB  Red Green Blue
RI  Redness Index (vegetation cover)
RMS  Root Mean Squared
RSF  Ratio of Second to First lags
RUP  Round Kernel Variance Weighted Upscaling resampling
RVF  Ratio Variance at First lag
SAGA  System for Automated Geoscientific Analysis
SARVI  Soil and Atmospherically Resistance Vegetation Index
SAVI  Soil Adjusted Vegetation Index
SCV  Spatially Correlated Variance
SD  Standard Deviation
SLATS  Statewide Landuse and Trees Study
SMA  Spectral Mixture Analysis
SR  Second Range
SRTM 1s  Shuttle Radar Topography Mission one second resolution
SRTM3  Shuttle Radar Topography Mission three second resolution
SSC  Soil Surface Conditions
STVI-4  Stress related Vegetation Index #4
SUP  Square Kernel Variance Weighted Upscaling resampling
SV  Sill Variance
SWIR  Short Wavelength Infra Red
TERN  Terrestrial Ecosystem Research Network
TEXTNN  Textural Neural Network
THREDDS  A proprietary data server operated by Unidata
TM  Thermatic Mapper
TRAPS  Transect Recording and Processing System
TTRP........ Trigger Transfer Reserve Pulse
UPV......... Universidad Politecnica de Valencia
VAST........ Vegetation Assets, States and Transition
VC........... Vegetative Cover
VLS......... Variance Leakiness Scalograms
VW........... Variance Weighted resampling
WGS......... World Geodetic System