Transition of Remote Sensing Research to Operational Use

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Abstract - Any form of environmental monitoring requires measurements to be repeatable, consistent and reliable. The spatial, spectral and temporal resolutions of the Landsat series of satellites are at scales particularly relevant, for which on-ground measurements can be accurately made, and as such are well placed to provide necessary and updated information for land managers. This paper looks at examples of this information and the processes of introducing this technology from research into applications within an operational department.

Relevant information on the health, condition and changes occurring in the environment are of great interest from a variety of perspectives. Satellite imagery, primarily due to its synoptic views of landscapes and multi-temporal sensing, is suited for monitoring this information. One of the benefits of continued collection of satellite imagery, by programs like Landsat, is the ability to study changes at landscape scale over time, with changes in vegetation cover being among the most common features sort. Skidmore *et al* (2002) states, the historical archive of satellite imagery for studying landscape change continues to grow and its duration now covers almost a third of a century. It is unmatched in quality, detail, coverage and importance. The dramatic increase in studies using this archive of historical satellite imagery indicates the growing value of imagery and points to a future where remote sensing data will play a key role in our understanding of how environments are changing and how humans are influencing its health and sustainability.

The uptake of information derived from remotely sensed systems within operational departments such as DEC is dependent on many issues. Some of these identified here are: (1) data accessibility, continuity, and standards, (2) outcomes and benefits, (3) involvement of users, (4) training and teaching, and (5) sustainability and acceptance

Keywords: satellite, monitoring, remote sensing.

1. INTRODUCTION

Over the last decade a number of Landsat based remote sensing monitoring programs have been implemented in Australia. These include the Queensland's Statewide Landcover and Trees Study (SLATS) http://www.derm.qld.gov.au/slats/, the Land Cover Change Project (LCCP) of the Department of Climate Change http://www.climatechange.gov.au/default.aspx/, and the Western Australian Land Monitor Project http://www.landmonitor.wa.gov.au/, a multi-agency project producing information products for land management in Western Australia. Land Monitor has mapped and monitored changes in salt-affected land (Caccetta *et.al*, 2009) and woody vegetation in the south-west agricultural region (Wallace *et.al*, 1995) since 1988. All these programs use methods which investigate the long-term sequences of Landsat data to provide observations relating to land use and vegetation trends.

A methodology developed by staff based at the Remote Sensing and Image Integration Group (CSIRO), located in the Leeuwin Centre for Earth Sensing Technologies in Perth use multispectral Landsat TM imagery to detect changes in vegetation density or cover over time. The method can be applied to detecting long-term changes in woody vegetation health caused by factors such as increasing salinity, disease, water-logging, climate and livestock grazing. A key factor in using satellite imagery for this purpose is to calibrate the satellite image with ecological data obtained from field observations such as 'crown' and 'projected foliage' cover. These measures are directly related to natural changes we are interested in.

At present Land Monitor vegetation trend and change maps are prepared in the absence of ground data. Visual interpretation of these maps has proved useful for indicating areas of relatively stable cover over a given time period, and areas that have undergone some change in vegetation cover.

This information shows that remote sensing products have the potential to be useful to a variety of decision makers and policy makers because of the opportunity to investigate and evaluate the long-term management outcomes. Three examples of remote sensing applications from the Western Australia Department of Environment and Conservation (DEC), are presented here and include monitoring woodland decline, rangelands, and for wetlands resource management.

Transitioning from research and development to successful applications must overcome challenges. These include the lack of awareness by end users of the technologies, inadequate feedback mechanism between application analysts and end users, and unproven cost benefits of remote sensing data. Experience from within DEC indicates that these issues could be reduced by educating and training end users, demonstrating the utility of remote sensing data in improving decision making, and establishing and maintaining a continuous dialogue between analysts and end users. Sustainability of remote sensing applications ultimately depends on users continuing reliance on products and benefits from remote sensing data.

Example 1: Monitoring Woodland (*Eucalyptus Wandoo*) Decline

In recent years, widespread decline of *Eucalyptus wandoo* (wandoo) has been observed in the southwest of Western Australia. Mature trees provide important refuge and nesting hollows for a number of threatened birds and mammals, and their felled limbs are habitat for species like the numbat.

The causes of the problem and the mechanisms by which wandoo trees are affected are not yet understood. The 'Wandoo Recovery Group', which includes representatives from local rural councils, government and non-government agencies, and research institutions, was established by the Western Australian Minister for the Environment, in 2003. The initial difficulty facing the Group's research was that they lacked a comprehensive picture of the location, timing and extent of the problem.

Satellite imagery has been used to provide valuable monitoring information of changes in wandoo vegetation across the region from 1988-2009 (Garkaklis & Behn, 2009). The information is provided as maps which indicate where changes in vegetation have occurred. The changes at particular sites can be quantified and compared using graphical plots of the responses over time to determine when the events occurred.

Example 2: Rangeland Monitoring (Karijini National Park)

Knowledge of up-to-date vegetation cover density and variations are basic data requirements for Government agencies like DEC. To date the only vegetation cover mapping or knowledge of vegetation densities has been related to broad Land Unit or Land Systems mapping as defined in the National Vegetation Information System (NVIS) framework dataset (Cofinas *et al.* 1999**).** Satellite remote sensing technologies were seen to have the means of providing the required monitoring information on vegetation cover. It provides an areal capacity plus the spectral sensitivity to accurately discriminate density of vegetation cover.

A simple but significant approach was applied to 're-construct' the image area to that of a stable unaltered landscape (Behn, 2005). This method was based on extracting the best pixel value, in terms of spectral sensitivity for each pixel from a terrain corrected image set. The final product being a composite image containing the best information for each spectral band and is used to eliminate vegetation cover variations due to disturbances, such as fire and un-seasonal events.

A simple linear index was applied to the spectral information of the re-constructed image to locate areas of vegetation occurrence and mask areas without vegetation cover. A second vegetation index was used to divide the vegetation cover into the three appropriate cover classes.

These vegetation cover classes were then intersected with the Land Systems boundaries and attributed with typical land unit association including vegetation structure (growth form, height and cover) and floristic (genus and species).

The changes in the index values at a location indicate physical changes on the ground and can be associated with changes in vegetation densities. It is important to note that there are many causes and interpretations of changes in vegetation reflectance, and that the physical changes which result in a similar numerical reflectance response will vary with vegetation type and background. The numerical values, while consistent and comparable, were not calibrated to vegetation density cover on the ground. For example, while the data may indicate cover in terms of reflectance values, no inference can be drawn from these data alone concerning the type or condition of the vegetation.

Mapping vegetation cover is a subjective task in itself as the term 'mapping' implies a static look, where in reality vegetation is constantly changing. In Karijini National Park the vegetation cover has varied over time in both structure and floristic composition with the primary variation caused from fire impacts and climate change. The use of multiple dates of imagery to create a re-constructed image of the vegetation minimizes patterns and allows the cover to be more reliably mapped.

Example 3: Wetland Conservation Value

The objective was to produce a 'wetness' classification of identified wetland areas in the Avon region of Western Australia using a sequence of available Landsat TM imagery (Zdunic *et al.* 2009) The resulting product was used to investigate the wetland regime in summer from 1990 to 2007.

The project area covered the Avon region in the south west corner of Western Australia. The analysis was restricted to the wetland areas which have boundaries captured in vector format.

Surface water can be separated from exposed land using Landsat TM imagery due to the difference in the spectral response of water and land in the short-wave infrared portion of the spectrum. Band 5 in the Landsat TM imagery can be used to discriminate damp exposed soils while some separation appears possible in Band 1 to identify saline surface water and fresh surface water. This is reliant on the greater reflectance of saline water due to a lack of macrophytes present. Fresh water bodies tend to appear darker due to macrophyte growth.

Using the above properties of the water response four wetness classes has been developed:

1. Fresh surface water
2. Saline surface water

3. Damp areas
4. Dry areas

To obtain some measures of the changes in classification for each year, four class area statements for each wetland are extracted. The area statements can then be converted to percentages and compared throughout the sequence of imagery.

When comparing the surface water classification with ground data there is a 100% accuracy rate. However the separation of the surface water class into fresh and saline has been found to have an accuracy of 80%. This is due to the presence of dark benthic materials or macrophytes in some saline lakes. Hence this separation of the surface water class should be used as an indicator in any analysis. With greater ground data and more analysis it may be possible to improve this result.

Terrestrial vegetation that does not allow penetration to the ground below obscures the ability to classify the pixel. However the presence of this type of vegetation in the identified wetlands is restricted and thus its effect on the result is limited.

2. DISCUSSION AND CONCLUSION

To introduce remote sensing data and applications into existing government operations, it must deal not only with major non technical issues but also with significant technical issues. How these issues are addressed will often determine whether a particular application of remote sensing will succeed and whether remote sensing will be able to provide the information needed for management and decision making.

The non technical issues affecting development and operational use of remote sensing can be labelled into several broad categories:

- financial and budgetary constraints;
- institutional, organisational, and political issues;
- experience, skills, and training;
- transition from analogue photographic to digital data.

Bearing these issues in mind, and from the above case studies examples, the promotion of remote sensing technologies for decision making by State Government departments such as DEC can be summarised as follows.

Data accessibility, continuity, and standards

Remote sensing imagery often consists of large digital files. Fast network connectivity is, therefore, essential for efficient transfer of imagery among data providers, analysts, users, and decision makers. Similar to other technologies, remote sensing technology is evolving. A number of remote sensing applications require data collected over multiple years for temporal analysis to observe patterns, trends and changes. Others may need near real time acquisitions. Managing these differing requirements is complex and necessary.

Users expect consistency in data format and content over time and need to be assured of data longevity before they are willing to switch to remote sensing data products and techniques for operational decision making. Decision makers and policy makers require datasets and techniques that can provide consistent results each time they are used. It is also critical that the remote sensing data have the right spectral, spatial and temporal characteristics and be economically viable in terms of cost for successful application development.

Remote sensing data and products are generated by various agencies in a variety of formats. These formats may be suitable for researchers, but end users in non-research organisations require data in a format that can be readily displayed and analysed using simple software packages. End users in DEC typically do not have access to high-end image processing software and tools. Products from remote sensing imagery should, therefore, be generated in formats that can be readily ‘read’ into a variety of popular low cost image and GIS packages and should be compatible with user’s existing systems and infrastructure. To promote wider use, DEC and its partners are developing translation tools converting data into a variety of formats and graph products as input to existing image processing and reporting technologies.

Outcomes and benefits

One of the major obstacles to date for adoption of remote sensing data for application use has been the lack of proven benefits, particularly in relation to cost. Adopting remote sensing imagery requires investment in hardware, software, and training. Before a group of users adopt this technology as an alternate to existing methods, they need to be convinced that remote sensing solutions are economically viable and save time and money with respect to other environmental benefits. It is possible to show the monetary savings for applications that directly use remote sensing techniques for regulation and allocation of resources. It is, however, more difficult to assign a monetary value to benefits to the environment and quality of life which result from policy changes. Putting a monetary value on indirect benefits from using remote sensing data is complex and challenging. Nevertheless, demonstrating the benefits of remote sensing through either cost savings or cost avoidance would build a strong case for investing in these technologies by DEC.

Involvement of users

Early and continuous involvement of the users is essential for the success of application development, and for the impact on decision-making. The products and datasets that are developed have to be driven by a convincing requirement by the users. Methods for adequate feedback should exist through periodic meetings and workshops between analysts (remote sensing scientists) and the product users for continuous improvement. Ongoing workshops with users from within DEC's Regions, Branches and Sections have helped in overcoming internal barriers by bringing together different user groups with similar requirements and facing similar challenges. These workshops have provided a forum for exchange of ideas among the groups. By having these regular face-to-face meetings between the analysts and users, it enables the opportunity to engage in a collective discussion.

Training and teaching

At present, remote sensing technologies are not widely used within DEC, and so the training and teaching of users is critical for the successful adoption of the technology. Users' familiarity in remote sensing techniques helps in building an agreement between end users and analysts on the product specifications.

After successful demonstration of the benefits of remote sensing products, these products and methods would then be transferred to the various Regions, Branches and Sections who would then adopt and maintain them. Training and learning are, therefore, critical to the transferring of the technology and knowledge from the application analysts to the users within DEC.

Establishing peer teaching groups, in which an advanced user of a product teaches his peers within the same user area, enhances product value. For example, a group of scientists is more comfortable adopting a product when a fellow scientist endorses it and shares his positive experiences.

Sustainability and acceptance

Factors such as the benefits, ease of use, timeliness of data, and continuity of data contribute to the acceptance of remote sensing applications. Various applications of medium and coarse spatial resolution remote sensing data, weather forecasting, disaster mitigation, and climate prediction have found markets because of recognisable economic and social benefits. Other applications such as vegetation monitoring and compliance are more localised requiring imagery at a higher spatial resolution. The higher cost associated with this imagery compared to medium or coarse resolution data remains an issue.

New users of remote sensing technology are not willing to invest unless the application has been proven to be a viable alternative to current practices. Experiences show that 2–4 years or more are required before the end users gain confidence in using remote sensing data and formalise their use. During the initial phases of application spread, the end users need hands-on training and advice, access to free data and processing software, technical support, and sometimes access to equipment as well. The rate of acceptance is directly related to the perceived value that remote sensing data has by users responsible for policy development or implementation.

3. REFERENCES

Behn, G. (2005), *Mapping of Vegetation Cover Within Karijini National Park*. Internal DEC report.

Caccetta, P. A., Campbell, N. A., Evans, F. H., Furby, S. L., Kiiveri, H. T. and Wallace, J. F. (2000), *Mapping and monitoring land use and condition change in the South-West of Western Australia using remote sensing and other data*, (2000), Proceedings of the Europa 2000 Conference, Barcelona.

Caccetta, P., Dunne, R. and McFarlane, D. (2009), *A Methodology to Estimate the Future Extent of Dryland Salinity in the Southwest of Western Australia*. J. Environ. Qual. 2009 39: 26-34.

Cofinas, M., Cresswell, I.D., Howell, C., Thackway, R. Watt, A. and Wood, M. (1999). Theme 3: Vegetation Cover, Condition and Use Work Plan. National Land and Water Resources Audit, Canberra.

Garkaklis, M., Behn, G. (2009), Assessment of *Eucalyptus Wandoo* canopy decline using Landsat Trend Analysis. Internal DEC report.

Skidmore, A., Prins, H., (2002), CRC Press *Environmental Modelling with GIS and Remote Sensing*

Stone, C., and Haywood, A., (2006), *Assessing canopy health of native eucalypt forests*. Ecological Management and Restoration 7: S24-S30.

Wallace, J. F., Behn, G. and Furby, S. L. (2006), *Vegetation condition assessment and monitoring from sequences of satellite imagery*. Ecological Management and Restoration, Vol. 7, Sup 1, pp 33-36.

Wallace, J. F., Furby, S. L. and Campbell, N. A. (1995), *Methods for monitoring vegetation using multi-date image data.* Proc. Second North Australian Remote Sensing and GIS Conference, pp. 62-67.

Zdunic, K., Behn, G., (2009) *Exploiting Time Sequences of Satellite Imagery to Monitor Landscape Aspects.* Proc. Spatial Sciences Institute Biennial International Conference, Adelaide, South Australia.