GIS and Remote Sensing based land cover change detection, prediction modeling and assessment of change on biodiversity using time-series data

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Abstract

Various anthropogenic transformations and modifications have continuously modified and/or changed the land cover for centuries for different forms of human productions. These ultimately impacted or changed the biodiversity, nutrient and hydrological cycles as well as global environment and climate, especially in the developing world. Australia has a great variety of native vegetation ranging from rainforests, alpine habitats, wetlands, grasslands, eucalypt forests and woodlands reflecting the diversity of species, habitats and ecosystems found across the country. The destruction of habitat due to native vegetation clearing has been identified as the greatest single threat to biodiversity in New South Wales (NSW), Australia. The clearing has mainly taken place in grassy woodlands areas for pasture improvement by the application of fertilizers, ploughing and the sowing of introduced grasses and clovers. This research explored the potential of a range of remote sensing and modelling techniques to assist in the investigation of suitability of land cover mapping in terms of time-period, methods, and seasonal and long term land cover change in the north-eastern parts of NSW, Australia. The overall aim of this research was to investigate the potential of remote sensing, GIS and modelling techniques in detailed investigations of seasonal and nearly four decadal land cover change analysis and assessment of long term pattern of land cover change for future change predictions. The research also aimed at assessing the impact of land cover change on terrestrial habitat configurations.

The importance of considering seasonal variations in land cover classifications was considered since accuracies can vary seasonally within and between years and the selection of a particular season can have a large impact on the accuracy and reliability of the resulting classification. The study investigated the issue of selection of the most appropriate season for land cover mapping by studying the spectral response of land cover categories in different seasons. The highest accuracy was obtained with a mid-summer (January) image and the lowest with an early spring (September) image. The superiority of mid-summer images in generating highly accurate land-cover classifications was demonstrated by the analysis of additional images under varying rainfall conditions in different years. Investigation of class-wise land cover classification accuracies in different seasons provided a scope of selection of most suitable season or month for mapping of individual classes. This was done using conditional Kappa ( ) coefficient which

further confirmed that most of the classes showed 100% agreement with the January classification.

Considering the need for information on land cover change in short intervals and understanding the usefulness of binary change images for such assessment, the study identified the requirements of highlighting the areas where land cover features' brightness values had increased or decreased (mostly due to change in vegetation density), or remained unchanged and also the issues related to traditional means of threshold determination for change/no-change identification. The study proposed a new method for optimal threshold value determination by considering the left and right parts of a histogram from mean separately and computing the two separate mean and standard deviation for spectrally decreased and spectrally increased parts. The issue of asymmetrical nature of distribution histogram for the two sides was tested by comparing the results from the proposed with other techniques.

Investigations of the relative performance of object-based and pixel-based analysis in land cover classification and in change identification was carried out over a 37-year period. The results showed that the object-based classification had an improvement in overall accuracy compared to results from maximum likelihood classifier (MLC).

This study considered the importance of evaluation of landscape metrics with respect to remote sensing data characteristics and also difficulties associated in the selection of appropriate and effective metrics for change identification. The study proposed a new rank-based metric selection process through the computation of four difference-based indices using a Max–Min/Max normalization approach. The method was found simple and straightforward, capable of highlighting change in two contrasting landscapes.

Modelling the change process using time series satellite data using Markov chain model (MCM) provided an opportunity of detailed land cover change pattern investigation and also helped in projecting the probability of temporal change developments into future land cover change. The study addressed two major issues associated with the use of Markov models in land cover change predictions: the issues of stationarity of change and the impact of neighbouring cells on change areas. The model was considered suitable for predicting land cover change for future years. The land cover prediction ten years into the future indicated that future land cover changes would

continue to affect the natural vegetation, which would continue to decrease over the years by being converted to agricultural lands. According to the report on BCASR (2002), the main driving force of land cover changes in this region was identified as vegetation clearing. Extensive logging has reduced the original tree size classes in forests on basalt soils on the Liverpool Range, while biologically significant dry rainforests were vulnerable to fire, grazing from feral animals, including goats and rabbits, and invasion by exotic plant species. The succession of droughts over the three decades was an additional factor of change in the natural vegetation areas in combination with land use extensification (BCASR, 2002). The remote sensing analysis reveals, however, that land cover changes have increased in recent years compared to the seventies and eighties when the annual rate of land cover change was more than 10%.

Analysis of the impact of land cover change on habitat configuration by automated mapping of habitat linkages in the landscape using the concept of metapopulation and the least cost path algorithm indicated that there was a significant loss in the terrestrial habitat in the region. The loss was more in the slopes on the southern side that had been developed for pasture or crop production, but on the northern slopes the forests were mostly still present. The use of time series land cover data provided an opportunity to evaluate the pattern of change in vegetation situation over time along with the threatening process responsible for change, if it existed. The identification of clearing as a major threat in EHA decline, particularly after the year 1993, supported this fact, which otherwise would not have been identified in case of normal change detection process

Overall, the research demonstrated the potential of various image processing techniques for improved land cover mapping and change identification and also modelling land cover change for future change. The outcome from long term change analysis and modelling future change results will provide a scope for land managers and policy makers in the region for better understanding the amount and pattern of change that happened in the past and their future predictions. These understandings will help them in better policy formulation for effective and sustainable land management in the region.

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Note to Examiners

This thesis has been written in journal-article-format. I have attempted to minimize the duplication of material between chapters. However, some repetition remains, particularly in the methodology sections of the articles as these were independent publications.

Although effort has been made to ensure consistency in the format for the purposes of this thesis, I acknowledge that some inconsistencies remain because of the requirements of each of the journals to which the separate papers were submitted.

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