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Revealing Long Term Land Use and Land Cover Change in a Severely Disturbed Environment

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Abstract. Land use and land cover change (LUCC) is one of the important drivers of environmental change on all spatial and temporal scales. LUCC contributes significantly to earth atmosphere interactions, forest fragmentation, and biodiversity loss. It has become one of the major issues for environmental change monitoring and natural resource management. This study aims to reveal the long term land use and land cover changes (from 1939 to 2004) in the Strzelecki Ranges, Victoria, Australia by integrating remote sensing and geographical information system (GIS) and to provide quantitative analysis of LUCC information in the area. The land use and land cover is derived from historical aerial photography with the support of Vicmap Elevation, Ecological Vegetation Classes (EVCs) map and stereo models established by using stereo pair of aerial photographs. The EVC map provides a good ground truth not only for the 2004 imagery, but also is part of the reference for interpreting 1988, 1972, 1954 and 1939 orthoimages. The interpretation was carried out with respect to the forest canopy patterns that appeared on the imagery, relationships with other land covers, and DEM derived attributes such as aspects and slope declivity. The results show that land use and land cover in this area changed substantially from 1939 to 2004. Large areas of cleared land and natural forest regrowth on previously cleared land were gradually converted to plantations. The area covered by cool temperate rainforest has remained relatively stable throughout the period.

Keywords: land use and land cover, GIS, classification, environment, ecology.

1. Introduction

Land use and land cover data provide basic information for better understanding of historical land use practices, current land use patterns and future land use trajectory. Identifying, delineating and mapping the types of land use and land cover are important for sustainable natural resource management. Land use and land cover constantly change over time. Land use and land cover changes interact with one another. Documentation of the land use and land cover change (LUCC) provides information for better understanding of historical land use practices, current land use patterns and future land use trajectory. LUCC has also been recognized as an important driver of environmental change on all spatial and temporal scales (Turner *et al.*, 1994). LUCC contributes significantly to earth atmosphere interactions, forest fragmentation, and biodiversity loss. It has become one of the major issues for environment change monitoring and natural resource management. Identifying, delineating and mapping of the types of land use and land cover are important activities in support of sustainable natural resource management. To understand how LUCC affects and interacts with environmental systems, information is needed regarding what changes occur, where and when they occur, the rates at which they occur, and the social and physical forces that drive those

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changes (Lambin *et al.*, 2003).

The Strzelecki Ranges are recognised as one of the four major Victorian areas of cool temperate rainforest along with the southern uplands of the Otways, the Central Highlands, and East Gippsland (Adam, 1992; O'loughlin and Blakers, 1992). It contains some of the most ancient species of plants. The Strzeleckis, once densely vegetated by wet forest and cool temperate rainforest, have experienced wide scale land clearing since European settlement. Agriculture was only successful on the low and gentle slopes at the Western end of the Ranges. It failed in the Eastern Strzeleckis because the upper parts of the Eastern Strzeleckis were two inaccessible, too steep and too difficult to clear. The story of that failure is a story of heartbreak and suffering as people toiled the best years of their lives for nothing. Most of the cleared land in the eastern Strzeleckis was subsequently abandoned, resulting in weed invasion. Exotic weeds like blackberry infiltrated surrounding native vegetation including disturbed rainforest remnants. Wide scale land clearing, agricultural abandonment and several bush fires have all resulted in severe landscape disturbance in the Ranges. Rainforest is sensitive to bushfire, but some species such as eucalypt forest rely on bushfires to open their protective seed pods so that their seeds can germinate. There was natural regeneration of extensive areas of eucalypt forest following bush fires in 1939 and 1944. Land use and land cover have undergone further significant changes with the establishment of large scale plantations in the area over the last four decades. However, details of land use and land cover change and its influence on the rainforest in this area are yet to be assembled and interpreted.

Areas bordering cool temperate rainforest in the Eastern Strzeleckis are a mosaic of different land use histories formatted by both natural and human disturbances. Different land use patterns have different influences on imbedded remnant patches of cool temperate rainforest mainly through edge effects. When the surrounding landscape patterns change, the environmental conditions (e.g. microclimate) produced along these edges (the boundaries between surrounding forests and the cool temperate forest) may be modified and influences the interior cool temperate forest (Murcia, 1995; Bannerman, 1998).

This study aims to reveal the long term land use and land cover changes (from 1939 to 2004) in the Strzelecki Ranges by integrating remote sensing and geographical information system (GIS) and to provide quantitative analysis of LUCC information in the area. The land use and land cover is derived from historical aerial photography with the support of Vicmap Elevation, Ecological Vegetation Classes (EVCs) map and stereo models established by using stereo pair of aerial photographs. The EVC map provides a good ground truth not only for the 2004 imagery, but also is part of the reference for interpreting 1988, 1972, 1954 and 1939 orthoimages. The interpretation was carried out with respect to the forest canopy patterns that appeared on the imagery, relationships with other land covers, and DEM derived attributes such as aspects and slope declivity.

2. Materials and Methods

2.1. Study Area

The study site is located within the West Gippsland Catchment Management region, Southeast Victoria, and falls within the Strzelecki Ranges Bioregion, one of the six defined bioregions in the West Gippsland region. The Strzelecki Ranges are an isolated series of mountains in the southern section of the Gippsland region that are surrounded by the Gippsland Plain. Human and natural disturbances have resulted in significant changes to the landscape in the Strzelecki Ranges, leaving much of the area as cleared and abandoned land. Bracken, scrub, blackberries, and ragwort became serious problems (DSE, 2004).

Reforestation began on abandoned properties using pine and hardwoods after the Second World War (Hill et al., 2001). APM Forests Pty Ltd (later Grand Ridge Plantations Pty Ltd, and now HVP Plantations Pty Ltd) began purchasing land in the 1950s and began planting in the 1960s (Noble, 1978). Today, the landscape of the Strzeleckis consists of a mosaic of land uses ranging from protected forests to plantation forests to agriculture with small settlements and hobby farms interspersed throughout the area (Mainville and Brumley, 2004). This study focuses on an area, where land use and land cover surrounding the rainforest patches has undergone significant changes over the time. The study area covers an area of 475 hectare, shown in Figure 1 and Figure 2.

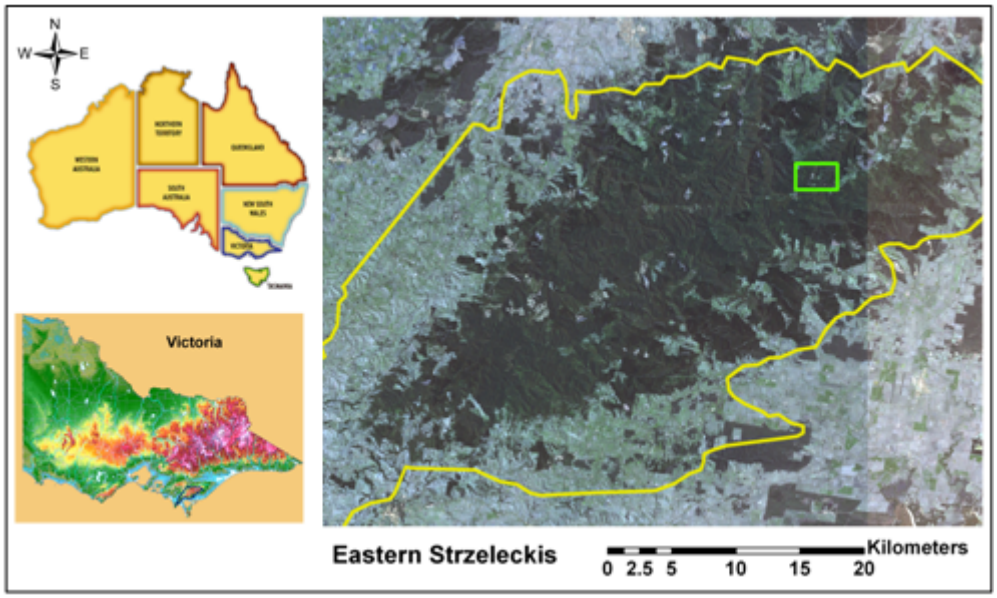

Fig. 1: Eastern Strzeleckis.

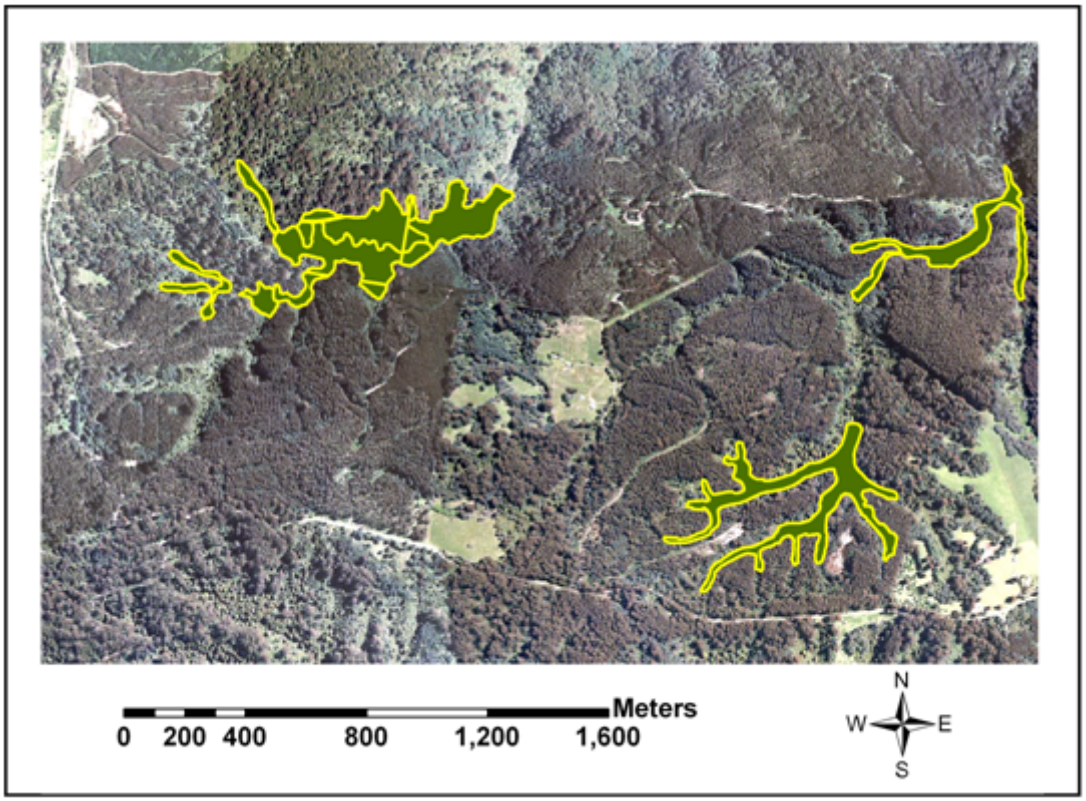

Fig. 2: Study Areas.

2.2. Data

Historical aerial photography has much longer history and generally higher spatial resolution than satellite images. The State of Victoria, Australia, has been photographed from the air since the 1930's. Historical aerial photography, which recorded the whole history of landscape dynamics, is therefore the main source of data for this study. The available photographs, which cover the study area, were taken in 1939, 1954, 1972 and 1988. The 1988 colour photographs are at a nominal scale of 1:15,000. 1939, 1954 and 1972 black and white photographs are at scale of 1:18,900, 1:25,000 and 1:27,000. These photos were scanned to convert them to digital format for digital photogrammetric processing. Scanned aerial photos, together with digital colour aerial photos taken in 2004 were used for identifying the land cover classes.

Ecological Vegetation Classes (EVCs), which describe native vegetation using a system of classification introduced by the Victorian Department of Sustainability and Environment in the 1990's, is another valuable dataset. EVC mapping was implemented as part of the Regional Forest Agreements (RFAs), driven by a need to determine a Forest Reserve System. The EVC mapping was undertaken by initially outlining native vegetation patches and any obvious related patterns via interpretation of aerial photographs. The range of aerial photograph patterns was then field checked and lists of plant species recorded (Davies *et al.*, 2002). EVCs are the basic mapping unit used for forest ecosystem assessments, biodiversity planning and conservation management at the regional scale in Victoria. EVC mapping constitutes baseline data for planning decisions at all levels of government and is invaluable data for the conservation and management of remnant vegetation and for the development of vegetation programs. It has become one of the key sets used in terrestrial biodiversity management. For this study, the EVC map is taken as depicting the current situation of land use and land cover and as such can be regarded as a good reference during derivation of the past land use and land cover classification.

In addition, *Vicmap Elevation*, a state-wide 20 m resolution DEM is used for terrain analysis to support land cover classification. The *Vicmap Elevation* is structured in a regular array of pixels representing Victoria's terrain surface, is a commonly used elevation data source in Victoria for various terrain-related applications. *Vicmap DEM* was produced by using elevation data mainly derived from existing 1:25,000 contour maps and digital stereo capture. Estimated standard deviations are 5m and 10m for vertical and horizontal accuracy respectively (DSE, 2002). Terrain analysis based on DEM will support the classification of land cover with different forest species.

2.3. Methods

Table 1. Definition of land cover classes used in this study.

Land cover class	Description and pattern
Cleared land	Areas appearing as mostly light in colour and devoid of any vegetation. This could include roads, haul trails and log assembly areas.
Forest Regrowth	Areas where regrowth can be seen to be occurring as indicated by pattern of variably spaced woody vegetation of different heights.
Wet Forest	Characterized by large Mountain Ash (*E. regnans*) trees which can be identified as very tall (>30m) trees with distinct separation between individual trees. Mostly on wet southern slopes all the way from the lower slopes to the ridge line.
Rainforest	Closed canopy of non-Eucalypt trees near streams and protected slopes. Appear as uniform height closed canopy woody adjacent to or surrounded by wet forest.
Plantation	Areas of uniform height and pattern. Includes both Eucalypt and Pine plantings. Depending upon degree of canopy cover, row patterns may or may not be evident.
Other forests	Includes areas of roadside forest, power line forest, unidentified forest, and native forest (exclude wet forest and rainforest)

Land cover classes for this project in the study area were defined. Details of the description and pattern refer to characteristics observable on aerial images are listed in Table 1. Scanned multi-temporal aerial photographs were all first orthorectified to produce orthoimages using the digital photogrammetric system, ERDAS Imaging software. Orthorectification is the process of geometrically adjusting a perspective image to an orthogonal image by transforming coordinates from image space to the ground space and removing tile and terrain relief displacement. Image interpretation and classification were carried out based on pre-defined land cover classes.

The EVCs in the study area, which were mapped mainly based on 2004 digital imagery and were field checked, provides a good ground truth for the 2004 imagery. It is part of the reference as well for interpreting 1988, 1972, 1954 and 1939 orthoimages. The interpretation was carried out with respect to the forest canopy patterns that appeared on the imagery, relationships with other land covers, and DEM derived attributes such as aspects and slope declivity. For example, cool temperate rainforest appears as closed canopy in or adjacent wet forest and distributes along valleys with above 300 m elevation, especially where aspect provides the shadiest local climate. The most daunting photo interpretation challenge refers to the black and white orthoimages. Stereo models were built using stereo pairs of aerial photograph to support the interpretation. This 3D view of terrain and canopy helped to identify land cover boundaries from orthoimages.

3. Results and Discussion

The wide scale land clearing and subsequent agricultural abandonment resulted in large patches of cleared land by 1939. Figure 3 shows changes of land cover in the study area since 1939. Bushfires in 1939 and 1944 further disturbed the landscape (Howard, 1981). Following the bushfires, there was natural regeneration of eucalypt forest, which relies on bushfires to open their protective seed pods so that their seeds can germinate. By 1954, cleared land, regrowth forest and wet forest dominated the area. During the period between 1954 and 1972, forest regrowth had occurred in much of previously cleared and abandoned land. Although plantations have been established in the area since the 1960s, large area plantation had not occurred in this area during this period. From 1972, plantation area expended considerably. Large areas of cleared land and some forest regrowth areas were converted to plantation area between 1972 and 1988. From 1988 to 2004, plantation area continued to increase while cleared land area decreased. The area covered by cool temperate rainforest remained relatively stable throughout the period.

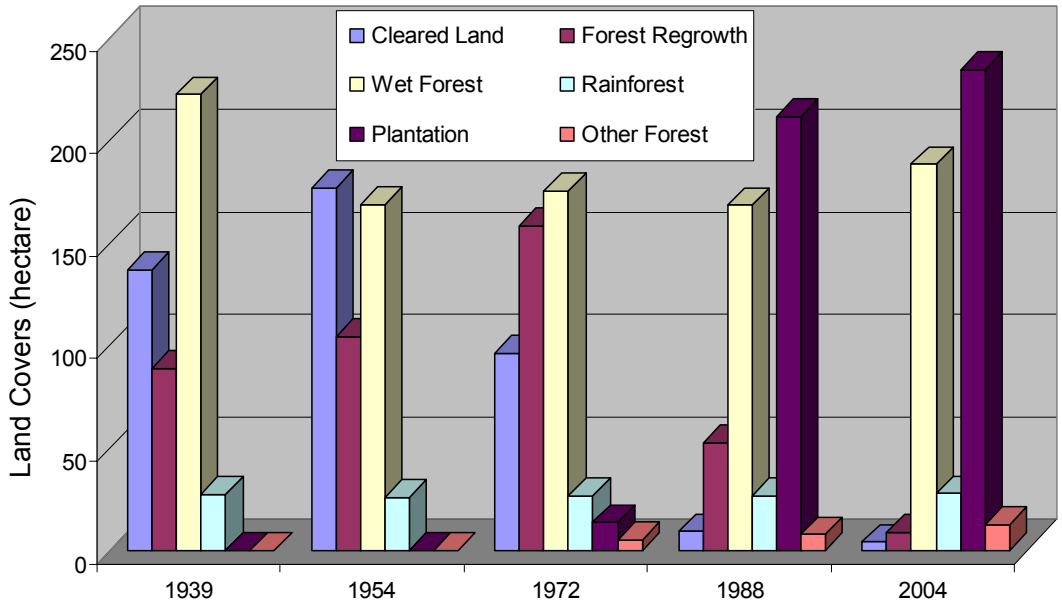

Fig. 3: Land covers in different years. The bars for each time period are from left to right: cleared land, forest regrowth, wet forest, rain forest, plantation and other forests

The overall trend of land cover changes in the study area was an increase in forest regrowth between 1939 and 1972, and a significant increase in plantation area from 1972 to 2004. During this whole period, there was a decrease of the area of cleared land and forest regrowth. Wet forest decreased during the period between 1939 and 1954 because of bushfires, but remained relatively stable. By 2004, the study area was dominated by planted forest, accounting for over half of the study area. Although plantation forest is interrupted by harvest with rotation cycles and is not offering habitat equivalent to native forest, it has improved total forest cover thereby offering refuges for wet forest and surrounded cool temperate rainforest communities, especially in the most severely disturbed areas like our study area (Lamb, 1998; Loyn, 2000;

Cawsey and Freudenberger, 2003; Kanowski *et al.*, 2003; Kanowski *et al.*, 2005; MacHunter *et al.*, 2006; Koskela *et al.*, 2007).

4. Conclusion

The Strzelecki Ranges have experienced a wide scale of land clearing since European settlement. Subsequent agricultural abandonment and bushfires resulted in severe landscape disturbance in the study area. This study mapped and revealed the long term (from 1939 to 2004) land use and land cover changes and provided initial analysis of LUCC information in the area. The LUCC information will be used for further quantitative analysis and assessment of the impacts of landscape dynamics on the cool temperate rainforest in the Strzeleckis. The results show that Land cover changed significantly over the last six decades in the area. There was an increase in forest regrowth, and a subsequent increase of plantation area a throughout the period. There was no significant change in the extent of cool temperate rainforest in this study area. In a severely disturbed area, plantation to some extent contributes to biodiversity and has significantly increased forest cover in the study region. This may help to preserve the remnant cool temperate rainforest.

5. Acknowledgements

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