Modelling Land Use and Land Cover Change in the Strzelecki Ranges

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EXTENDED ABSTRACT

Land use and land cover change (LUCC) has 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 environmental change monitoring and natural resource management. In Australia, modification of land cover since European settlement has largely been due to land clearing and weed invasion, as well as to some natural disturbances such as bushfire. In the Strzelecki Ranges, located in south eastern Victoria, the wide scale of land clearing, subsequent agricultural abandonment and fires have all resulted in severe landscape disturbance in the Ranges. 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 is unknown.

The Strzelecki Ranges, along with the southern uplands of the Otways, the Central Highlands, and East Gippsland, are recognised as one of the four major Victorian areas which support cool temperate rainforest ecosystems. Cool temperate rainforest, although now very restricted in its distribution, is of major historical and ecological significance. Areas bordering cool temperate rainforest in the Eastern Strzeleckis comprise a mosaic of different land use patterns and have histories which are affected 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 model the long term land use and land cover changes (from 1954 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 reconstructed history of land use and land cover is mainly based on 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. Available archived historical aerial photographs, taken in 1954, 1972 and 1988, were all scanned and converted to digital format for digital photogrammetric processing. Scanned aerial photos, together with digital colour aerial photos taken in 2004 were used for classification to identify different land covers.

The results show that land use and land cover in the study area changed substantially from 1954 to 2004. Large areas of cleared land and forest regrowth on previously cleared land were gradually converted to plantations. Wet forest cover kept increasing during this period, especially from 1954 to 1988. The area covered by cool temperate rainforest has remained relatively stable throughout the period. Large scale plantation, although not equivalent to native forest as wildlife habitat, may improve environmental balances (Lamb, 1998; Loyn, 2000; Cawsey and Freudenberger, 2003; Kanowski *et al.*, 2003; Kanowski *et al.*, 2005; MacHunter *et al.*, 2006; Koskela *et al.*, 2007) and provide refuges for wet forest and surrounded cool temperate rainforest fauna, especially in areas of severe disturbance like that of our study area.

1. INTRODUCTION

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 changes (Lambin *et al.*, 2003)

Like other areas in Australia, the modification of land cover in the Strzelecki Ranges (south eastern Victoria) since European settlement is largely due to land clearing and weed invasion; as well as to some natural disturbances such as bushfires. The Strzelecki Ranges experienced wide scale land clearing, subsequent abandonment of agricultural areas and several bush fires, resulting in severe landscape disturbance in the Ranges. 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.

Along with the southern uplands of the Otways, the Central Highlands, and East Gippsland, the Strzelecki Ranges, are recognised as one of the four major Victorian areas of cool temperate rainforest (Adam, 1992; O'loughlin and Blakers, 1992). Cool temperate rainforests, although now very restricted in their distribution, are of major historical and ecological significance. They are the remanets of oldest extant vegetation formation in Australia; and is categorised as an endangered Ecological Vegetation Class within Victoria (Kershaw, 1992). 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).

Historical aerial photographs have much longer temporal history than satellite images, and are an important source of data for long term land cover change analysis (Carmel and Kadmon, 1998; Okeke and Karnieli, 2006). In addition, aerial photographs have generally higher spatial resolution and therefore offer the possibility of providing more detailed local and regional vegetation information for landscape ecological assessments. Moreover, the advances in digital photogrammetry, digital image processing, and geographical information systems (GIS) have further increased the potential for the use of historical aerial photographs for land cover change analysis (Okeke and Karnieli, 2006).

This study aims to model the long term land use and land cover changes (from 1954 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 history of land use and land cover is reconstructed mainly based on 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.

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. The Strzelecki Ranges, previously densely vegetated by wet forest and cool temperate rainforest, have experienced wide scale clearing mainly for agriculture since European settlement. Cool temperate rainforest, that previously existed throughout the Strzeleckis, where microclimate and

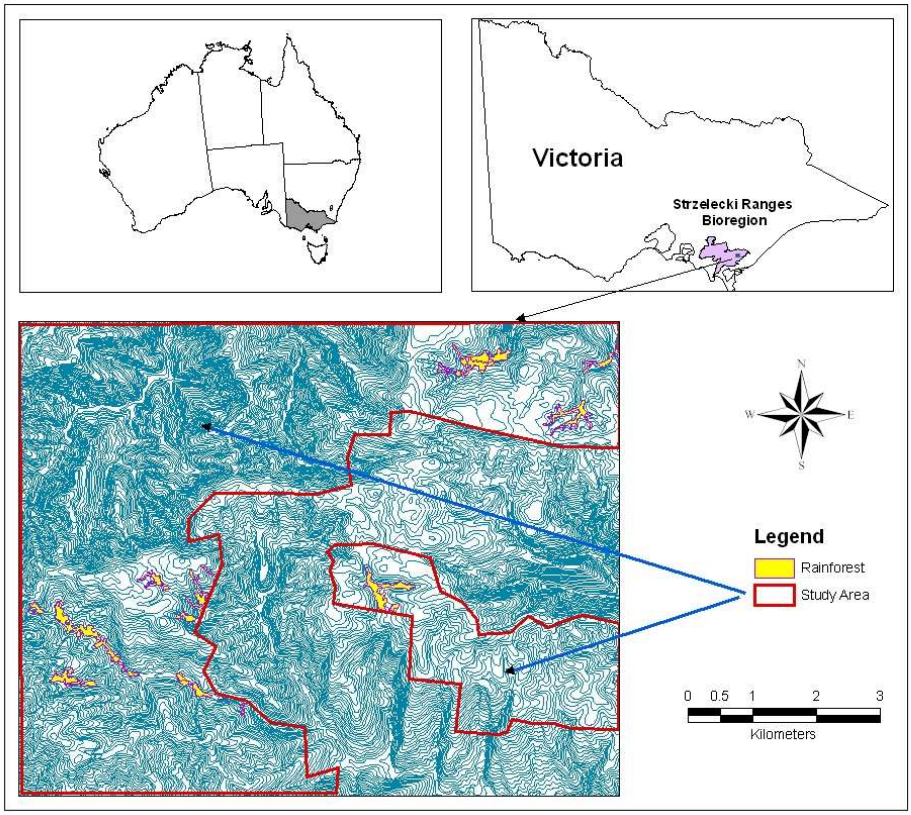

Figure 1. Study area

fire history allowed, has also been impacted. However, agriculture was not successful in the upper parts of the Eastern Strzeleckis because the areas were too inaccessible, too steep, too hostile and too difficult to clear. Most of the cleared land in the Eastern Strzeleckis became neglected and abandoned farmland was overtaken by secondary forest communities.

The Strzelecki Ranges bioregion has also experienced a number of wildfires since European settlement, the worst being in 1898 in which much of the bioregion burnt. Between 1899 and 1944 there were another 15 large fires in the region (Noble, 1978). Human and natural disturbances have therefore 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 present report refers to vegetation communities under HVP Plantations Pty Ltd custodianship, covering an area of about 40 km², with altitude varying from 111 to 714 m above see level, shown in Figure 1.

2.2. Data

Historical aerial photography is the main source of data for this study. The State of Victoria, Australia, has been photographed from the air since the 1940's. The available photographs, which cover the study area, were taken in 1954, 1972 and 1988. The 1988 colour photographs are at a nominal scale of 1:15,000. 1954 and 1972 black and white

photographs are at scale of 1:25,000 and 1:27,000 respectively. 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.

Vicmap Elevation, a state-wide 20 m resolution DEM which 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.

Another valuable dataset is 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. 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.

2.3. Methods

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. The orthorectified photographs were then combined into a single image mosaic: one for each year in the time series. Image interpretation and classification were carried out based on several land use and land cover classes defined for this project. Class definition in this study area is described in Table 1.

Table 1. Definition of land cover classes used in this study. The description and pattern refers to characteristics observable on orthorectified aerial photographs.

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)

The interpretation of orthorectified photographs started with 2004 digital imagery. The EVCs in the

study area were mapped mainly based on 2004 digital imagery and were field checked. It provides a good ground truth not only for the 2004 imagery, but must also be part of the reference for interpreting 1988, 1972 and 1954 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

Table 2. Areas (km²) of land covers in different years

Classes	1954	1972	1988	2004
Cleared Land	21.437	8.381	2.037	0.135
Forest Regrowth	14.353	23.766	6.490	1.562
Wet Forest	3.689	6.398	8.935	9.663
Rainforest	0.705	0.713	0.785	0.793
Plantation	0.430	1.318	12.607	17.543
Other Forests	0.004	0.042	9.766	10.923

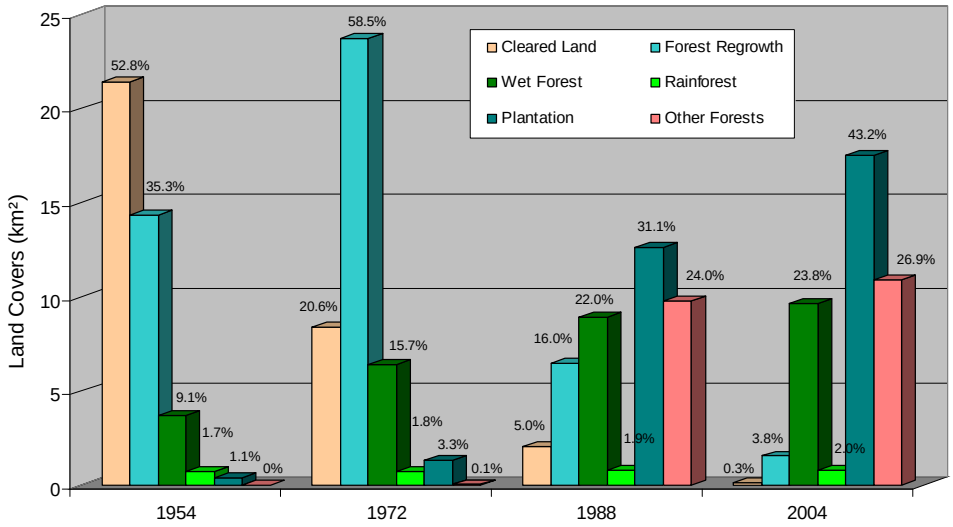

Figure 2. Land covers in different years. The bars for each time period are from left to right: cleared land, forest regrowth, wet forest, rain forest, plantation and other forests

Land use and land cover in the study area has changed substantially over the study period. The areas of land covers in different years are listed in Table 2. Figure 2 shows changes of land cover in the area since 1954, when the area was dominated by cleared land and natural regrown forest. By 1972, forest regrowth had occurred in much of the cleared land. Plantation area had also increased. During the period between 1972 and 1988, plantation area expanded considerably. Large areas of cleared land and some forest regrowth areas were converted to plantation area in this time period. From 1988 to 2004, plantation area continued to increase while cleared land and forest regrowth area decreased.

The overall trend of land use and land cover change in the study area from 1954 to 2004 was a significant increase in plantation area and a decrease of the area of cleared land and forest regrowth. Wet forest increased during this period, especially from 1954 to 1988. The area covered by cool temperate rainforest remained relatively stable throughout the period, if anything, slightly increasing its extent. Areas of other forest types accounted for a large portion of the study area in 1988 and 2004 mainly due to the introduction of forest reserves along roads and power lines, and the regeneration of native forest on previously cleared land.

4. DISCUSSION

Severe landscape disturbance has occurred in the study area since European settlement. The wide scale land clearing and subsequent agricultural abandonment resulted in large patches of cleared land. Bush fires, especially the one in 1939, further disturbed the landscape and reduced the distribution of rainforest to its most sheltered enclaves (Howard, 1981). By 1954, cleared land and regrowth forest on previously cleared and abandoned land dominated the area, accounting for 88.1% of the total area. Wet forest and cool temperate rainforest only accounted for 9.1% and 1.7% of the area. Remnant rainforest patches were threatened in this severe environment and at high risk of disappearing.

Plantations have been established in the area since the 1960s; and since then, cleared land and regrowth forest on previously cleared land have been progressively converted to plantation cover. Eucalypts are extensively planted in this area. The main species planted include *Eucalyptus globulus* (blue gum), *E. nitens* (shining gum), and *E. regnans* (mountain ash). By 2004, the study area was dominated by planted forest, accounting for near half of the study area. In this context, large scale plantation cover, especially the eucalyptus plantations, must constitute support for biodiversity. Plantation can function as buffers to protect and enhance biodiversity in embedded remnant forest patches (Lamb, 1998; Loyn, 2000; Cawsey and Freudenberger, 2003; Kanowski *et al.*, 2003; Kanowski *et al.*, 2005; MacHunter *et al.*, 2006; Koskela *et al.*, 2007). 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.

5. CONCLUSION

The wide scale land clearing, subsequent agricultural abandonment, and bush fires since European settlement resulted in severe landscape disturbance in the study area. Land use and land cover changed significantly and again with the growth of large scale plantation over the last four decades in the area. This study mapped and modelled the long term (from 1954 to 2004) land use and land cover changes and provide quantitative analysis of LUCC information in the area.

The results show that land cover has gradually changed from cleared land to plantation dominated area during this period. There was no significant change in the extent of cool temperate rainforest in this study area, indeed a slight increase demonstrated. In a severely disturbed area, plantation to some extent contributes to biodiversity and has significantly increased forest cover in the study region (Lamb, 1998; Loyn, 2000; Cawsey and Freudenberger, 2003; Kanowski *et al.*, 2003; Kanowski *et al.*, 2005; MacHunter *et al.*, 2006; Koskela *et al.*, 2007). This may help to preserve the remnant cool temperate rainforest.

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