LONG TERM LAND USE AND LAND COVER CHANGE AND ITS IMPACT ON COOL TEMPERATE RAINFOREST IN THE STRZELECKI RANGES, AUSTRALIA

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ABSTRACT:

The Australian landscape, as in many countries, has undergone a significant change. The extent of native forests in Australia has steadily decreased over time since European settlement. The establishment of towns and cities, mining and a range of other factors have all reduced forest cover, however it is land clearing for agriculture that has been the most significant process by far. 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. Cool temperate rainforests, although now very restricted in their distribution, are of major historical and ecological significance. They are the remanets of the oldest extant vegetation formation in Australia and are categorised as an endangered Ecological Vegetation Class within Victoria. 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. This study aims to model the long term land use and land cover changes (from 1939 to 2004) and their impacts on cool temperate rainforest in the Strzelecki Ranges by integrating remote sensing and geographical information system (GIS). 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. The general trend of land use and land cover change, including rainforest in study areas was analysed.

1. INTRODUCTION

Land use and land cover change (LUCC) is increasingly 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. LUCC and its impacts on terrestrial ecosystems including forestry, agriculture, and biodiversity have been identified as high priority issues in global, national, and regional levels (Fuchs, 1996). Land use and land cover, as the basic spatial element of landscape, plays an important role in the study of landscape ecology. Analysis of the relationship between landscape spatial patterns and functions is based on the accurate and timely information of land use and land cover.

The Australian landscape, as in many countries, has undergone a significant change. The extent of native forests in Australia has steadily decreased over time since European settlement. The establishment of towns and cities, mining and a range of other factors have all reduced forest cover, however it is land clearing for agriculture that has been the most significant process by far and is a process that continues today (Blair and Dockray, 2004). Victoria's landscapes have changed significantly over the past 150 years. An estimated 66% of Victoria's native vegetation has been cleared as a result of the growth and economic development of the State (Woodgate and Black, 1988; DSE, 2005). Victorians have made significant progress in protecting and enhancing native vegetation. However, further efforts are still needed because a permanent loss of native vegetation at an estimated 2500 hectares a year still occurs and the quality of the remaining native vegetation continues to decline (DSE, 2005).

Rainforests are the planet's most ancient forests. They appeared about 200 million years ago, well before eucalypts and wattles (Wrench and Pizzey, 1995). Rainforests are also one of the most complex and diverse ecosystems on earth. They are home to more than half of the world's plant and animal species. Rainforests in Australia include tropical rainforest, sub-tropical rainforest, and temperate rainforest. There are three types of temperate rainforest: warm temperate rainforest (found in eastern New South Wales and Victoria), cool temperate rainforest (found at higher altitudes in New South Wales, Victoria and Tasmania), and dry rainforest which is the least widespread of all Australia's rainforest types, occurring mainly in Northern Australia (Wrench and Pizzey, 1995). 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. Some of the smallest plants such as the mosses, ferns and lichens are amongst the oldest survivors in the plant world. Rainforests, although now very restricted in their distribution, are of major historical significance. They are the remnants of the oldest

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extant vegetation formation in Australia. All possible measures should be taken to ensure the survival of this important component of heritage (Kershaw, 1992).

The Strzelecki Ranges are a highly significant landscape with a complicated landscape disturbance history in south Gippsland, Victoria. The Strzelecki forest is one of Victoria's most significant sites for cool temperate rainforest. Once Crown Land, much of the Eastern and nearly all of the Western Strzelecki Ranges was privatised and converted to agricultural land between the 1850's and the 1920's (Noble, 1978). However, 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 too inaccessible, too steep, too hostile 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 (Noble, 1978). Much of the higher ranges were abandoned by the early 1930s and reverted back to the Crown for reforestation (CVRFASC, 1999a). On the other hand, this failure meant that some of the valuable native forests in the Ranges remained. Since the 1930's much of this cleared land has been purchased by the Victorian Forests Commission and APM Forests, and gradually reforested with *E. regnans* and *Pinus radiata*. (CVRFASC, 1999b). In addition, natural regeneration of extensive areas of eucalypt forest occurred following fires in 1939 and 1944. However, the impacts of these fires on cool temperate rainforest are not well known.

Wide scale land clearing, subsequent abandonment of agricultural areas and several bush fires resulted in severe landscape disturbance in the Strzelecki Ranges. Land use and land cover have undergone further significant changes with the establishment of large scale plantations in the area over the last six decades (Zhang *et al.*, 2007). 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).
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. This study aims to model the long term land use and land cover changes (from 1939 to 2004) and their impacts on cool temperate rainforest in the Strzelecki Ranges by integrating remote sensing and geographical information system (GIS) and to provide quantitative analysis of LUCC information in the area. 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. Therefore, 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 a series 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 fire history allowed, has also been impacted. However, because of the failure of agriculture in the upper parts of the Eastern Strzeleckis, most of the cleared land in the Eastern Strzeleckis became neglected and abandoned farmland was overtaken by secondary forest communities.

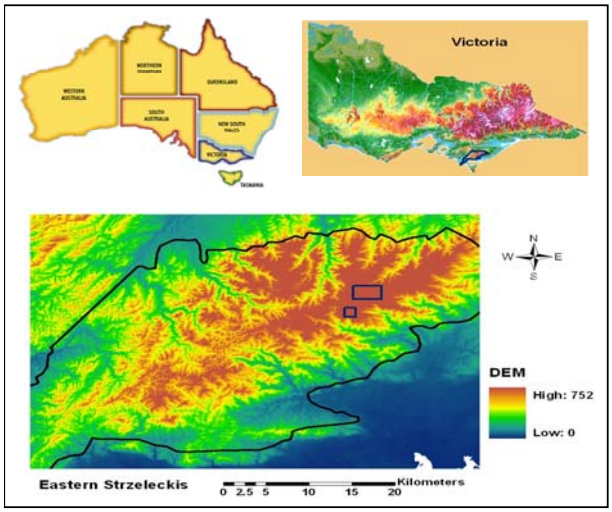

Figure 1. Eastern Strzeleckis

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 two areas 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 areas of about 475.3 hectare and 121.7 hectare respectively. These two study areas are shown in Figure 2.

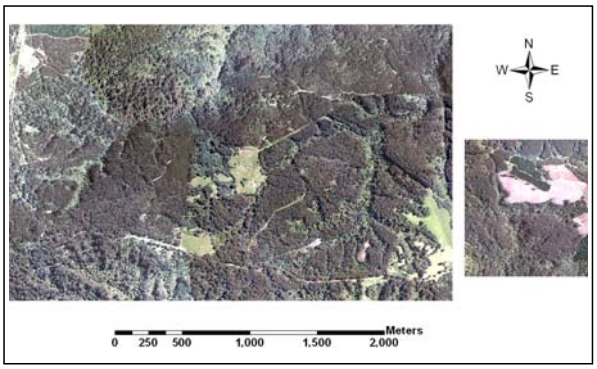

Figure 2. Two study areas

2.2 Data

As mentioned before, 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

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)

Table 1. Definitions of land cover classes

Scanned multi-temporal aerial photographs were first all orthorectified to produce orthoimages using ERDAS Imagine software. Image interpretation and classification were then carried out based on pre-defined land cover classes. Defined land cover classes for this project in the study areas are described in details and are listed in Table 1.

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, 1954 and 1939 orthoimages. The interpretation of orthorectified photographs started with 2004 digital imagery. 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

Classes	1939	1954	1972	1988	2004
Cleared Land	136.8	176.8	96.1	9.2	4.0
Forest Regrowth	88.9	104.5	158.5	52.2	8.7
Wet Forest	222.4	168.5	175.3	168.3	188.3
Rainforest	27.2	25.5	26.5	26.5	27.7
Plantation	0.0	0.0	13.6	211.4	234.4
Other Forest	0.0	0.0	5.3	7.7	12.2

Table 2. Areas (hectare) of land covers in different years in study area 1

Classes	1939	1954	1972	1988	2004
Cleared Land	68.4	48.8	25.9	9.0	32.7
Forest Regrowth	1.2	26.0	21.8	3.3	0.0
Wet Forest	41.1	35.6	42.4	44.8	43.5
Rainforest	11.0	11.3	11.2	11.3	11.3
Plantation	0.0	0.0	14.8	45.9	22.1
Other Forest	0.0	0.0	5.6	7.4	12.1

Table 3. Areas (hectare) of land covers in different years in study area 2

Since 1939, land use and land cover in two study areas has changed substantially. The areas of land covers in different years in two study areas are listed in Table 2 and Table 3. Figure 3 and Figure 4 show changes of land cover in two study areas since 1939. The bars in the figures for each time period are from left to right: cleared land, forest regrowth, wet forest, rain forest, plantation and other forests. In 1939, both areas were dominated by cleared land and wet forest. From 1939 to 1954, wet forest decreased, possibly due to the bush fire in 1944, but forest regrowth had occurred. The increase of forest regrowth is significant, especially in study area 2. Plantation areas were established in the study areas between 1954 and 1972, and since then plantation area continued to increase while cleared land and forest regrowth area decreased. Large areas of cleared land and some forest regrowth areas were converted to plantation areas.

The overall trend of land use and land cover change in the study areas from 1939 to 2004 was a significant increase in plantation area and a decrease of the area of cleared land and forest regrowth. Wet forest had a decrease due to the bush fire, but had no significant change during this period. Some forest species such as eucalypt forest rely on bushfires to open their protective seed pods so that their seeds can germinate. Therefore, following the bush fires in 1944, there was natural regeneration of eucalypt forest in the study areas. However, these areas had gradually converted to plantation areas in the following period. The area covered by cool temperate rainforest remained relatively stable throughout the period. Areas of other forest types accounted for a portion of the study area mainly due to the introduction of forest reserves along roads and power lines, and the regeneration of native forest on previously cleared land.

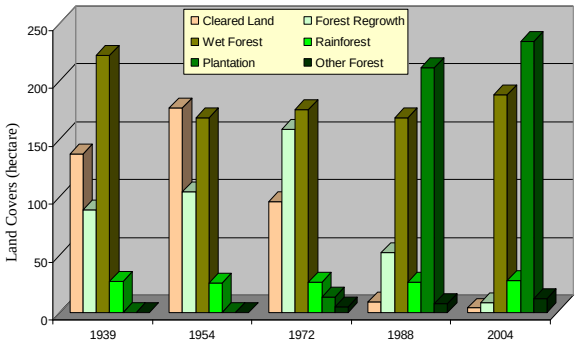

Figure 3. Land covers in different years in study area 1

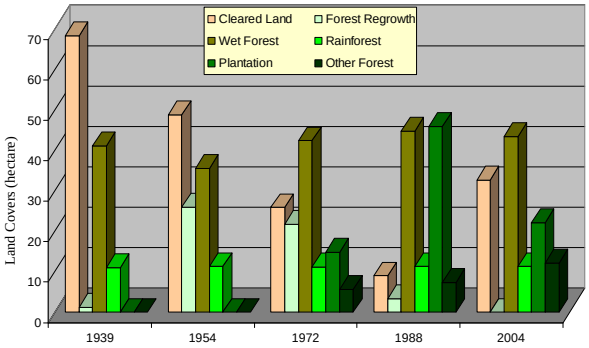

Figure 4. Land covers in different years in study area 2

4. DISCUSSION

Severe landscape disturbance has occurred in the Strzelecki Ranges since European settlement. Wide scale land clearing and subsequent agricultural abandonment resulted in a severely disturbed landscape in the Ranges. Several 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 1939, cleared land accounted for a big portion of total area. Remnant rainforest patches were threatened in this severe environment and at high risk of disappearing.

Since the 1960s plantations have been established in the area, 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. 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 and environment balances thereby offering refuges for wet forest and surrounded cool temperate rainforest communities, especially in the most severely disturbed areas like our study areas (Zhang *et al.*, 2007).

5. CONCLUSION

Human and natural activities resulted in a severely disturbed landscape in the Strzelecki Ranges. Land use and land cover changed significantly. By 1939, cleared land accounted a big portion of the study areas, with remnant rainforest patches being at high risk of disappearing. The growth of large scale plantation over the last four decades further modified the landscape in the area. This study mapped and modelled the long term (from 1939 to 2004) land use and land cover changes and provide 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 these two study areas during the period between 1939 and 2004. In a severely disturbed area, plantation has significantly increased forest cover in the study region and to some extent contributes to biodiversity (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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