# Long-term changes in grassland, woodland and forest vegetation of south-eastern Australia: Impacts of land-use change

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*Cover photographs:*

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| *Top left* | *Remnant native grassland, Melbourne–Lancefield Road Railway Reserve, Clarkefield, Victoria.* |
| *Top middle* | *Unlogged native wet sclerophyll forest gully, Monga National Park, New South Wales.* |
| *Top right* | *Remnant native grassland, Elaine–Blue Bridge Road Railway Reserve, Elaine, Victoria.* |
| *Bottom left* | *Logged native wet sclerophyll forest, Tallaganda State Forest, New South Wales.* |
| *Bottom middle* | *Remnant native grassland, Bolac Plains Road via Woorndoo, Victoria.* |
| *Bottom right* | *Logged native wet sclerophyll forest, Tallaganda State Forest, New South Wales.* |

# Certificate of Originality

I certify that this thesis is my own work and to the best of my knowledge contains no materials previously published or written by another person, or substantial portions of material which have been accepted for the award of any other degree or diploma at any university, except where acknowledgement is made in the thesis. Any contribution made to the research by others is explicitly acknowledged in the thesis. I also certify that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation and linguistic expression is acknowledged.

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# Abstract

Since European settlement of south-eastern Australia in 1788, native vegetation assemblages have been dramatically changed by Europeans with activities such as land clearing associated with forestry, agriculture and urban development. These have either destroyed or fragmented a large proportion of the original native vegetation. The plant species composition of vegetation assemblages has been modified by native species extinctions and exotic species colonizations. Acting in concert, the alteration of native vegetation by human activities, the decline and extinction of native species and the successful colonization by exotic species have the potential to lead to the homogenization and/or differentiation of the plant species composition of native vegetation associations.

In this thesis, I address the broad question: Have native species extinctions and exotic species colonizations resulted in the plant species composition of vegetation assemblages becoming more similar (i.e. homogenized) or less similar (i.e. differentiated) in south-eastern Australia? I compared historical species assemblages with contemporary species assemblages in three vegetation associations, at three separate spatial scales, to determine change in species composition over time. Specifically, I examined forest vegetation at the catchment spatial scale over a period of four decades, grassland vegetation at a regional scale over two decades and both woodland and forest vegetation at a continental scale over a period of c. 220 years.

At the catchment spatial scale, I used historical (1968–69) and contemporary (2007) vegetation surveys to determine change in species composition of vegetation assemblages. I investigated the effects of logging as well as both native species extinctions and exotic species colonizations on changes in species composition of 30 native wet sclerophyll forest stands, 10 unlogged and 20 logged, in the upper Shoalhaven River catchment over a period of four decades. Changes in the similarity of species composition of the unlogged and logged stands over time were compared, the findings indicating the species composition of wet sclerophyll forest in the catchment has become homogenized since the historical survey. It is likely that homogenization in unlogged stands is due to successional changes in the vegetation resulting

from long inter-fire intervals. However, logging has been the key driver of homogenization across the logged stands.

Historical surveys are generally not available at large spatial and long temporal scales because accurate surveys were not conducted in the long-term past at large spatial scales or records of such surveys no longer exist. To circumvent the problem of a lack of historical survey data, ecologists have devised a method to reconstruct the species composition of historical vegetation assemblages. Historical species assemblages are reconstructed by both removing exotic species from the species inventory of the contemporary assemblage and adding currently extinct native species. Exotic species are removed because these species are assumed to not have been present in the historical assemblage. Added extinct native species account for species lost due to extinction.

I used the above method to reconstruct the historical species composition of woodland and forest vegetation in 20 conservation reserves, first comparing changes in the similarity of species composition at a continental scale cross a broad region of south-eastern Australia since European settlement (c. 220 years ago). Then, observed patterns of homogenization and differentiation were related to the geographic and human-related attributes of each conservation reserve. Both native species extinctions and exotic species colonizations differentiated the species composition for all species, native species only and exotic species only in woodland vegetation. In forest vegetation, however, only native species extinctions differentiated the species composition of all species and native species only. For woodland, patterns of differentiation in woodland for native species were associated with both latitudinal and longitudinal separation of reserves. Furthermore, the differentiating effect of exotic species was also associated with longitudinal separation of reserves. In forest vegetation, the differentiating effect of native species extinctions could not be associated with any of the geographic or human-related factors.

The reconstruction technique above is problematic if data sources are of a different spatial scale. To address the lack of historical data and the shortcomings of the existing method, I employed two novel stochastic models to reconstruct the species composition of historical assemblages at large spatial and temporal scales. I used contemporary survey data on the species composition of 87 woodland and 51 forest locations at a continental scale over a period of c. 220 years (i.e. since European settlement).

Both models consistently indicated that native species extinctions promote homogenization of woodland vegetation. In contrast, exotic species colonizations promote differentiation in woodland vegetation. Similarly, in forest vegetation, both stochastic models suggested that native species extinctions promote homogenization. Furthermore, my observations suggested that exotic species colonizations promoted differentiation.

At a regional scale, I investigated change in the species composition of 30 native remnant grassland sites located along a 280 km urban–rural gradient in western Victoria. Their species composition was first sampled in 1984, re-sampled in 2001 (14 sites) and 2007 (the other 16 sites). The contemporary surveys oversampled the species composition across all 30 sites. I used a variant of the earlier stochastic modelling technique to correct for oversampling. For all 30 sites as well as urban, peri-urban and rural subsets of these sites I determined patterns of homogenization and differentiation resulting from native species extinctions and exotic species extinctions and colonizations.

For all 30 sites across the region, native species extinctions promote differentiation in the native species composition of grassland vegetation. In contrast, exotic species extinctions and colonizations promote homogenization of the exotic species composition of grassland sites. However, the composition of all species remains in stasis. For urban sites, native species extinctions promote differentiation in native species composition. Exotic species extinctions and colonizations promote homogenization in exotic species composition, but these patterns of change are not statistically significant. However, changes in exotic species composition were large enough to buffer the opposite (i.e. differentiating) effect of native species extinctions. As a result, the species composition for all species has become homogenized in urban sites. In peri-urban sites, exotic species extinctions and colonizations homogenize the exotic species composition, but do not have an overall effect on the composition of all species. Native species extinctions promote differentiation in native species, and exotic species extinctions and colonizations homogenize the exotic species composition of rural sites. However, the differentiating effect of extinctions in the native flora is greater than the homogenizing effect of exotic species extinctions and colonizations. Consequently, the composition for all species in rural sites has become differentiated.

The patterns of homogenization and differentiation above were examined to see how human-related and environmental site attributes might be associated with patterns of vegetation change for the same 30 remnant grassland sites and their subsets – how change in human population density, maximum fire interval, solar radiation, temperature and precipitation are associated with patterns of homogenization and differentiation.

At a regional scale, differentiation in native species composition is associated with change in human population density. However, for urban, peri-urban and rural subsets of these sites no statistically significant association emerged. The only environmental site attribute that was associated with patterns of homogenization and differentiation was maximum temperature, which was associated with homogenization resulting from exotic species extinctions and colonizations in all 30 sites and peri-urban sites as well as change in the composition of all species for urban sites.

Overall my results revealed complex patterns of homogenization and differentiation in forest, woodland and grassland vegetation at a range of spatial and temporal scales. Moreover, I was able to relate change in individual vegetation associations to a range of human-related and environmental factors.

# Terminology

In the context of this thesis the following terms are used:

**Biotic homogenization** – The process by which a species, functional trait and/or genetic trait assemblage becomes more similar in both space and time as a result of species colonizations, species extinctions and habitat modifications. **Biotic differentiation** is the opposite process.

**Colonization** – The process by which both native and non-native plant species are introduced and established.

**Exotic plant species** – All non-native and non-indigenous native plant species found growing in areas outside their native geographic range.

**Grain size** – The level of resolution of an investigation determined by the spatial area of the sampling unit (also **granularity**).

**Occupancy** - The total number of locations in which a species is found to be present

**Revisitation method/technique** – A technique that employs vegetation survey data collected from the same location(s) in two time periods.

**Reconstruction method/technique** – Any technique that uses contemporary lists of extant and extinct species to reconstruct the historical species composition of plant species assemblages.

**Standard reconstruction technique** – A method that reconstructs the historical species composition of plant species assemblages by both removing exotic species and adding extinct native species. Exotic species are removed from the contemporary list because it is assumed that these species would not have been present in the historical species assemblage. Extinct species are added to account for historically present species lost due to extinction.