Forest Ecology and Management 260 (2010) 1230–1240

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

The distance to structural complement (DiSCo) approach for expressing forest structure described by Aerial Photograph Interpretation data sets

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ARTICLE INFO

Article history:
Received 18 December 2009
Received in revised form 7 July 2010
Accepted 7 July 2010

Keywords:
Landscape structure
Forest
Structural complexity
Heterogeneity
Connectivity
Index

ABSTRACT

At the landscape-level Aerial Photograph Interpretation (API) is one of the oldest and most common tools for mapping forest structure. The variety of attributes available for API classifications can produce 100s of different patch types as a basis for mapping landscape mosaics. However, these maps are often difficult to interpret or use for monitoring the impacts of management and natural disturbance. In this study, we demonstrate an approach for quantifying the landscape forest structure described by API data sets. For this purpose we utilised a forest dataset comprising 1197 field plots and API mapping of crown structural characteristics for 773,280 ha of State Forest in Victoria, Australia. Our approach involved: (i) stratification of the landscape into distinct forest communities; (ii) construction of stand-level structural complexity indices for each forest community; (iii) use of stand-level indices of structural complexity to classify API typing into distinct canopy structural classes; (iv) calculation of the distance from each point within a landscape grid to achieve a full complement of canopy structural classes within each forest community. We term our methodology the distance to structural complement (DiSCo) approach, because it identifies the minimum distance to achieve a full complement of structural units within the landscape. We demonstrate the use of these values in mapping landscape structure and their potential for monitoring and modelling the effects of disturbance at this scale, including impacts on heterogeneity, connectivity, individual faunal species and particular forest communities.

1. Introduction

The maintenance and conservation of biodiversity is an important objective of ecological sustainable forest management and is explicitly recognised within national and international commitments (*e.g.* Montreal Process Working Group, 1995; Australian State of the Environment Committee, 2001). To meet these commitments, forest managers need practical ways of assessing biodiversity and monitoring the impact of management regimes at the stand and landscape levels (Lindenmayer et al., 2000; Sarkar and Margules, 2002; Williams, 2004). Many authors have concluded there is a positive correlation between forest-structural complexity and biodiversity (*e.g.* Pretzsch, 1997; Woinarski et al., 1997; Brokaw and Lent, 1999; Mac Nally et al., 2001; McElhinny et al., 2006b). Consequently, there is increasing interest in using easily measured indices of forest structure to assist measuring and monitoring biodiversity. At a stand level many structural attributes contribute towards structural complexity (see review by McElhinny et al., 2005). By summarising data on an array of attributes, stand-level indices may express this complexity in a single number (*e.g.* Newsome and Catling, 1979; Koop et al., 1994; Watson et al., 2001; McElhinny et al., 2006a). Several authors have used such indices to permit the ranking of stands in terms of their potential contribution to biodiversity (*e.g.* Koop et al., 1994; Van Den Meersschaut and Vandekerkhove, 1998; Neumann and Starlinger, 2001; McElhinny et al., 2006a).

In terms of Whittaker's (1972) three key scales of diversity – α, β and γ – variation within stands identified by a structural-complexity index is one measure of α diversity. The β and γ scales of diversity relate more to the dynamic nature of the ecosystem and the variety of the habitats and species across the landscape. Thus, even though stand-structural diversity has value for ranking biodiversity, it is limited to a single scale.

At the landscape level Aerial Photograph Interpretation (API) is one of the oldest and remains one of the most common tools for mapping forest structure (Lucas et al., 2008). Data sets or archives of these photographs may extend over several decades for many forests. Typically, skilled technicians use high-resolution stereoscopic photographs to analyse attributes of overstorey crowns as a basis for identifying distinct forest patches, or API types. Within each API type, overstorey structure is judged to be relatively homogenous and different to other API types. For example,

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doi:10.1016/j.foreco.2010.07.016

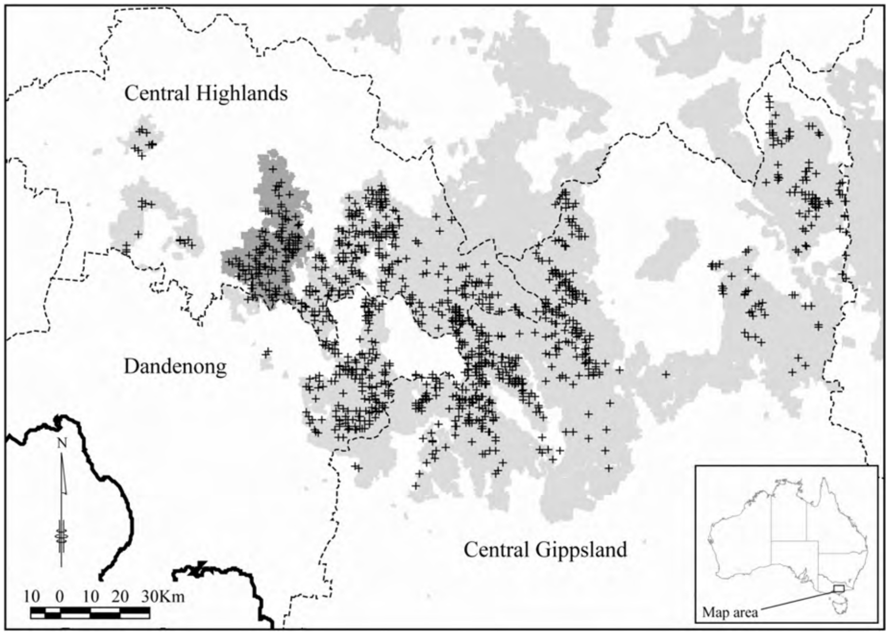

Fig. 1. Study area. State forest areas in each of the Dandenong, Central Gippsland and Central Highlands Forest Management Areas (FMAs) are shaded in light grey. The Black Range State Forest in the Central Highlands FMA is shaded in dark grey. (+) indicates the locations of the 1197 field plots used in the study.

the relative canopy cover of crown forms associated with regrowth, mature and senescent trees can be used to classify patches into distinct growth stage types (DNRE, 2000). Sensors mounted on space-borne satellites are increasingly being used to collect data that is used for mapping this sort of forest structure. Since the late 1970s, these sensors have subdivided the spectral range of radiation into bands (intervals of continuous wavelengths) and allowed the acquisition of "multispectral" images. A multispectral camera system, flown on the Skylab spacecraft in 1973/74, demonstrated the "...value of multispectral photography to discipline scientists, particularly geologists, hydrologists, agronomists, foresters, and those concerned with environmental monitoring and land use/cover assessment" (Short, 1998). As with API, visual interpretation of these images is carried out to generate maps of forest structure. However, it is increasingly common to use computer algorithms – especially supervised and non-supervised classification techniques – to model the boundaries between relatively homogenous areas (Brack, 2003). In an unsupervised classification, computer algorithms attempt to group spectral-response patterns into clusters that are statistically separable. The different clusters are examined (by visiting representative areas – ground truthing – or relying on the interpreter's local knowledge) to determine if they relate to meaningful ground categories. Supervised classification depends largely on the skills of a specialist to recognise relevant scenes from prior knowledge or personal experience with the region in question.

The variety of attributes available for classifying API types or "homogeneous" remotely sensed areas is large and can produce hundreds of different patch types. While this allows detailed maps of the mosaic of patch types to be created for landscapes, these maps are often difficult to summarise, interpret or use for monitoring the impacts of management and natural disturbance. Thompson (2000) for example, recommends summarising the (potentially hundreds of) types identified under API into about 6–8 strata to maximise the improvement in precision of resource estimates and change. Forest managers therefore require objective and quantitative metrics to summarise the landscape structure described by API or remote sensing mapping and allow comparisons over time.

Numerous approaches exist for quantifying landscape structure. Some focus upon diversity of patch size and type and are not spatially explicit. For example, Shannon's information index (Shannon and Weaver, 1949) is often used to report attributes of heterogeneity, such as the number of landscape patches and the

Table 1
Crown form classification. Crown forms reflect the different growth stages, or morphological forms, eucalypt crowns exhibit with increasing age.

Crown form class	Description
Regrowth	Trees with narrow, conical crowns with relatively high individual crown densities
Regular	Generally compact, smooth textured, circular to oval shaped crowns with at least half of their boundaries intact. The Regular crown form class is subdivided in stands where it constitutes at least 30% of the total crown cover (+) Highly regular. Stand-level Regular crown component dominated by crowns with at least three-quarters of their boundaries intact and no dead branches are visible (=) Equally regular. Stand-level Regular crown component is a relatively even mix of Highly and Moderately Regular forms (−) Moderately regular. Stand-level Regular crown component dominated by crowns with between one half and three quarters of their boundaries intact. A few dead branches may be visible
Irregular	Crowns that have experienced a significant loss of crown foliage and/or individual large branches resulting in an irregularly shaped crown where large dead branches are visible