ASSESSMENT OF FOREST STRUCTURE AND DIVERSITY USING THREE DIFFERENT APPROACHES

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Amanda Barbosa Lima[1], José Javier Corral Rivas[1], Klaus von Gadow[1], Uwe Muuss[2]

[1]Institut für Waldinventur und Waldwachstum, Georg-August-Universität Göttingen, Germany, [2]Tropenzentrum, Georg-August-Universität Göttingen, Germany. e-mail: amandablima@hotmail.com

INTRODUCTION

Forest structural diversity can be indicative of overall biodiversity. The ability to assess and to describe spatial structures with affordable cost is the key to managing uneven-aged multi-species forests. Many authors have suggested variables that can be used to describe forest structure and diversity. To assess the different scales and levels of forest structure within a given area, more integrated and comprehensive approaches are required which include not only species diversity, but also the distribution of the tree positions and the arrangement of the tree dimensions (Hui and Gadow, 2002).

This study describes the use of three groups of indices: (1) aggregation index of Clark and Evans combined with the segregation index of Pielou, and the Shannon index; (2) the three neighbourhood-based parameters "contagion", "species mingling", and "dominance"; (3) pair-correlation function and mark-correlation function which is based on point pattern analysis.

The specific objectives of this study were: (a) To describe forest structural diversity in different forest types using a variety of approaches; (b) To compare the performance of three groups of forest structural diversity attributes for three forest types.

MATERIAL AND METHODS

Forest structural diversity was studied using fully enumerated plots with measured tree positions from three different forest types: a boreal forest from Northern Mongolia, a temperate forest from Europe, and a subtropical forest from Southern Africa (Table 1).

Table 1. Information of the plots used in this study

Plot	Plot size (ha)	Average rainfall (mm/year)	Species ≥ 10 cm dbh	Individuals ≥ 10 cm dbh
Khentii (Mongolia)	0.25	322	4	135
Lensahn (Germany)	0.60	737	13	386
Virée 20 (Southern Africa)	1.18	873	22	845

Methods for assessing forest structural diversity at:

a) Stand level:

• The aggregation index of Clark and Evans (Clark and Evans, 1954) was used to describe aspects of variability of tree locations;

• The Shannon index was applied as an ecological measure for diversity (Shannon, 1949);

• Spatial segregation between species was determined through the segregation index of Pielou (Pielou, 1977).

b) Neighbourhood level:

• The *contagion* index (W_i) takes into account the regularity of the tree positions (Gadow et al., 1998);

• The spatial species *mingling* index (M_i) takes into consideration the diversity of species (Gadow and Hui, 2001);

• The tree *dominance* index (U_i) that is quantified on the basis of diameter (Albert, 1999; Hui and Hu, 2001).

c) Point level :

• The pair correlation function (g(r)) that takes into consideration pairs of neighbours separated by a distance r (Stoyan and Stoyan, 1994);

• The mark correlation function (K_{mm}(r)) describes the distribution of trees associated with their diameters at the forest stand (Stoyan and Stoyan, 1994).

RESULTS

The aggregation index of Clark and Evans indicates a random distribution of the tree positions in each of the three forests (Table 2). Mean values of W_i around 0.5 also suggest a random distribution of the tree positions. The same can be observed using the pair correlation function at all inter-tree distances r with values around 1 (Figure 1). According to the Shannon index the plot Virée 20 is the most diverse. The segregation index of Pielou suggests that the plot Virée 20 has a high degree of mixture (Table 2). The mingling index also indicate that the plot Virée 20 has the highest mixture of trees with approximately 60% of the trees in the class 1 (Figure 1). The dominance distribution (*Ui*) shows that the trees are well distributed through the different dominance classes. However, the Kmm (r) for the plots Khentii and Lensahn shows a negative correlation for distances lower than 8 m, which suggests competition between trees with smaller diameters (Figure 1).

Table 2. Structural diversity indices at the stand level

	Khentii	Lensahn	Virée 20
Clark and Evans index	0.95	0.96	0.97
Shannon index	0.45	0.81	2.49
Pielou index	0.05	-0.07	0.80

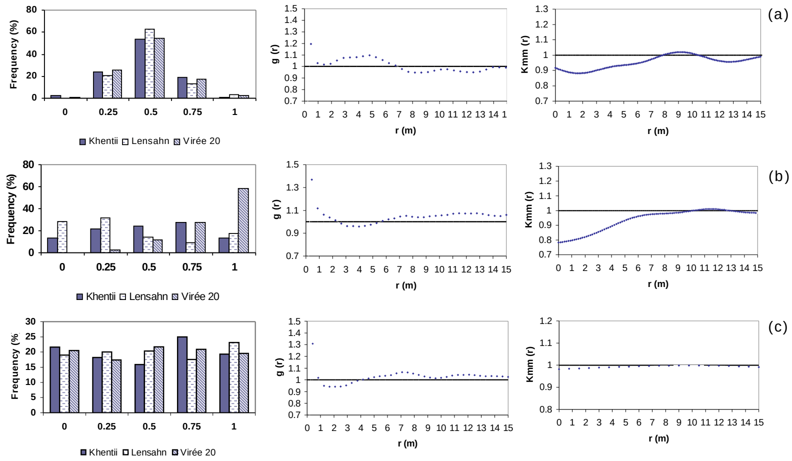

Figure1. Neighbourhood indexes, pair correlation functions, and mark correlation functions for the plots Khentii (a), Lensahn (b), and Virée 20 (c)

CONCLUSIONS

The ability to describe forest spatial structures, and their modifications through timber harvesting, is of prime importance for sustainable management of complex forest ecosystems, especially in uneven-aged and multi-species forests. For this purpose, forest managers require spatio-statistical indices which are meaningful descriptors of the spatial structure of a given forest ecosystem. This paper describes the performance of various indices. The emphasis is on point patterns. However, the neighbourhood variables *spatial mingling* and *species dominance* are also indispensable for a complete description of forest spatial structure and diversity. In common forest practice the measurement of tree-to-tree distances is expensive and rarely done. When evaluating spatial distributions of forest trees using *neighbourhood-based* indices, it is not necessary to measure distances between trees or to establish tree coordinates. Field assessment of such indices is very easy when compared with a complete enumeration of tree coordinates

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