Methodology for intensive monitoring of forest dynamics in strict forest reserves in Flanders (northern Belgium)

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Abstract. – The standard methodology for monitoring of strict forest reserves in Flanders, consists of a combination of grid-based nested plots and a core area. This methodology complies with the standards internationally set for the monitoring of forest vegetation dynamics in strict forest reserves. Moreover, the results of the circular plots are compatible with the datasets from the Flemish Forest Inventory. This methodology therefore provides possibilities for detailed description and analysis of processes within the forest stand, a decent description of the forest reserve as a whole, and comparisons with other managed and unmanaged forests in Flanders and Europe. In order to illustrate the possibilities of the methodology, some results from the forest reserve Kersselaerspleyn (Zoniënwoord) are presented. The accuracy of the dendrometric results from circular sample plots is tested by comparing them to full-inventory data. The possibilities to study relationships between herbal layer and tree layer in the core zone are also evaluated. The results from the core zone showed clear links between structural diversity of this beech forest and floristic diversity, with low diversity in large storm gaps and regeneration groups, and a much higher species richness in the old stands with small gaps. Especially uprootings created new opportunities for light-demanding perennial species.


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Résumé. – Méthodologie de surveillance intensive de la dynamique forestière dans les réserves forestières intégrales de Flandre (nord de la Belgique). La méthodologie standard pour la surveillance de réserves forestières intégrales en Flandre consiste en une combinaison d’une grille de placeaux emboîtés et d’une zone-noyau. Cette méthodologie se conforme aux standards établis au niveau international pour la surveillance de la dynamique forestière dans les réserves forestières intégrales. En plus, les résultats de ces placeaux circulaires sont compatibles avec les collections de données de l’Inventaire Forestier Flamand. Cette méthode fournit dès lors des possibilités de description et d’analyse détaillées des processus dans la station forestière, une description convenable de la réserve forestière comme unité et des comparaisons avec d’autres forêts, aménagées ou non, de Flandre et d’Europe. Afin d’illustrer les possibilités de la méthodologie, quelques résultats de la réserve forestière "Kersselaerspleyn" (Forêt de Soignes) sont présentés. La pertinence des résultats dendrométriques tirés des placeaux circulaires est testée en les comparant à des données d’inventaires complets. Les possibilités d’étude des relations entre strate herbacée et strate arborescente dans la zone-noyau sont également évaluées. Les résultats obtenus dans la zone-noyau ont montré un lien clair entre la diversité structurale de cette forêt de hêtre et la diversité floristique, avec une faible diversité en espèces dans les zones de chablis de tempête importants ou dans les aires de régénération, et une richesse en espèces bien supérieure dans les stations âgées à petites trouées. Les chablis en particulier créent de nouvelles opportunités pour les espèces héliophiles vivaces. Traduit par la rédaction.

Key words: methodology, monitoring, forest dynamics, forest reserve, Fagus sylvatica, Pteridium aquilinum, Flanders

Abbreviations: DBH, Diameter at Breast Height (tree diameter at 130 cm height); LAI, Leaf Area Index.


1 Introduction

Strict forest reserves are forest areas that have been left unmanaged for spontaneous development. In Flanders, the first forest reserves were designated in 1995 and since then, a network of approximately 1700 ha of forest reserve has been established, the great majority of which being strict reserves. In a European context, strict forest reserves are mainly conceived for the study of spontaneous forest dynamics (Parviainen et al. 2000). Forest reserves in Flanders additionally have an important nature conservation function (Vandekerkhove 1998).

As stated by many authors, strict forest reserves are considered as an important information source for close-to-nature forestry outside the reserves (Leibundgut 1966; Mayer 1978; Thomasius 1992; Parviainen et al. 2000). This requires reliable dendrometric and vegetation data that are comparable both over time and amongst one another. Therefore, a monitoring methodology was developed that had to comply with European standards set by COST-action E4 (Hochbichler et al. 2000), and is also in accordance with the methodology of the Flemish Forest Inventory, thus allowing both comparisons with other forest reserves in Europe and other forests in Flanders, both managed and unmanaged. The aim was to develop a methodology that not only produces reliable and comparable dendrometric and floristic data, but also provides possibilities for research into
ecological processes within the forest stands. In this paper, the development of the methodology is described and discussed, and is subsequently illustrated by presenting some results from the monitoring of the forest reserve of Kersselaerspleyn (Zoniënswoud).

2 Development of the methodology

2.1 Aims
The global aim is to monitor the development of the vegetation in forests that are deliberately left unmanaged. The sampling method should provide knowledge on the development of the reserve as a whole, as well as better insight in the processes triggering the development.

2.2 Material and methods
The development of a standard methodology for the monitoring of strict forest reserves in Flanders was based on experiences in other countries, the guidelines of the European COST-action E4 (Hochbichler et al. 2000) and some own preliminary studies (Van Den Meersschaut & Lust 1997a & b; Van Den Meersschaut et al. 2000). Many European countries have a long tradition in monitoring of strict forest reserves, and have developed detailed methodologies and guidelines to do so.

From the 1950’s onwards, elaborate research programmes have been set up in central Europe, using full inventories and strip transects to study the distribution and structure of different developmental stages of strict forest reserves (Leibundgut 1959, 1981; Mayer 1966, 1967; Mayer et al., 1987; Milsnek 1970; Korpel 1995; Prusa 1985). Measurements have almost exclusively been focused on trees and dead wood (for the latter not so much on the necromass itself, but on the die-back-mechanism of living trees, the so-called mortality).

From the 70’s onwards, full inventories have been abolished and replaced by sampling methods based on regular sampling plots within a grid system, or studies of strip transects or core zones or a combination of both (Albrecht 1990; Altshof et al. 1993; Broekmeyer, 1995; Bücking 1990; Bücking et al. 1986; Kätzler 1984; Kirby et al. 1996; Koop, 1989; Mountford et al. 1999; Peterken & Backman 1988; Projektgruppe Naturwaldreservate 1993). The use of sample plots allowed to include other important aspects in the recordings, such as the analysis of soil and ground vegetation, that are important for the analysis and explanation of forest dynamics. In recent times the scope of the monitoring research has further widened to include important topics that affect nature conservation: inventories and surveys of populations of fungi, birds, bats, saproxylic invertebrates and red-list species and their relations to the forest dynamics are increasingly integrated into the monitoring programmes (Bücking, 1996; Rauh, 1993; Köhler, 1996; Winter 1999).

From the analysis of all these documents, following requirements were drawn (followed by the principle reference):

- An adequate monitoring of the reserve should involve at least the basic dendrometric measurements (species, DBH, height of upper storey, regeneration), combined with vegetation relevées. Analysis and typology of the soil should also be done, at least once at the beginning of the monitoring (Hochbichler et al., 2000).
- A standardised grid of sampling plots will produce reliable data on the development of the reserve as a whole, while as the core area or transect will provide more detailed information on the ecological processes that trigger the spontaneous development, and the interactions between tree layer, soil and ground vegetation. It is therefore advisable to apply a combined sampling, with both sample plots and core areas, in order to cover both scales (Van Den Meersschaut & Lust 1997a).
- The sample plots are preferably round plots (less edge effects and uncertainty on the relocation), with a minimum size of 500 m². Within this plot, square or round subplots should be established for measurements on regeneration and ground vegetation (Hochbichler et al. 2000).
- In order to produce reliable data for the whole reserve (accuracy levels of 5 to 10 %) on basal area, species composition and stem number, based on data from the sampling plots, a sampling intensity of at least 15-20 % is needed (Van Den Meersschaut et al. 2000). Core areas should at least have a surface of 1 ha. They consist of a number of juxtaposed strip transects, forming a square or rectangle, with a minimum width of two times the tree height (60-80 m) (Koop 1989; Albrecht 1990).
- A combination of the measurements with analysis of aerial photographs is recommended, in order to cover particular developments outside the plots and in the surroundings of the reserve (Hochbichler et al. 2000).
- Measurements should be repeated at least every 10 years. Long time experiences show that the interval of 10 years is long enough to produce relevant changes, and yet frequent enough not to overlook important developments (Koop 1989; Hochbichler et al. 2000).
- Additional monitoring of other organisms (fungi, birds, insects,...) is promoted, if done in a standardised way and linked to the sampling network, thus providing a better insight into the ecological processes and their effects on species composition and diversity and vice versa (Albrecht, 1990; Bücking, 1996).
2.3 Results
This results in a methodology based on permanent plots, combining a grid of sample plots with a core area (fig 1). The grid system consists of circular nested plots of 1000 m², covering 20% of the total area. In these plots basic measurements are done on woody vegetation and herbaceous layer (see fig 1). These measurements are combined with soil samples, light measurements and/or fish-eye images, and aerial photographs if available.

![Diagram of forest reserve, nested plots, and grid-based sampling](image)

Figure 1. Design of the standard methodology of forest reserve monitoring: a combination of grid-based nested plots and a core area

The core area is located in the centre of the reserve and aims for more intensive measurements. The standard dimensions of the core area are 70x140 m. All trees above 5 cm DBH are identified, positioned and measured, vegetation and regeneration is mapped in detail in 10 m x 10 m subplots, soil and light conditions are analysed. All plot and tree positions are measured by Total Station, and the data are imported into a GIS-environment, allowing geographical analysis.

The methodology is flexible, in this sense that it can be adjusted to local conditions, be it that the minimal requirements are respected (see below).

2.4 Discussion
The monitoring methodology is similar to the one used in the Netherlands, combining the advantages of both circular samples and a core zone. The circular plots are mainly to be considered as pure samples, allowing a global overview on the development of the area as a whole: how is the distribution of tree species, stem number, basal area, vegetation types and species, etc. of the reserve. However, as these plots are permanent, they can also be considered as individual, be it small permanent plots, allowing precise analysis of future changes on the plot area. For detailed analysis, they are less useful, as the set of measurements and the size of the plot required for that purpose, would make the set-up too labour-intensive. The need for more detailed data in order to allow analysis of the processes and interactions triggering the development, is covered by the information from the core area. The detailed information provided here on ground cover, tree positions, crown parameters, soil properties, light measurements, etc. allow for instance a robust analysis of multilateral influences between soil, woody layer and ground vegetation.

The plot design and the methodology of the measurements in the circular plots are identical to the ones in the Flemish Forest Inventory, thus allowing immediate comparison. They also comply with the international requirements, so international data comparison is also possible. The size and measurements in the core area are in accordance with the SILVI-STAR method developed by Koop (1989) and used in the Dutch forest reserves programme, thus also providing opportunities for co-operation.
Some preliminary results from the core area in the forest reserve Kersselaerspleyn are given below and provide a first impression of the potential of the methodology.

This monitoring programme is quite intensive and elaborate. It doesn’t only aim at a global assessment of the diversity of the site, using biodiversity-indicators, as proposed for forests by Vandekerkhove et al (2002), and for urban parks by Hermy & Cornelis (2000). The programme also aims at detailed descriptions of status and dynamics of the forest structure and analysis of the driving forces of these ecological processes, and their effects on the ecosystem and specific organisms. This requires detailed and time-consuming measurements and analysis. For an average sized reserve (50 ha) the whole process of set-up, field measurements and processing the data covers about 500 working days.

3 Illustration of the methodology using some preliminary results from the core area of the forest reserve Kersselaerspleyn (Zoniënwoed)

3.1 Material and methods
The forest reserve of Kersselaerspleyn has a size of 98 ha and is located in the centre of the forest of Zoniënwoed (4300 ha), south of Brussels (fig 2). A description of the area and its management history has been given in another paper in this volume by Vandekerkhove et al (2003).

![Diagram of forest reserve location](image)

*Figure 2. Location of the forest reserve Kersselaerspleyn south of Brussels, with a detailed view of the sample design within the forest reserve.*

In the forest reserve Kersselaerspleyn (Zoniënwoed) the standard methodology was slightly altered. As stated, the methodology is flexible and allows some alterations in function of the local conditions. The size of the circular plots was expanded to 2000 m² as tree dimensions and distances are extraordinary high in this site. Size extension was necessary in order to comply with the basic principles of Kramer & Akça (1982), Richter & Grossmann (1959) and Spurr (1952) pointing out that an individual plot should at least contain respectively 25 to 30, 12 to 14 or 20 to 30 trees per plot. By widening the grid to 100 x 100 m, the sample size of 20% could be respected. Also the core area was considerably larger than required, covering 10.5 ha in stead of 1 ha. This extension was based on the fact that detailed dendrometric information was available for this area from 1986 and 1990, providing opportunities for interesting detailed comparisons. Measurements in the core area were according to the prescriptions: all trees were positioned and measured, and
vegetation was mapped in 10 m x 10 m squares, using the decimal scale of Londo (1975). The vegetation grid covered a total area of 7.5 ha (fig 2). Gaps and woody cover were digitized from aerial photographs and derived from subplot data.

3.2 Results

3.2.1 Comparison of dendrometric data from circular plots and full inventory. In the core area, a full inventory and tree positioning was performed for all dead or living trees with DBH>30 cm (fig 3). After loading the data into a GIS-system, simulations of different subsamples are easily made. By comparing a subsample coinciding with the sample of the grid of circular plots to the full inventory, it was possible to evaluate the accuracy of the sample, and thus give an estimation of the accuracy of the data gathered in the sample plots outside the core area (fig 4).

![DBH of living trees (cm)]
- 0 - 30
- 31 - 50
- 51 - 75
- 76 - 100
- 101 - 158

Lying dead trees

Figure 3. Map of the forest structure in the 7.5 ha core area of Kersellaerspleyn, with the position of lying dead trees and living trees divided into 5 diameter classes

The total area of circular plots in the core area amounted to 28% of the total area of the core zone, which is well above the sampling intensity of 15-20% recommended by Van Den Meersschaut & al. (2000). Comparison of the sample to the full inventory on dendrometric characteristics indicated that overall results were very similar. Calculations based on the circular plots slightly overestimated the total stem number and slightly underestimated the total volume. The error on the total stem number is comprised between 5 and 10 %, the error on the total volume is even below 1% (table 1). However, errors are more substantial for less frequent tree species, in casu oaks. Stratification of the calculations by taking into account the area of the circular plots situated in regeneration groups and in the large storm gap did not provide a more accurate picture. The heterogeneous structure of both areas might be responsible (table 1).
3.2.2 Relationships between woody layer and ground cover in the core area. The stand, in which the core area was established, consists almost exclusively of beech (*Fagus sylvatica*), planted in 1775, and left unmanaged since 1983. The canopy was closed until the gales of 1990 created gaps of varying size.

The detailed vegetation survey (750 plots of 10 m x 10 m) revealed that the species richness is clearly linked to the canopy cover and gap sizes, as well as to the soil pH(KCl) (fig 5). The linear regression model, including both variables and their interaction, is highly significant. The relationship between forest structure and ground vegetation was elaborated in detail by De Keersmaeker et al. (2000).

The distribution of some characteristics plant species in the vegetation grid of the core area, in comparison with the tree cover, is illustrated by figure 6.

The floristic inventory indicated that dominance of Bracken (*Pteridium aquilinum*) is restricted to large gaps (>1 ha) as found in the north-west of the core area. Sample plots where Bracken was dominant showed a reduced species richness.

In the west of the core area, a planted 30-year-old regeneration group of beech of approximately 0.5 ha is present. Our inventory indicated that also here species diversity was very low. Moreover, also total vegetation cover was very low probably as a consequence of extreme
shading. Species that are common elsewhere in the core area like *Pteridium aquilinum* - a semi-shade plant (Ellenberg & al. 1992) that suffers from deep shading by beech (den Ouden, 2000) – but even species which are regarded to be very tolerant to deep shading by Ellenberg & al. (1992), such as *Dryopteris carthusiana* + *dilatata* and *Oxalis acetosella*, are almost absent in the regeneration group (fig 6).

Areas with small gaps however showed the highest species richness. Bracken is less dominant here, allowing other species to accompany, and a high range of moderate light conditions is present, creating good conditions for most forest plants. Moreover, the logs and rootplates in the small windthrow-gaps provide new habitats for quite a number of light-demanding species with a persistent seed bank, accounting for an important share of the species diversity (Vandekerkhove et al. 2003). *Carex pallescens*, *Rubus idaeus* and *Luzula luzuloides* for instance have a clear preference for mineral soil of uprootings.

### 3.3 Discussion

The results for the forest reserve Kersselaerspleyn illustrate that the developed methodology provides sample data that is detailed and accurate enough to give a full picture of the development of the reserve as a whole. Moreover the data from the core zone already have indicated that the developed monitoring methodology can be effective in providing better insight in processes and relations, and can produce guidelines towards a better conservation-oriented management in other forests outside the reserves. These preliminary results indeed suggest that structure and management of beech forests can be important determinants for floristic diversity. Both large gaps and large closed regeneration areas prove to be unfavourable environment for many forest plant
Figure 6. Distribution of Pteridium aquilinum, Dryopteris carthusiana + dilatata and Oxalis acetosella in the 7.5 ha core area of forest reserve Kersselaerspleyn, compared to the tree cover map (white line = location of large 30 year old artificial regeneration of beech).
species resulting in the disappearance of the species from this area. Most of these species have poor colonisation capacities and short-living seed bank. Large regeneration groups and relative short rotations can thus cause considerable decline of these species, and of the floristic diversity in beech forests. Small gaps and presence of logs and rootplates on the other hand prove to be favourable for most species and species diversity as a whole.

A forest management using shelterwood system, and leaving some of the uprooted trees untouched in the forest, is therefore preferred in order to conserve or even enhance the species richness of the ground vegetation.

References


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