1 Introduction

The forests of Europe constitute the habitats for a wealth of animals and plants - by definition not least trees. At the same time, they form parts of cultural landscapes, or when of appropriate size, they constitute landscapes in their own right. Most forests are also production systems that provide timber and other products, as well as having important recreational functions. There are thus many reasons to take interest in the way forests are managed and their ecological state. Field-based forest mapping and inventories are however expensive and time consuming, and not considered feasible for environmental monitoring tasks. Therefore methods for rapid and inexpensive mapping and analysis of forest have been requested during the last centuries. At the same time, the discipline of landscape ecology has emerged, providing a framework for spatial analysis and quantification of landscape structure. Meanwhile the availability of satellite images, starting with the successful launch of the Landsat-1 satellite in 1972, offers synoptic views of landscapes and data in digital format that, if interpreted correctly can be converted to maps of land cover and possibly land use. Today several satellite platforms provide very-high-resolution imagery of pixel size down to 60cm as well as multi-spectral data well suited for discrimination of vegetation types. Following the revolutionary development of computers and their exponentially increasing power to perform calculations, it has been possible to readily implement extraction of the many metrics of spatial structure, that has been proposed in the ecology and landscape ecology literature. The intuitive observation, that spatial structure affects biological diversity and habitat quality, supported by findings from island biogeography, has led to several attempts to statistically link measures of landscape structure and ground-survey based observations of flora and fauna, accompanied by definition of new metrics.

This specific study aimed at contributing to sustainable forest management and land use through use of spatial metrics as indicators in monitoring frameworks, using existing general land cover data, as well as satellite imagery that was processed to produce forest maps. The **objective** of this thesis was thus to **select, and if necessary develop spatial metrics that can be used to relate forest and landscape structure with the state of ecological systems at the landscape level.** It should be possible to derive the metrics through processing of satellite imagery and from existing map data stored in Geographical Information Systems (GIS).

Several theoretical and empirical studies have shown that ecological processes are hierarchically structured, as has also been found for landscape features. Values of spatial metrics appear to depend on the scale at which they are calculated, typically expressed by the pixel size of the imagery from which the underlying maps are derived. It was therefore considered important to assess the influence of scale on the selected metrics, and if possible to quantify scaling effects in order to allow comparison of metrics values derived from different data sources.

In the literature survey (chapter 2 of this thesis), the complex relationship between spatial structure and biological diversity and naturalness of landscapes is explored, with focus on forest and woodlands. The concepts of scale in Remote Sensing, biology and landscape ecology respectively were compared, and the issue of scaling addressed, especially relating to influence of scale on metrics values. The relation of metrics to dominating theories in conservation biology and landscape ecology is discussed, as well as the possible use of Earth Observation (EO) data and derived metrics in forest management. Fragmentation, seen as a state as well as a process, is introduced as field of study of special interest.

The theoretical considerations and practical approaches taken throughout the studies for this thesis can be summarised in the following **hypotheses**:

- Certain relationships can be found between biological diversity and naturalness (state) of landscapes and spatial metrics derived from EO data of the same areas.

- Different properties of landscapes are/can be revealed from data at different spatial and thematic resolutions.
- The scaling behaviour of spatial metrics can be quantified and displayed graphically.
- Combinations of spatial metrics can be optimised to yield information on forest and landscape structure in order to characterise landscapes at local and regional levels.

The last three of hypotheses above naturally lead to formulation of various research questions, posed in order to test different assumptions, these questions are stated in the empirical chapters, which are structured as follows:

Chapter 3 describes the first empirical study, where focus was on metrics describing forest structure, with the Umbria region in central Italy as the study area. Forest maps were made from detailed GIS information and from high resolution (Landsat-TM sensor) and medium resolution (IRS-WiFS scanner) satellite images. Scaling effects on metrics of fragmentation were predicted from synthesised images degraded to increasingly coarser resolutions and compared with metrics values from the EO based forest maps, and the possibility of extrapolating values found at high resolution through use of larger-area maps at lower resolution was assessed.

In the subsequent study, described in chapter 4, the objective was to describe forest structure and diversity over larger areas, with output as maps as well as tables and graphs. The spatial extent increased to cover Central and Northern and Italy and surrounding areas. Existing land use/land cover (LUC) data from the Corine Land Cover (CLC) database and a satellite based forest map were used for comparison of metrics values over large areas, now including metrics of forest area, patch numbers and diversity. A Moving-Windows (M-W) method for extraction of metrics values in areas of similar extent was implemented, allowing output of results as thematic maps of metrics values, thus visualising spatial structure. Scalogram curves were used to describe scaling effects. Results from M-W calculations were analysed at watershed and administrative region level, allowing for reporting of metrics values at different hierarchical levels. A Forest Concentration (FC) profile metric was proposed, which allowed multi-scale description of the distribution of forest within a region or study area (however any object of interest can be described).

Then, chapter 5 presents results from in a study that covered Vendsyssel, the northernmost part of Denmark. Here focus moved to application of spatial metrics for description of landscape structure and diversity, particularly for assessment of naturalness and disturbance. Spatial metrics derived from maps at different thematic levels were compared, with the objective of evaluating their sensitivity to changing spatial and thematic resolution. Input data were vector and raster based LUC maps from the Area Information System (AIS). Changing resolution was found to influence patch count metrics strongly and with an unpredictable response to grain size; metrics of fragmentation changed linearly with grain size and metrics of cover area and diversity showed little change. Correlations between metrics values from different data sources and thematic levels were found to change significantly with window size employed in the M-W method. A spatial Hemeroby index was introduced and metrics values from LUC data at 25m pixel size found to be highly correlated with values from CLC data at 250m pixel size. This provided evidence in favour of creating large-area Hemeroby-maps, based on CLC data.

The final empirical study is described in chapter 6. Here the objective was to demonstrate possible applications of spatial metrics and M-W for forest and landscape management. Different afforestation scenarios were created for Vendsyssel, a simple and fast method was used for assignment of new forest types to selected target areas, and changes in metrics values and FC profiles were calculated. Different responses to the simulated landscape changes were observed, and change-maps as well as tables and FC-curves provided promising tools for spatial planning.

In the conclusion in chapter 7, a synthesis of the findings from the empirical studies is made, and recommendations are provided for quantification of fragmentation using EO data and spatial metrics and on the use of spatial metrics for environmental monitoring at landscape, regional and national levels.

All references used are listed in chapter 8, and chapter 9 contains some more personal comments regarding the process of preparing this thesis as well as acknowledgements. The implementations of moving-windows calculation of the spatial metrics, scaling and averaging operations are documented in the IDL-scripts in Appendix 1, while Appendix 2 contains a list of the various types of software used for image processing and statistical analyses of the data.
