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Neighbourhood-defined approaches for integrating and designing landscape monitoring in Estonia

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Abstract

Landscape monitoring is a rapidly developing approach in the field of environmental science and management. In order to develop a sound landscape monitoring programme, key theoretical concepts and study objectives should be clearly stipulated, and the specific objects to be monitored, as well as the criteria for selecting study areas, hierarchical levels, and techniques of data collection and analysis should be identified. This paper describes the development and implementation of the Estonian monitoring programme for agricultural landscapes, conventional approaches for landscape monitoring, and by neighbourhood analysis, assesses how landscape features are covered by different complementary monitoring data and how the current pattern of monitoring networks represents the landscape features. A spatially explicit method of network design for monitoring and sampling strategies combines stratified and multi-scale agricultural landscape monitoring and uses neighbourhood analysis characterised by the nearest neighbourhood index and Ripley's *K*-function. Data for landscape analysis are obtained from landscape monitoring (three sets) and other complementary environmental monitoring sets, such as biodiversity, forest, soil, and water monitoring (11 sets). It is shown that several monitoring sets follow an approach that aims to achieve national geographical coverage, representing various landscape types. Small sets having less than 50 stations are biased and the networks are not statistically significant. Proportional stratified sampling requires fewer sites for large homogenous inland landscape districts. The concept of agricultural landscape monitoring was tested in pilot areas. The chosen multi-scale object-based methods provide a good overview of the level of human pressure on different categories of agricultural land. Results of the monitoring showed that the species composition and abundance of bio-indicators was, to a great degree, determined by landscape structure. A systematic approach focused on landscape classes helps to integrate the monitoring set as a whole and to achieve a coherent and efficient layout of monitoring sets for Estonia.

Keywords: Landscape monitoring; Neighbourhood analysis; Agricultural landscapes; Estonia

1. Introduction

Environmental, including landscape monitoring can be seen as a process by which we maintain an overview of the state of the environment. It provides essential data on the ways systems are changing and how rapidly. In addition, it provides essential feedback to management, so that we can adjust what we are doing and get the best information out of the system. In several countries a special scientific research programme on landscape monitoring has been established (O'Neill et al., 1994; Ihse, 1995; Winkler and Wrbka, 1995; Herzog et al., 2001), and in some countries landscape monitoring programmes have already been launched (Barr et al., 1993; Bunce et al., 1993; Fuller et al., 1993; Fuller and Brown, 1994; Howard et al., 1995; Roots and Saare, 1996; Ihse and Blom, 1999; Groom and Reed, 2001; Bailey and Herzog, 2004).

The first landscape monitoring programmes focused mostly on land cover aspects (Bunce, 1979). The need for objective information on land cover was recognised in Britain as early as the 1930s when Stamp (1962) implemented the Land Use Survey. Over recent years, landscape mapping and classification has evolved to become a highly sophisticated science with extensive use of satellite remote sensing data (Griffiths and Mather, 2000; Mücher et al., 2000). The exploration of the dynamics of landscape structural features and landscape compositional analysis are important topics in scientific research in many countries (Bailey and Herzog, 2004). The landscape monitoring methodologies have become more sophisticated, covering various landscape elements from biodiversity and vegetation,

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through the analysis of abiotic landscape components, such as soils, water systems, and landscape structure, to anthropogenic and cultural aspects, such as scenery and landscape aesthetics (Bunce, 1979; Gulinck et al., 1991; Barr et al., 1993; Brandt et al., 1994; Cherill et al., 1994; Fuller et al., 1994; O'Neill et al., 1994; Hulshoff, 1995; Winkler and Wrbka, 1995; Ihse, 1996; Seibel et al., 1997; Aaviksoo, 1998; Mücher et al., 2000; Dramstad et al., 2001; Herzog et al., 2001; Bastian et al., 2002; Brandt et al., 2002; OECD, 2002; Bailey and Herzog, 2004; Groom, 2004). Often, programmes of landscape monitoring are policy driven (Groom and Reed, 2001) or focus on specific values, i.e. the properties of intact landscape that provide services to society and that we wish to maintain (O'Neill et al., 1994). Values change as societies and their natural capital change (Haines-Young et al., 2003), and monitoring programmes are adapted and developed accordingly.

2. Scope and objectives

Many authors have emphasised that there are no readily available methodologies for landscape monitoring (O'Neill et al., 1994; Herzog et al., 2001; Groom, 2001, 2004). There are only a few standardised status reports on landscapes. For example, 3Q in Norway and LIM in Sweden elaborate a reporting standard for agricultural landscapes (Blom and Ihse, 2001; Fjellstad et al., 2001). There is, however, an evolving set of basic principles for designing a monitoring programme. Thus, when developing a landscape monitoring programme, one should first define the theoretical concept for monitoring, the objectives and objects to be monitored, and the criteria for selecting study areas. In addition, one should define optimal methods of data collection, acquisition, and analysis (use of landscape indicators, time series), followed by tests in pilot areas and applications of the methodology at a national level. In practice, every monitoring programme is unique, depending mostly on geographical coverage, landscape features, range of monitoring, available technology, and financial capacities.

Whereas some aspects of landscape, such as the structure or land cover, can be monitored through specifically designed landscape-monitoring programmes, often a number of other landscape elements, such as soil, habitat, and water are monitored through independent studies. In this paper we propose the integration of landscape monitoring using primarily the concepts of geocomplexes and neighbourhood within the framework of the Estonian national monitoring programme. A data set on landscape features, stressing neighbourhood relations, configuration, and coherence of the environmental monitoring networks for integrated landscape analysis is tested. We explore what dataset is provided by agricultural landscapes monitoring and what data could additionally be obtained from other environmental strata, and what spatial unit might be employed for interpolation of datasets.

2.1. Development of landscape monitoring in Estonia

In general, the dynamics of land use structure are an important indicator of socio-economical and political changes in society. Since 1991, the process of land reprivatisation in Estonia has been under-way. Over 200,000 farmer owners or their heirs are claiming back their land. The impact of land reform on landscape structure has been unpredictable. In 1992 the Agricultural Reform Act was passed. The purpose of the Agricultural Reform Act was the liquidation of collective and state farms (*kolkozes* and *sovkhozes*) and the transition to agriculture based on private ownership. Slow and incomplete privatisation and an inadequate rural policy have resulted in extensive land abandonment. This has created several environmental problems—a decrease in biodiversity and in the aesthetical value of the landscape, a rise in the distribution of weed seeds and the danger of fire. Taking this context and these problems into account, the main objectives of landscape monitoring programmes were defined as:

- To determine the landscape structure.
- To follow landscape changes and to predict future trends on the national level.
- To give statistics and an overview on the state of Estonia's landscapes.
- To obtain information enabling optimisation of the use of landscapes as a resource.
- To explain the relationships between landscape diversity indicators and other environmental characteristics (e.g. characteristics of the ecological status).
- To compile a comprehensive reference list on Estonian landscape diversity.

Since January 1994, a National Monitoring Programme has been implemented in Estonia under the supervision and coordination of the Ministry of the Environment. The main purpose of the programme is to monitor long-term and large-scale changes in the environment and thus identify the problems that call for operational measures or complementary studies in the future (Roots and Saare, 1996). A draft concept of the Estonian landscape monitoring programme was presented to the Estonian Ministry of the Environment in 1995 (Sepp and Kaasik, 1995). To develop the Estonian monitoring programme, experiences from other countries were examined. For example, "Landscape Monitoring and Assessment Research Plan" (O'Neill et al., 1994), "Countryside Survey 1990" (Barr et al., 1993; Bunce et al., 1993; Fuller et al., 1993; Fuller and Brown, 1994; Howard et al., 1995) and LIM-project in Sweden (Blom and Ihse, 2001) were assessed for the background, and aspects were incorporated into the Estonian plan.

The Estonian national landscape monitoring programme concept introduced four monitoring sub-programmes: agricultural landscapes, coastal landscapes, protected and valuable landscapes, and land cover (Sepp, 1999). Since 1996, three programmes (monitoring of protected and valuable landscapes and land cover monitoring were combined) have been implemented (Table 1). In developing a landscape monitoring programme, several aspects were considered, including: available technology (GIS and spatial database tools, satellite images, aerial photos); the objectives and structure of existing Estonian and European monitoring programmes; institutional and financial capacity; and the scientific principles of landscape ecology (Fig. 1).