Landscape biodiversity monitoring in the Swedish NILS program

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As climate change and other unknown premises implies extraordinary challenges in landscape use, management and governance, the demand is increasing for relevant data on landscape-level biodiversity. Decision makers, stakeholders and the public require up-to-date and applicable information on state and changes of various landscapes and habitats. As well, the need for immediate analyses of cause, effect and possible management and governance solutions, calls for a close communication with the research community.

The Swedish national landscape biodiversity monitoring program NILS (National Inventory of Landscapes in Sweden) is a unique creation internationally. It is developed to monitor conditions and changes in landscape biodiversity and land use, as basic input to national and international environmental frameworks and reporting schemes and to applied research. NILS has been in operation since 2003 with two parallel and integrated inventory routes, field inventory and interpretation of color infrared aerial photos, both using quantitative variables in a context-dependent flow that captures spatial information on species, habitats, structures and processes. The design is a stratified grid of 631 permanent large-size (5 km x 5 km) squares covering all terrestrial habitats in Sweden, from alpine mountains to urbanized areas. The data is captured without pre-classification and at several geographic scales (0.25 m^2 to 25 km^2), to constitute a common platform for other type of monitoring and various research approaches. In 2007 the final set of squares were inventoried and a full national set of data was compiled. Analyses and results are continuously being produced to support high quality management and governance of the Swedish natural and cultural landscape. In 2008 the first re-inventory was initiated and the first temporal analyses may be conducted.

Experiences so far indicate that the NILS infrastructure allows for inclusion of parallel and supplementary inventories, e.g., fragmented aquatic and terrestrial biotopes in agricultural landscapes, cultural remains in the landscape, game, birds and other animal patterns, and conservation values of Nature 2000, nature reserves and key biotope areas.

A variety of approach, methodology and technique improvements are being examined, e.g., laser-scanned data for image matching to extract tree height and detailed ground topography, and climate change induced vegetation changes in the alpine treeline zone. In a pan-national perspective it is evident that there is a need to harmonize existing environmental monitoring programs and create common schemes to capture similar data using comparable methodology.

Key Words: Environmental monitoring, remote sensing, field inventory, terrestrial habitats

Introduction

Unknown land use and land management premises are to be expected due to changing conditions, e.g., climate change and globalizing natural resource markets. As a result, the need is obvious for timely, accurate, relevant and applicable biophysical landscape data input into adaptive landscape planning modules and decision-making processes (cf. Bunce et al. 2008; Nassauer and Opdam 2008), that covers different land cover types and that can be combined with socio-economic data. There is also a need for monitoring infrastructures that allow for inclusion of new or supplementary variables into the program, to deliver on-demand data and analyses concerning current problems and challenges in sustainable landscape management. Moreover, as policy, legislation and other fundamental strategic groundwork more and more evidently becomes a pan-national issue, there is a need to develop landscape-based monitoring systems that are pan-national by nature, but that also have an inherent capacity to adapt to national and local premises and needs concerning sustainable use and management of forests and landscapes.

The Swedish NILS program – National Inventory of Landscapes in Sweden – is a unique creation in Europe and internationally (Ståhl et al. *in prep*). It is developed to monitor and analyze conditions and trends in landscape biodiversity and land use on all terrestrial habitats across the Swedish land base. Despite its short history of existence, NILS has developed a monitoring infrastructure that is applicable for many different purposes (http://nils.slu.se).

In its original set up, NILS data and analyses are applicable on national or regional geographic levels. County-level approaches are currently being developed to assist in county-level environmental reporting. In addition, new innovative local (municipality-level) approaches are being explored under the objective to provide monitoring data and analyses into landscape planning modules. Such an approach requires methodological processing and development as well as conceptual and operational input about the specific needs and premises among land use actors and decision makers.

Continuous supply of information is imperative for the decision-making at all levels, from global policy conventions to land-use management decisions on specific estates and sites (Lovett et al. 2007). As a consequence, in many countries much work is currently being devoted to developing environmental monitoring programs. A general understanding is that there needs to be an ultimate connection between basic data and decision-making (Löfvenhaft 2002; Ahlqvist 2008). This requires understanding of ecosystem processes and their relation to policy and decision-making, as well as what features are possible to monitor with adequate accuracy given the available techniques (Noss et al. 1992; Lovett et al. 2007).

Several biodiversity-oriented environmental monitoring programs are ongoing in different countries at present, although most of them have been established fairly recently. At present, however, there is a lack of consistence between different programs that impede sharing of knowledge, experiences and information. Approaches towards standardized framework of surveillance and monitoring on European level are being developed (Bunce et al. 2008), however.

As reflected by the Convention of Biological Diversity (CBD), several EU agreements and well as national frameworks (UNEP 1993; United Nations 1992; Council of Europe 2000; Ministry of Environment Sweden 2004; European Commission 2008), maintained biological diversity is widely acknowledged as a central objective. Since the Rio Summit (Council of Europe 2000), massive work has been conducted to define the concept, to develop appropriate indicators, and to develop suitable monitoring techniques (e.g., Geoghegan et al. 1997; Yli-Viikari et al. 2002). Recognition of national-level Environmental Quality Objectives is one obvious example of work in that direction. The Swedish Government has adopted 16 broad objectives as a framework for efforts to achieve sustainable development on national level (Ministry of the Environment Sweden 2001). NILS currently provides data and information for the evaluation of existing interim targets as well as for the formulation of new targets within ten out of the 16 objectives, including those for wetlands and mountains, where NILS currently is the main national monitoring program in Sweden:

- Thriving wetlands
- Sustainable forests
- A varied agricultural landscape
- A magnificent mountain landscape
- A good built environment
- Reduced climate impact
- Zero eutrophication
- Flourishing lakes and streams
- A balanced marine environment, flourishing coastal areas and archipelagos
- A rich diversity of plant and animal life

The broad application of NILS data and analyses is a necessity to secure relevance and impact with respect to societal sustainability and reporting schemes on regional, national and pan-national levels. As well, close cooperation with stakeholders (academia, decision makers, public authorities, land managers) are of fundamental importance. In summary the following key NILS applications can be defined:

- Documentation, assessment and refinement of the environmental quality objectives
- Background data for national policy
- International reporting, including Nature 2000

- Input into strategic planning and large-scale landscape planning
- Cooperation with other national and international monitoring
- Platform for applied research on data, technology and methodology

Furthermore, changing conditions and premises in land use and land management, e.g. owing to climate change and globalizing markets, call for an intrinsic capacity to adjust the monitoring protocol to current issues, and, hence, to add variables to the protocol on top of the core variables that form the basis in the long-term monitoring program. New variables can be documented over short- or long-term depending on the specific issue to address.

Materials and methods

The specific design, statistical and methodological approaches within the NILS program are being presented elsewhere (Ståhl et al. *in prep*; http://nils.slu.se). In the context of this contribution, however, the following fundamentals of the NILS program has to be outlined:

1. The basic design is a random systematic grid of 631 permanent 5 km x 5 km squares (Fig. 1). All terrestrial habitats are represented; forests, agriculture land, wetlands and peatlands, alpine environments, shorelines and urban areas. The squares are documented with five year intervals to provide data and analyses on conditions and changes.
2. Biodiversity is addressed mainly on landscape and community/ecosystem levels, and only to some extent on population/species levels (*cf.* Noss 1990)
3. NILS became operational in 2003. In 2007 the first inventory rotation was completed and a first full national-scale monitoring data set became available. During 2003 to 2007 there has been a continuous process of adjustments in sample parameters and methods to fit practical and analytic premises. Attention is now being directed towards evaluating which features of the program that have been successful and which have not. As for the 2008 first year re-inventory, the core of the monitoring system has been set, but additional small refinements are expected to continue for some years until a final system of variables and methods have been defined and the monitoring system perpetually can provide statistically reliable data on landscape biodiversity on a national scale.
4. Two parallel and integrated inventories are conducted; field inventory in plots and along inventory lines, and interpretation of color infrared (CIR) aerial photos. This allows combination of different types of data to specifically address current problems and challenges in landscape analyses.
5. So far there has been a focus on the central 1 km x 1 km square within the 5 km x 5 km square. There, field inventory is conducted on a set of 12 inventory plots and 12 inventory lines (line crossing inventory) to capture areal features (*e.g.*, cover of trees or bottom layer mosses), linear features (*e.g.*, forest edges, streams, roads) and point features (*e.g.*, presence of species). Field inventory is also going on in the 5 km x 5 km square to some extent, e.g., on pastures and meadows to document, specifically, vegetation characteristics.
6. The inventory plots are composed of a sequence of circular plots with different radius; 20 m, 10 m, 3.5 m and 0.28 m, where different sets of variables are documented (Table 2).
7. The aerial photo interpretation generates polygon (area down to 0.1 ha), linear and point information (Skånes 1996; Allard 2003; Ihse 2007). As for the field inventory there is a focus on the central 1 km x 1 km square to develop approaches and applications.
8. Taken together the field inventory and aerial photo interpretation allows for analyses of various geographic scales, from large-scale landscape analyses (25 km^2) on the spatial composition of habitats, land use and other important landscape information, to occurrence of specific species on point scale (0.25 m^2).
9. Variables are documented without pre-classification (*a posteriori*). This allows for problem-oriented analyses of data, since variables can be combined to specifically address those questions that are in focus. Monitoring a general gross list of a large number of straightforward, grouped and quantitative variables allows the opportunity to adjust classification to the state and trends for selected variables and a variety of habitat quality measures (cf. Ahlqvist 2008; Metzger 2008). The *a posteriori* approach also allows analyses across land cover types, if, *e.g.*, land use scenarios are being created based on forest and agriculture habitats in combination.

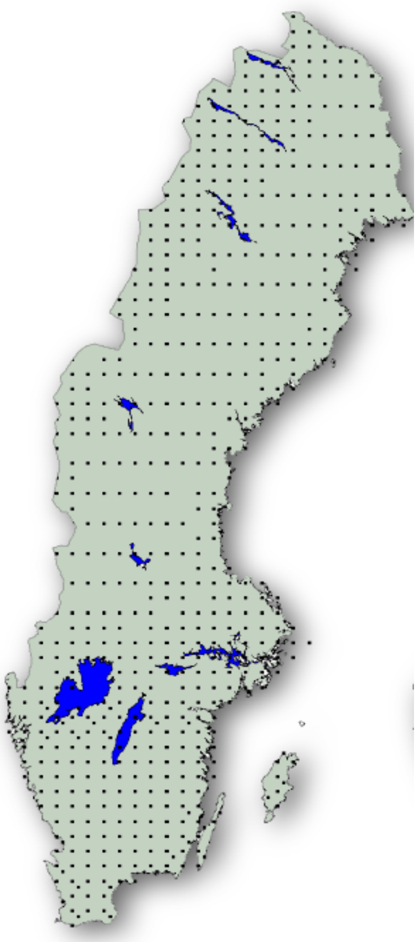

Figure 1.

Table 1			
20 m radius, 1257 m²	**10 m radius, 314 m²**	**3.5 m radius, 38.5 m²**	**0.28 m radius, 0.25 m²**
Cover of main habitat type Cover of trees Land use Disturbance on site Alpine habitat type	Shrubs Field layer Bottom layer Ground description Detailed tree measures Lichens	Detailed tree data Droppings from animals	Field layer Bottom layer Presence of herbs Presence of mosses Presence of lichens

As mentioned above, the NILS program became operational in 2003 and finalized the first inventory rotation in 2007. Moreover, a second inventory of semi-natural grasslands, pastures and meadows was initiated in 2006 and will complete the first inventory rotation in 2010. Hence, precision and accuracy of data and analyses still is limited. Hence, the results presented here are examples of outputs available so far.

Results and discussion

Field data have been collected for the first five year inventory rotation (2003-2007) and for 2008, and from aerial photo interpretation for 2003 to 2005 (ongoing). The data are being checked for errors and thereafter stored in a relational database system. Data management and data analysis systems are in progress and will gradually expand following the addition data from re-inventory that allows temporal assessments. Below we present some examples of results; field inventory linear landscape data on stonewalls and tree vegetation overgrowth, areal and point features on semi-natural grasslands, pastures and meadows from field sample plots, and some data on high altitude forest and alpine habitat types in the Scandinavian mountain range.

Data from the line intersect sampling have several possible applications. The line intersect data can be combined with data from the aerial photo interpretation to estimate length of objects by type of land cover. Another application is to assess changes in the quality of objects. For example, changes in vegetation cover and management on vegetation strips and stonewalls provide important information for managing biodiversity associated with these objects. Our initial results clearly show that linear landscape objects and shredded habitats are significant features of the Swedish landscape and contribute to landscape diversity.

The total length of stonewalls in Sweden was estimated to 145 million m, which equals 3.6 times around the equator, whereof about 60% still are in use as boarders between estates and fences for domestic animals. Stonewalls are mainly found along the borders of agricultural fields or in abandoned, now mostly afforested farmland in south Sweden. A clear geographical trend in the density of objects could be detected. Man-made linear objects were generally more abundant in South Sweden, not only stonewalls but also, e.g., roads, ditches, human and cattle paths, while natural objects, *e.g.*, paths made by wildlife and natural watercourses, showed the reverse pattern and were more abundant in the north. Stonewalls are now seen as landscape elements of high conservation value in cultural landscapes (Ministry of the Environment Sweden 2001). Therefore, data on the current status and need for management is essential information. Figure 2 shows the density of stonewalls in different regions in Sweden and the tree vegetation overgrowth on stonewalls as an estimate of ongoing landscape dynamics as a consequence of less intensive agricultural management. As well, data about the extent of trees and shrubs overgrowing stonewalls give information about the need for harvesting to expose the stonewalls and secure the quality of this specific type of sun-exposed cultural remains and management-dependent habitats.

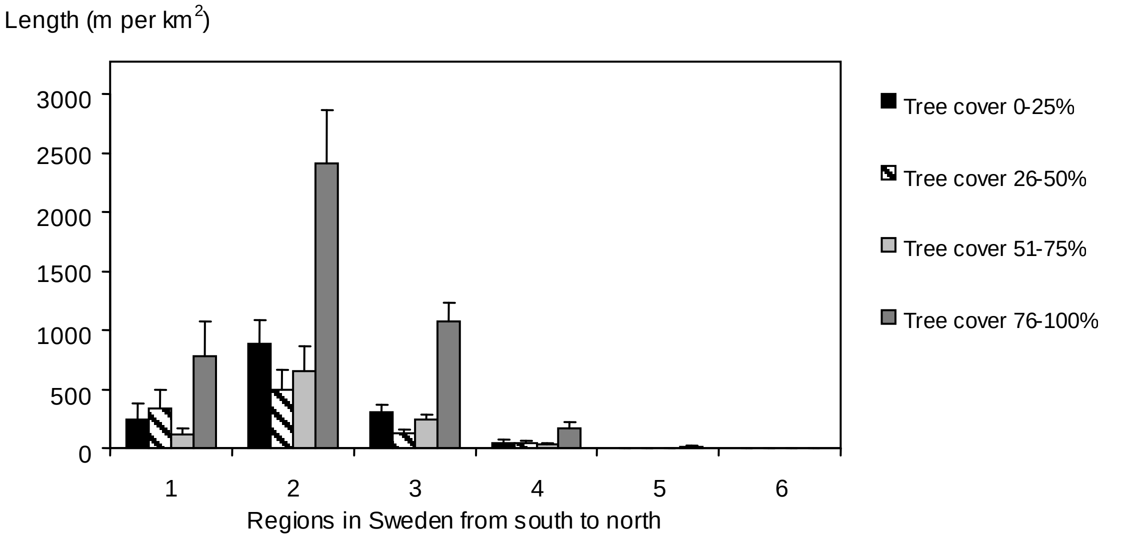

Figure 2

In semi-natural grasslands, pastures and meadows that traditionally are used for grazing by domestic animals and hay making, the vegetation composition and biodiversity is strongly an effect of the land use. Abandoned land soon become less diverse and afforested by trees through natural regeneration. Figure 3 shows that about 40% of the land are under agricultural management with a vegetation height less than 5 cm. In northern Sweden, however, regions 4 and 5 in particular, there is a tendency of less intense grazing resulting in taller vegetation.

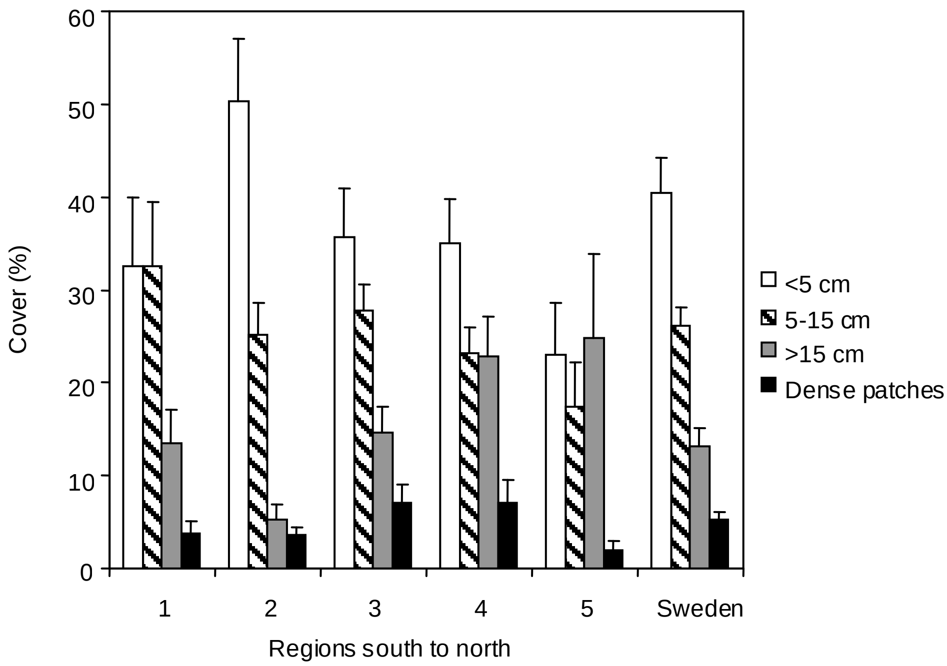

Figure 3

The total number of plant species is a common measure of high natural values. Figure 4 shows the number of management-dependent plant species per plot in semi-natural grasslands, pastures and meadows. Such species are commonly used as indicators of biodiversity in this type of habitats. The trend is that the number of species peaks in the transitional broad leaf dominated landscape between the open, agriculture-dominated landscapes in southernmost Sweden and the south Swedish coniferous landscape to the north (region 2).

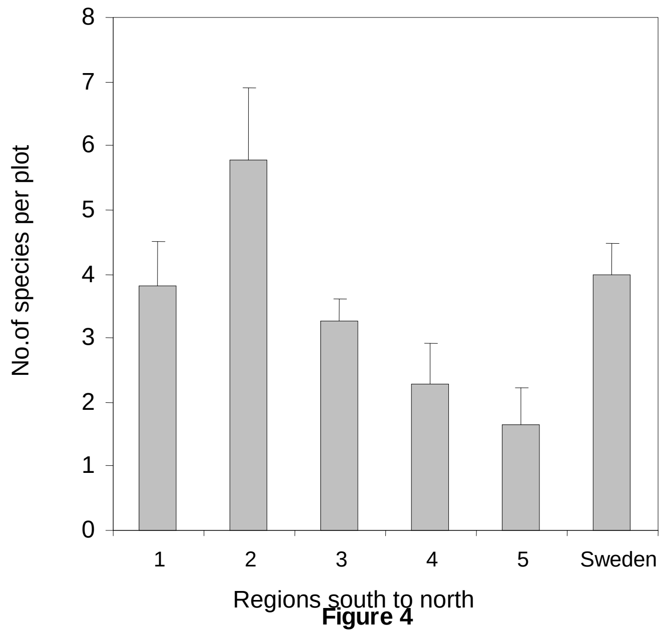

Figure 4

NILS covers all terrestrial habitats in Sweden, including the alpine region of the Scandinavian mountain range. Alpine regions are in particular interesting and relevant for long term monitoring since changes normally are slow. Under climate change, however, certain central bio indicators may be identified, such as the altitude position of tree lines (Kullman and Öberg 2009) and other features like semi-permanent snowbeds, glaciers and palsas (permanently frozen peat mounds). Therefore, a monitoring infrastructure in alpine regions is highly valuable for various purposes.

Out of 631 permanent NILS 5 km x 5 km squares, 144 are located in the alpine region of the Scandinavian mountain range. The position of these squares is illustrated in figure 5a, with the altitude representation of the 2128 circular sample plots (20 m radius) shown in figure 5b. The complete mountain range from south to north is represented, with most of the sample plots between 400 and 900 m above sea level. Thereby, the uppermost zones of coniferous forests, the birch (Betula pubescens ssp. czerepanovii) dominated tree line, and the intermediate barren alpine habitats are well represented in the sample. High altitude habitats are not well represented, however, and currently there are projects going on to supplement the original NILS square infrastructure with other monitoring approaches. The highest mountain on the Swedish side, Mount Kebnekaise, is 2117 m.

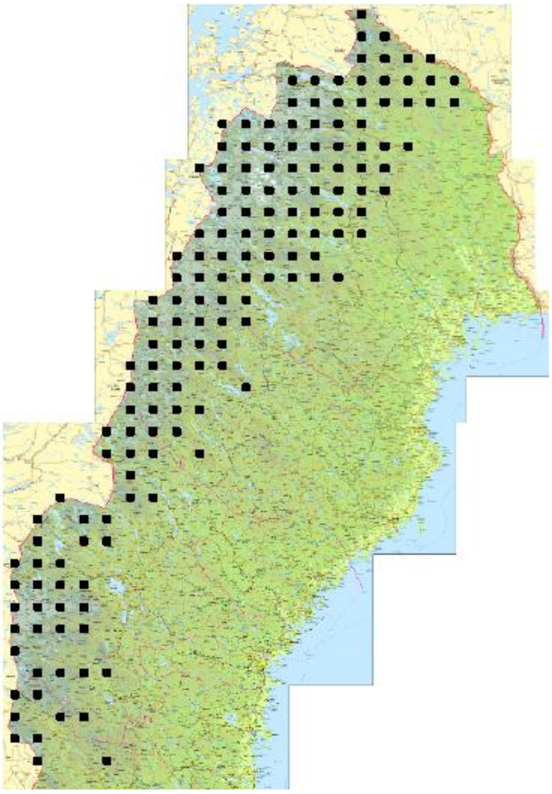

Figure 5a

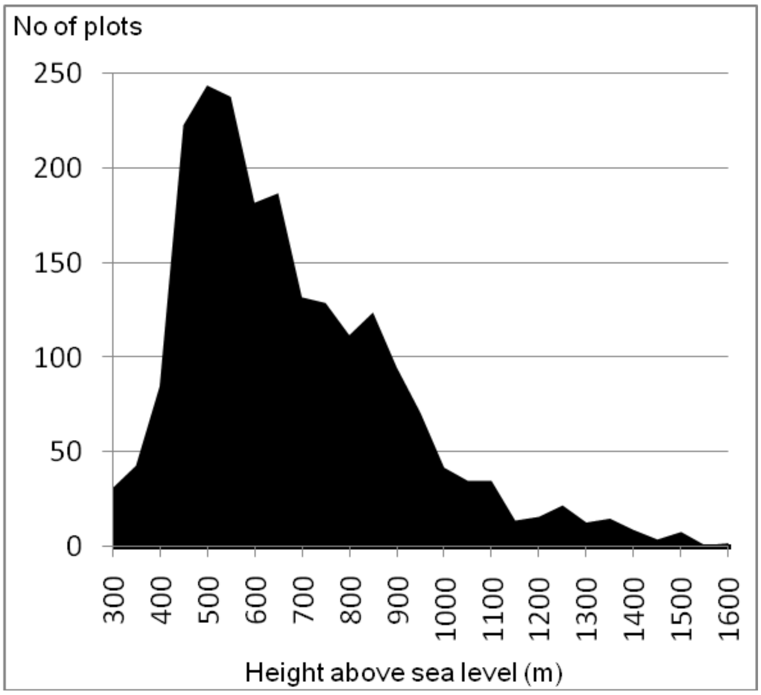

Figure 5b

Table 2 shows the total areas of different alpine habitats within the 2128 circular sample plots. Taken together the 144 NILS squares provides a substantial source of data and information on status and changes in alpine environments of the Scandinavian mountain range.

Table 2

Alpine habitat type	**Available area (ha)**
High alpine rocky and barren ground	19 540
Snow bed vegetation	4 900
Intermediate alpine grassland heath	16 980
Intermediate alpine mires and peatlands	14 900
Low alpine shrub heath	58 750
Low alpine herb-rich grasslands	9 350
Low alpine birch and *Salix* woodland	36 310
Low alpine coniferous woodland and forest	26 500

Conclusions

NILS provides a national level set of data for land cover and biodiversity analysis on different geographic scales. It is also evident that the NILS monitoring infrastructure is attractive to other initiatives and provides a platform for various approaches on top of the original set up. Some 15 (large and small, short- and long-term) side projects has been developed on top of the base commission from the Environmental Protection Agency, and about as many side projects (large and small, short- and long-term) has been organized by other organizations. Cooperation with several national and regional public authorities is established, and research projects are conducted based on NILS data, technology and methodology. Ongoing side projects include, e.g., monitoring of cultural remains, semi-natural grasslands, pastures and meadows, habitats under the European Habitats Directive, the Swedish bird survey, wildlife population survey and damage by browsing, and vegetation changes in the alpine environments due to climate changes. NILS is also connected to ongoing European programs, such EBONE (Anon. 2008). Further international approaches are under development.

The inherent flexibility in the NILS sample and methodological setup is an obvious strength both in term of its applicability and usefulness for other environmental monitoring and research initiatives and in terms of its capacity to add and make use of supplementary information, which is certainly of critical value (cf. Bunce et al. 2008). Hence, externally generated information can be used to deepen and broadening the NILS scope, just as NILS can provide background data for other purposes.

The need to apply a landscape perspective in biodiversity, ecosystem resilience, sustainability in using and managing natural resources, and other central environmental issues, is undisputed (e.g., Ahlqvist 2008; Wiens 2008). Adjustments to international frameworks and compliance of national environmental objects rely on input of reliable data. Despite fundamental advances in landscape ecology, the routes to policy and decision making is still undeveloped (Bunce et al. 2008; Nassauer and Opdam 2008). In particular under a climate change scenario, empirically derived cause and effect analysis is central to evaluate ecosystem response and processes (e.g., Metzger 2008; Shao and Wu 2008). Landscape-based monitoring can provide essential data into research and information to decision makers and other stakeholder on current issues on land use and landscape management.

As the first NILS inventory rotation was completed in 2007, a national set of data for all terrestrial habitats in Sweden became available. Ongoing NILS monitoring will provide essential information about change and trends. The connection to research is critical to validate the approach and the data, and to investigate further the applicability of the monitoring program (*cf.* Lovett et al. 2007). In a pan-national perspective it is evident that there is a need to harmonize existing environmental monitoring programs and create common schemes to capture similar data using comparable methodology.

Acknowledgements

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