

DEVELOPMENTS IN STRATEGIC
LANDSCAPE MONITORING
FOR THE NORDIC COUNTRIES

Developments in strategic landscape monitoring for the Nordic countries

Geoff Groom (editor)

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Foreword

The NordLaM project workshops, other project activities and this publication have been made possible through grants from the Environmental Data and Monitoring (NMD) working group of the Nordic Council of Ministers, with additional support from the National Environmental Research Institute (Denmark). The support of both the NMD and NERI is gratefully appreciated.

The help and support (not to mention patience) by the individual authors has also made this publication possible, as have the contributions of the many, many participants in project workshop over the past three years and other contributors to the work.

Geoff Groom
30th October 2003.

Summary

Landscape plays an increasingly relevant and prominent role in the protection and management of the Earth's terrestrial environments and ecosystems, including the diverse forested, agricultural, wilderness and build-up landscapes within the Nordic countries. However to be meaningful in the Information Age such landscape level work requires vast data resources, principally spatial and geographic, such as to undertake inventory and monitoring of the landscapes. Image data acquired by remote sensing have a major role to play in the information resourcing for landscape work, as is already manifest in many strategic Nordic mapping and monitoring programmes. Earlier work for the NMR has described several of the major Nordic programmes and identified areas of focus for increased collaboration and coordination in the use of image data. Activities during the past two years have developed these opportunities through a series of workshops and methodological activities. This second publication in a series of three to come out of this work presents further examples of Nordic landscape level monitoring, reports of four recent Nordic workshops, and two pieces of methodological work on the theme of the use of image data in Nordic landscape monitoring.

Sammandrag

Landskapsperspektivet spelar en alltmer framträdande och betydelsefull roll vid skyddandet och skötseln av Jordens terrestra miljöer och ekosystem, vilka inom Norden inkluderar en mångfald skogs-, jordbruks-, natur- och stadslandskap. För att i dagens informationsålder nå meningsfulla resultat vid inventeringar och övervakning på landskapsnivå krävs stora datamängder, främst rumsliga och geografiska. Fjärranalysdata spelar en framträdande roll inom landskapsforskningen vilket visar sig genom att många strategiska kartläggnings- och övervakningsprogram har etablerats inom Norden. Tidigare arbeten i NMR:s regi har beskrivit flera av de stora nordiska programmen, samt identifierat områden att fokusera på för utökat samarbete och samordning vid användning av fjärranalysdata. Under de senaste två åren har dessa möjligheter utvecklats genom en serie workshops och metodstudier. Denna publikation (den andra av tre), som är ett resultat av detta samarbete, ger ytterligare exempel på övervakning på landskapsnivå inom Norden samt presenterar rapporter från fyra nordiska workshops. Vidare presenteras två exempel på metodutveckling där fjärranalys används för övervakning av landskap inom Norden.

1. Introduction

Geoff Groom

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1.1 Scope and background

Across the World there are ever-increasingly efforts to advance the information resources available for protection and management of the Earth's environments and ecosystems. This is driven in part by the realisation of the fragility of many ecosystems and the importance of ensuring their sustainability for life on Earth. It is also driven by the IT revolution that is now underway across almost all organisations and branches of human activity, with increasing reliance on electronic media for storage and use of records, data and information.

Understanding our environments and ecosystems in terms of their landscapes (*i.e.* the synthesis of biophysical, socio-economic, cultural and aesthetic aspects) is increasingly recognised as a strong basis for sound science and natural resource management. Within the context of current advances in use of IT, the landscape focus requires masses of information, much of it spatial and geographic. Remote sensing (*i.e.* image data from Space or aircraft) provides the spatial/geographic component in much landscape work; indeed landscape mapping and monitoring without information from remote sensing can be considered as hardly possible.

Across the Nordic countries many diverse mapping and monitoring programmes and projects use remote sensing to provide landscape level information; in many cases these are strategic activities, undertaken on national and regional scales to provide input to many national and international reporting.

This basis for the strengthening and coordination of Nordic uses of remote sensing data for landscape level monitoring was noted in an earlier NMR publication (Groom & Reed 2001) that also laid-out the course for a set of related activities under the umbrella of the NMD NordLaM project.

The NordLaM project

NordLaM is a project of the Environment & Monitoring Data (NMD) working group of The Nordic Council of Ministers (NMR), to develop the use of information derived from image data in Nordic landscape level terrestrial monitoring (<http://nordlam.dmu.dk>). The project is motivated by the recognition that there are environmental and ecological issues that demand synthesis on a broad level, incorporating abiotic, biotic and human aspects, *i.e.* "a landscape perspective". To understand these issues and guide future developments there is a requirement for landscape level monitoring. A landscape perspective also recognises that for sustainable development of the countryside issues of ecological, economic, social and cultural relevance need to be integrated in decision-making, and that the landscape can form a relevant framework for this integration and for the monitoring of the development process.

Use of the term "landscape level monitoring" (LLM) in the NordLaM project serves as an umbrella, covering a broad sweep of monitoring and related mapping activities. Until quite recently there have been only a few strategic programmes in the Nordic countries, or indeed elsewhere, that specifically aim to monitor landscapes. However, there are numerous related projects and programmes that are monitoring at the landscape level, in the sense of undertaking mapping and related data collection that is highly relevant for the understanding of environment and ecology as landscape.

NordLaM is focussed upon co-ordination and development in the use of information derived from image data (remote sensing, including images from satellites and from aircraft) within LLM. Increasingly the use of information from image data within environmental and ecological work is not just a matter of improved, more sophisticated image data, and/or techniques for image data processing and analysis. It is also a matter of understanding the characteristics of the information derived by remote sensing, including relationships with information from other sources, and relationships with information-demanding situations. These types of remote sensing issues are particularly important within the field of landscape level monitoring.

The NordLaM project started with a meeting of over 60 persons in 1999, at which many of the major Nordic and other European activities related to LLM and using remote sensing were presented. The project's earlier NMD publication (Groom & Reed 2001) provided many of those presentations for a wider audience, as well, as noted above, setting-out the basis for onward activities.

This present publication represents a mid-point in the project's progression, between the earlier publication and a forthcoming final publication from the project that will present the status of remote sensing within Nordic LLM in the context of the issues investigated and developed by the project since the 1999 meeting.

1.2 Overview of the following chapters

The following 10 chapters comprise a mix of NordLaM workshop reports, reports of related meetings, papers describing Nordic LLM activities, and reports of methodological work undertaken within NordLaM.

Chapters 2 and 3 present, as with the earlier publication, examples of LLM work being undertaken in Nordic countries (Sweden and Finland), showing the types of questions that are frequently asked from LLM and the methods used in providing landscape monitoring information.

Chapters 4, 7, 8 and 9 each report on NordLaM workshops held in 2000 and 2001 that each explored four topics that have been focussed upon by the project, namely:

- the role and use of classification operations (class sets) in LLM (Chapter 4)
- the integration of partial and complete coverage monitoring data (Chapter 7)
- the advances and uses of very high spatial resolution image data in Nordic LLM (Chapter 8)
- the interface between image data, LLM and landscape indicators (Chapter 9, Chapter 10)

In the case of Chapters 4, 5, 6, 7, 8 and 9 annexes include presentations of additional material, such as lists of workshop participants, related papers or reporting of relevant subsequent developments.

An FAO/UNEP organised expert meeting, at which the Nordic region was represented through the project is reported in Chapter 5. As with Chapter 4, this chapter concerns the issue of classification systems used within LLM, focussing upon the needs of a classification system for the global mapping of land cover.

The issue of class sets and classification for LLM has been a major topic within the project and was the subject of a specific piece of methodological work during 2002 that is reported in Chapter 6.

The final two chapters (Chapters 9 and 10) describe respectively a workshop and a further piece of methodological work undertaken within the remit of the project, concerning the definition and use of indicators for landscape work.

Reference

Groom, G. & Reed, T. (eds.) 2001. *Strategic landscape monitoring for the Nordic countries*. (TemaNord 2001:523). Copenhagen: Nordic Council of Ministers.

2. Strategic selected landscape regions and landscape elements – A Swedish approach for base line mapping and monitoring in agricultural landscapes

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Summary

There is a pronounced need in Sweden for information regarding landscape and biotopes on a regional level. The aim with this study was to develop a method for landscape mapping and monitoring in the agricultural landscape, as a base for regional planning and nature conservation, with the focus on biodiversity. The two test areas were Malmöhus County and Uppsala County. The accuracy of the classification system was tested in Malmöhus County and the method for landscape classification, subdivision into regions and selection of monitoring plots was tested in Uppsala County. Uppsala County was subdivided into nine landscapes regions according to a stratified approach by using parameters for physical geographical factors, vegetation, actual land-use, historical land-use and regional characteristics. Inside each region 150 monitoring plots, of 1 km² square were randomly sampled, with the number of plots selected related to the size of the region, with five as a minimum. The mapping was made according to a specifically developed classification system of strategically selected landscape elements by the PLP (patches, lines, points) method. Grasslands, wetlands and deciduous trees are selected as the most important vegetation types and mapped in strategic selected landscape elements. The data collection was done by interpretation of colour infrared (CIR) aerial photographs. The base-line mapping includes all the 150 monitoring plots. In the monitoring phase, only the changed patches or landscape elements are re-mapped, not the whole area. In this paper the main focus is on the classification and division of the landscape into regions, the classification system and the base-line mapping for vegetation and biotopes.

Key words: agricultural landscape; monitoring; biotope; biodiversity; landscape ecology; landscape classification; aerial photo interpretation; colour infrared aerial film

2.1 Introduction

This paper presents an approach to monitor agricultural landscapes at a sub-national level. The study was undertaken in two counties in Sweden, Malmöhus county in the southernmost part of Sweden, and Uppsala county, in the middle of Sweden, just north of Stockholm (Figure 2.1). They represent thus two different regions of the main agricultural areas in Sweden.

There is a need to monitor the whole landscape and its content of biodiversity. This is expressed in politically binding international documents, such as the globally accepted Convention of Biological Diversity, the European "Natura 2000" network and the European Habitat directive. National level monitoring of landscape is a new task in the environmental monitoring programme in Sweden. The LiM project (Ihse 1995a, Ihse & Blom 2000) was the first attempt with a successful outcome in Sweden to monitor landscape on a national level. The aim of LiM was to describe the effects on the environment of the new agricultural policy. One part of LiM was for development of a monitoring method for the ordinary agricultural landscape, *i.e.* the rural countryside, which could follow changes of potential importance for biodiversity and the environment.

Monitoring has up to now mainly been a responsibility for the regions, with focus on different regional problems. The regions are mostly the counties, "Län" in Swedish, comparable to "Amt" in Denmark and "Fylke" in Norway. The project presented here was undertaken as part of these regional programmes.

Besides a more general significance of high biodiversity, it is important to recognise other aspects of high biodiversity that are not often discussed, and which are the function of the ecosystem. High biodiversity in an ecosystem gives it a high resilience. High biodiversity in a biotope or an ecosystem creates a buffer against unknown or unexpected changes. High biodiversity is insurance in the long-term



Figure 2.1. Location of test areas in Sweden.

perspective to maintain the functions of the ecosystem and diminish the threats from changes in the surroundings and change in the climate. From this it follows that the countryside surrounding nature reserves must also be taken into consideration when we are discussing ecosystem biodiversity and long-term preservation, to protect the high value inside the nature reserves (Bengtsson *et al.* 2003).

In the agricultural landscape in Sweden it is found that with regard to biodiversity certain biotopes are more important than others. The important biotopes are grassland, meadows and pastures, wetlands and deciduous woods (Ihse 1995b). This is valid also for the agricultural landscape of most of Europe. These biotopes may or may not be the best choice for many species in many organism groups, but these are the biotopes which have most semi-natural vegetation left or which have a low intensity in management practice in the agricultural landscape. The small biotopes of grassland vegetation are in many agricultural areas the only remaining natural or semi-natural vegetation. They are however also subjected to changes and they have been found to have also a high change rate. Many of these small biotopes have disappeared during the last decades. Compared to other land use types, grasslands

and wetlands with or without deciduous trees have the potential for high species diversity. They contain red-listed species in a high degree, as found by the Swedish Institute for Threatened Species (Gärdenfors 2000). In a wide survey of all species in the agricultural landscape during the 1980s the Swedish Agricultural University found that certain biotope and certain landscape structures contained the bulk of species (Svensson & Ingelög 1990). A national inventory of unfertilised grasslands with long continuity, ancient meadows and pastures was performed during the 1990s and the results clearly stressed the importance of these habitats for biodiversity in the agricultural landscapes (Lindahl & Vik 1997, Ihse & Lindahl 2000). From a botanical view the high value of these grasslands has been pointed out by several botanists in Swedish and Norwegian landscapes (Sjörs 1954, Bengtsson-Lindsjö *et al.* 1991, Eriksson *et al.* 1995, Norderhaug *et al.* 2000, Franzén 2002).

This background led in this work to a focus upon ecosystem and biotope levels in developing a method for monitoring biodiversity at a sub-national scale. From this biotope level we can include species level. To find the ecological parameters needed to analyse biodiversity, intensive detailed monitoring is needed. This has to be done in representative sites, where strategically selected biotopes are monitored. The sites should be small enough to be able to map and monitor the landscape elements on a detailed scale and large enough to also describe the structure. The sites should be selected in such a way, that they are statistically sound and representative for a large area. The rural landscape, the countryside, should then be subdivided into regions, where the parameters for stratification is not only based on a geographical and biological approach, that also on an anthropogenic approach, which includes aspects of management and cultural heritage.

2.2 Aim and hypothesis

The aim with this work was to develop a method for landscape mapping and monitoring in the agricultural landscape as a base for regional planning and nature conservation, with a focus on biodiversity. The method should provide a high accuracy in interpretation, and be quick and cost effective. The objectives were:

- to develop a classification system for CIR aerial photo interpretation in scale 1:30 000,
- to identify and strategically select biotopes and landscape elements that are of importance for the biodiversity and cultural values in the landscape and which were subject to changes,
- to test the accuracy of aerial photo interpretation and to evaluate the time used,
- to develop a strategy for selection of sample areas and sample techniques.

The hypothesis was that landscape mapping and monitoring at national or sub-national level can be efficiently performed with high quality by CIR aerial photo interpretation in a restricted number of small monitoring plots using a stratified random sampling approach and a classification scheme that is focused on strategically selected biotopes and landscape elements.

2.3 Approach for landscape mapping and monitoring

The suggested methods for a landscape mapping and monitoring based on CIR aerial photographs include the following steps:

- strategic selection of biotopes and landscape elements
- landscape stratification and classification for sample design
- base line mapping
- change detection, monitoring
- analysis of changes in a GIS with respect to effects on biodiversity
- cartographic presentations and visualisation.

These approaches for landscape mapping in the agricultural landscape by interpretation in CIR aerial photographs of strategically selected biotopes and landscape elements were tested in two sub-national regions in Sweden, Malmöhus County and Uppsala County. Both are landscapes dominated by agriculture, with many features in common but also many distinguishing aspects.

2.3.1 Strategically selected biotopes and landscape elements

The method development began in Malmöhus County, where the classification system was mainly developed and tested, the selected biotopes were characterised, and the accuracy in CIR interpretation *vis-à-vis* field inventories was tested. The classification system was based on the ideas and system used in the LiM-project. The LiM-system was modified and partially developed into a hierarchical system. The most important semi-natural vegetation ecosystems in this agricultural landscape were those of grasslands, deciduous forest with trees and wood-lots, and to a lesser extent wetlands. The grassland biotopes were distinguished according to physiognomy, moisture, cover and succession of tree and bush species and type and continuity in management. In the forest ecosystems the tree species, deciduous or coniferous, the age, the soil moisture and succession were factors for distinguishing different biotopes. Biotopes belonging to these ecosystems were found along all the linear elements and in the point elements. The system was found to function very well. Cousins & Ihse (1998) found the accuracy in interpretation in colour infrared photos in Malmöhus County to be very good, 92 – 98%, for patches as well as for point and linear elements. The rate of mapping was 0.4 – 1.8 km²/hour.

2.3.2 Landscape stratification and vegetation classification in Malmöhus County

In Malmöhus County the selected monitoring plots were 5 x 5 km, *i.e.* 25 km². This size was selected to be able to find enough landscape elements and biotopes in this coarse grained landscape with large fields and to be able to also map the fine grained landscape structure. The size of the monitoring plots was that of the land-use map (the so-called 'economic map', at scale 1:10,000) sheets that are often used as planning bases in Sweden. From the County administration a rough knowledge-based division of the county into four regions was provided. In each region only one monitoring plot could be selected, on account of the time limit for the project. The monitoring plots were located into the landscape regions according to prior knowledge of specially interesting, characteristic or changing regions, or areas with prior data from inventories.

The time for interpreting a single 25 km² monitoring plot was considered to be too long for an operational monitoring system. Different methods for data collection were tested and compared, including total inventory or sample by different types of transects or smaller monitoring areas, selected in different ways in the landscape. A quick survey of existing landscape elements could be done by interpreting perpendicular transects. On average, a transect survey of only 5% of the area gave information of the content of 88% of the landscape elements and biotopes. Transects are thus a very quick way to get information of the existence of different landscape elements. The disadvantage with using transects was that they did not give any information of the landscape structure. A more detailed description of this method is given in Cousins & Ihse (1996, 1998).

It was concluded that the strategies for selection of landscape regions and the selection of monitoring plots, both according to number, size and distribution needed to be developed in a more scientific way, that could be generally adapted. The method for stratification of the county into landscape regions, the

selection of monitoring plots and the classification system was therefore further developed for Uppsala County. The resulting classification scheme was modified and further developed to be more generally applicable for Swedish agricultural landscapes. Also the method for collection of the data in a database, by digitalisation for further analysis in a GIS system, was developed. The methods developed in Uppsala County are further described in Ihse & Runborg (1998, 2001).

2.3.3 Landscape classification in Uppsala County

The goal was to find homogenous landscape regions according to selected parameters and which were well distinguished from the surrounding regions. The typology should be applicable to similar types all over Sweden. These strategic approaches were developed in Uppsala, but are intended to be tested in other areas, and to be generally applicable all over Sweden.

The landscape classification includes the following steps 1); selection of parameters, 2) development of a typology, 3) inventories and selection of existing national / regional maps and 4) subdivision of the county into landscape regions.

Selection of parameters

- The parameters selected for landscape classification can be grouped according to:
- Physical geographical features (such as bedrock, soil, topography, hydrology, climate)
- Vegetation
- Land-use, present
- Historical land-use
- Boundaries, administration and ownership
- Specific regional characteristics.

Development of a typology

In the typology the selected parameters were ranked in the following order; 1) actual land-use, 2) physical features, 3) vegetation, 4) specific regional characteristics and 5) ownership type. The actual land-use is described as agriculture, forestry, or semi-urban / urban (including large infrastructure features such as high ways and railways). The physical feature is soil type, distinguished into fine sediment, till and moraine, bedrock outcrops, organic soils and peat, geomorphologic, glaciofluvial or glacial form elements, hydrology, topography (flat or undulating). The vegetation is described according to land cover as open ploughed field, meadows and pastures, deciduous woods, coniferous forests and mires. The specific regional characteristics are existence of manors and large estates, and existence of iron works. The ownership types are divided into private owned, company owned, giving either a small scale or a large scaled landscape.

Inventories and selection of existing national maps /regional maps

In the selection of landscape regions a systematic approach was applied, based on existing maps, showing the distribution of these parameters in a national scale. Most of the valuable thematic maps were found in The Swedish National Atlas (SNA), in scales from 1: 5 million to 1: 550,000. Larger or smaller scales were not appropriate, as they were either too generalised with too little information or too detailed and difficult to generalise. Nearly twenty different maps were reviewed. The selected ones, which mostly contributed to the boundaries, were 1) the map of the national cultural landscape, 2) land-use map, 3) maps of agricultural production, 4) maps of drainage basins, 5) maps of ownership types and 5) regional cultural heritage map. Some examples of these maps are shown (Figure 2.2 and Figure 2.3). However, no appropriate vegetation maps exist for Uppsala County.

Subdivision of the County into landscape regions

In Uppsala County as a whole nine landscape regions, comprising four main types, were suggested and described. Their spatial distribution is shown in Figure 2.4. The regions are divided according to their dominating vegetation/landuse (agricultural, forest or mire dominated), the size of the farms or the type of forest owners (big estates or small farms, industrial forest owners or farmers), the degree of landscape openness (open, semi-open or closed forest), or specific characteristic of the landscape (semi-urban, iron-work):

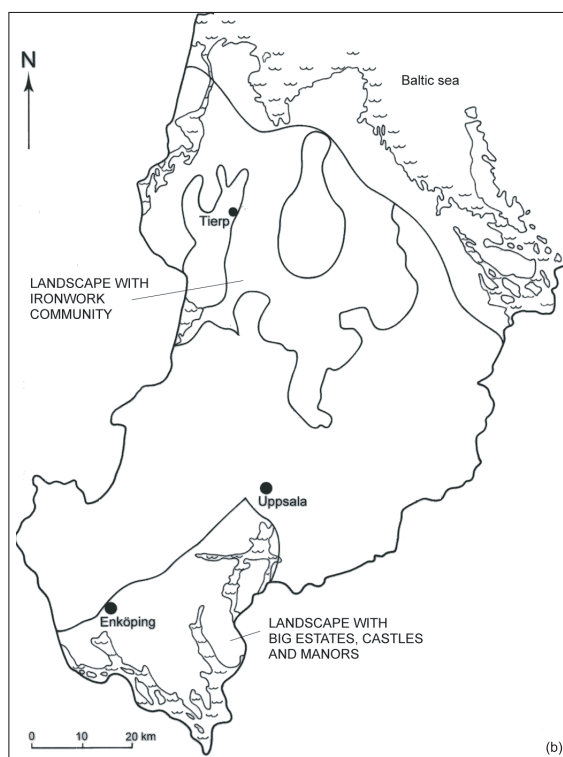
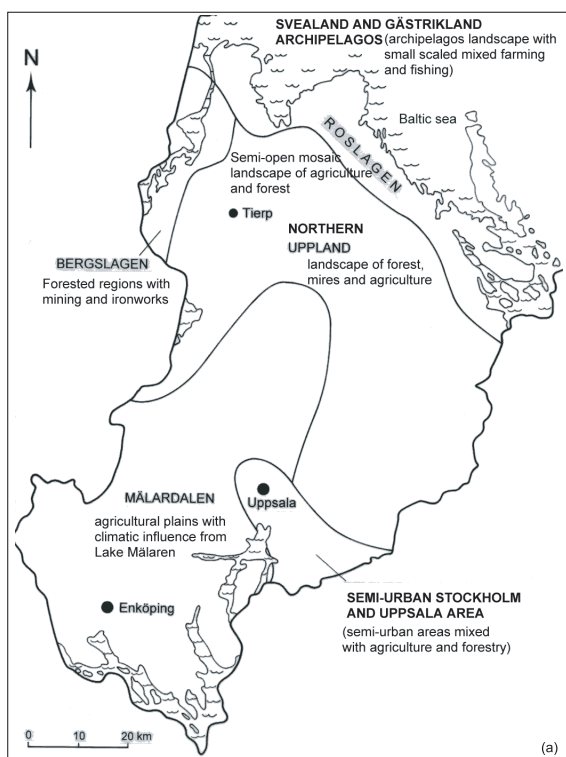


Figure 2.2. (a) Existing classifications of regions in the cultural landscape in Uppsala County, with short descriptions of characteristics. (modified from Swedish National Atlas, Band Cultural Landscape, 1994). (b) Areas with specific cultural characteristics (delineated from maps and text in Uppsala County's programme for cultural landscapes).

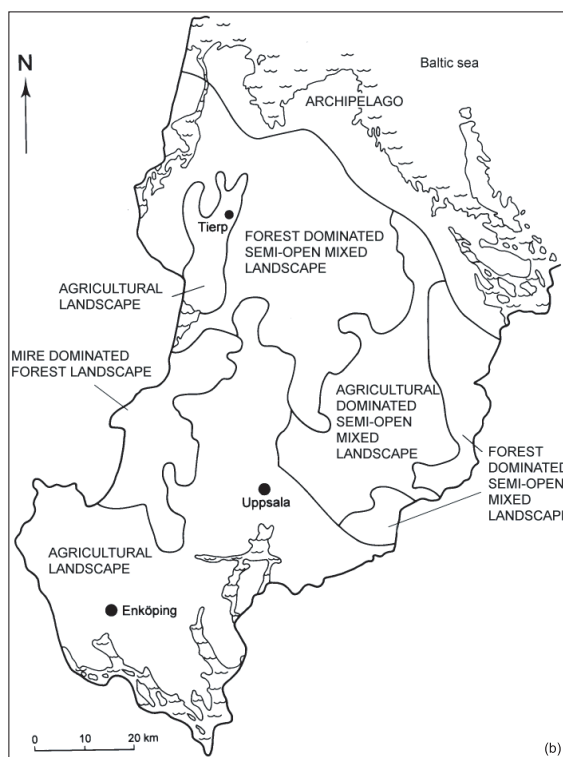
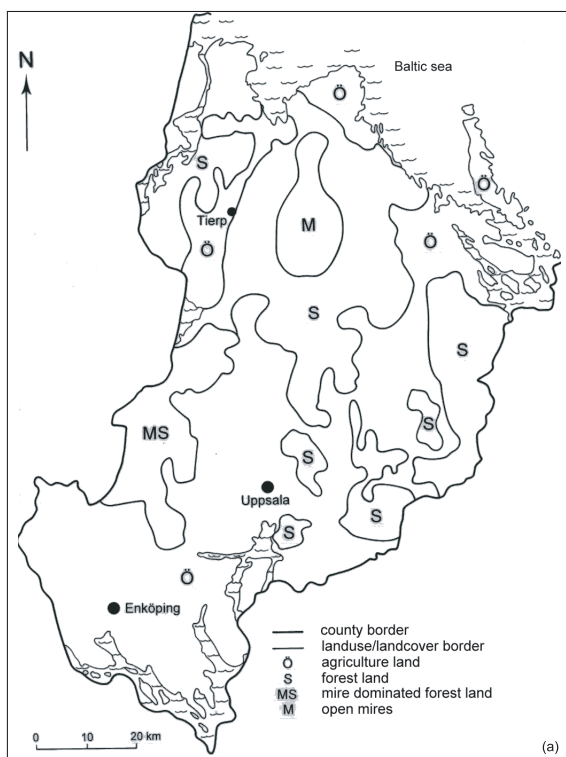


Figure 2.3. (a) Existing regions for landuse/landcover (modified from Swedish National Atlas, Band Forest, 1990). (b) Modified classification of regions according to production type, land use and cultural regions (merged and modified from the Swedish National Atlas, Band Forest, 1990, Band Cultural Landscape, 1994, Uppsala County's programme for cultural landscapes and landuse/landcover).

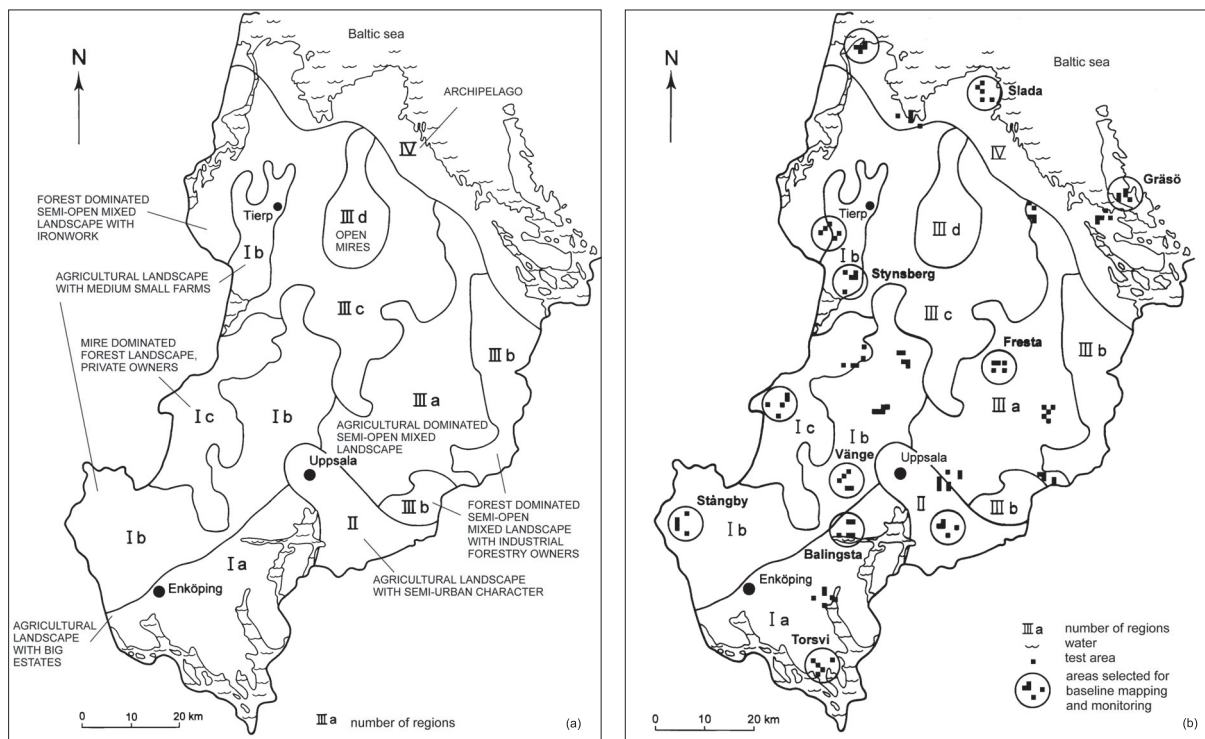


Figure 2.4. (a) Suggested landscape regions in Uppsala County for landscape and biotope mapping and monitoring (from Ihse & Runborg 1998). (b) Landscape regions in Uppsala County with strategic and random sampled test areas of 1 km². Areas selected for base-line mapping and monitoring are circled.

I Agricultural landscapes

- I a with big estates; private owners
- I b with medium and small farms; private owners
- I c with forest, mires and private owners

II Agricultural landscape, with semi-urban character

III Agricultural or forestry dominated, semi-open, mixed landscape

- III a agricultural dominated
- III b forest dominated, with large scaled forestry; industrial forest owners
- III c forest dominated, with small scaled forestry; private owners, and ironwork
- III d mire dominated landscape

IV Archipelago

To select the monitoring plots in these nine regions, thirty map sheets of the earlier mentioned land use maps of 5 x 5 km were randomly selected from the set of those covering the county. The number of maps in each region was selected according to the total area of the region. In each of these map sheets 1 km² monitoring plots were then randomly selected, totalling 150 plots. In each region at least 10 plots was selected. The size of the monitoring plots coincides with that used in the Countryside Survey in Great Britain, and which also have been discussed by the EcoLand forum (<http://www.tress.cc/ecoland/>) for monitoring all over Europe.

2.3.4 Base-line mapping

The base-line mapping started with development of the classification system, followed by data acquisition through air photo interpretation in stereopairs of CIR aerial photographs according to the PLP method and finally transformation of the data to a GIS database in ArcInfo. The PLP is a method to map landscape features separately in patches, lines and points.

Classification system

In order to effectively detect changes of importance for biodiversity the classification scheme must satis-

fy the following requirements:

- Comprise sufficient detail. The shorter the monitoring period is, the more detailed the system needs to be in order to detect fewer and smaller changes
- Include landscape structure elements of importance for plant and animal dispersal in a fragmented landscape.
- Include biotopes that are sensitive to changes, such as ancient unfertilised hay meadows that are sensitive to fertilisers, open formerly mowed hay meadows or grazed pastures that are sensitive to reforestation and encroachment of bushes, and wetlands that are sensitive to drainage.
- Include biotopes with high actual or future potential of high species biodiversity.

The development of the classification system aimed to integrate all these requirements. The classification system is detailed. The focus is on the important biotopes for biodiversity, such as grasslands (meadows and pastures) and deciduous forests. The structures are described by using the PLP method. This grouping is in accordance with the landscape ecological description of landscape structure and components where patches function as core areas, linear elements as corridors, or barriers and point objects as stepping stones or small key biotopes. The patches can also represent the matrix, around the important biotopes. In the patches a hierarchical classification was used, with land use, the cover of trees and bushes, species of trees and bushes, moisture, and management intensity, management continuity (historical land-use) and urbanisation type as the descriptors. This enables us to describe the biotopes and the elements that are most subject to changes in the agricultural landscape (Tables 2.1 and 2.2). The linear elements are roads or railways, earth- or stonewalls, tree rows, watercourses (such as meandering streams and straight ditches), forest borders and edge zones. The point objects are ponds, natural or artificial, islands of forest in the field, heap of stones, solitary trees and buildings.

Data acquisition and interpretation technique

The technique by the base line mapping is well developed and described from other types of mapping of vegetation from CIR infrared aerial photographs. It has been used for mountain vegetation (Ihse & Wastenson 1975, Sickel *et al.* 2003), for vegetation in south and middle Sweden (Ihse 1978, Ihse *et al.* 1993), for deciduous forests (Robertson *et al.* 1992, Skånes & Ihse 1988), for wetlands and mire vegetation (Rafstedt & Andersson 1982, Ihse *et al.* 1990), for coast and archipelagos vegetation, (Granath 1981, Ihse *et al.* 2000) and in urban and semi-urban areas (Arnberg & Ihse 1996, Löfvenhaft & Ihse 1998). The interpretation is done by direct drawing on separate transparencies laid upon the diapositive stereo pairs of CIR aerial photos, in the zoom stereoscope Aviopret. The interpretation is always be followed by field control. The stereo pairs of the CIR air photos together with the interpretations on transparencies and a field mirror stereoscope (Wild TSP1) are taken into the field. This field control can then be carried out in a short time and directed towards uncertain interpreted areas or certain areas of more importance than others. Several months of interpretation can thus be field checked during one week.

This data acquisition and interpretation is very quick and accurate. The mapping rate is high, varying from 0.4 – 1.8 km² /hour in agricultural landscape to 10 – 20 km²/hour in mountain vegetation; this corresponds to 3 – 14 km² per day in an agricultural landscape and 80 – 160 km² per day in mountain vegetation. This could be compared to field mapping with the same accuracy rates of 1 – 2 km² /day in the agricultural landscape. After field checking, the transparencies from the aerial photo interpretation are digitised and photogrammetrically transformed in an analytic stereo plotter (AP190). Finally the typology is built and defined to every polygon, and a GIS database is built in ArcInfo/ArcView. The comparison between the information in the land-use map, the CIR infrared aerial photographs and the interpreted biotopes shows very well the advantages of the described technique. In the monitoring plot called Farin village, the land-use map contains two classes, the base-line map 38 classes and the CIR aerial photo numerous colours and hues and structures.

2.3.5 Change detection, monitoring

In the monitoring phase, a method for change detection is still under development. The most common, when using satellite images is to classify two full satellite scenes and apply automated techniques for change detection. In aerial photo interpretation it is not cost effective to re-map the total area in the monitoring phase. The most promising method is instead to map only the changes, and not the full land-use and biotopes. The changes seem to be most quickly detected by interpretation in the Aviopret by way of ‘twinkling’. In this, the stereo pair comprises of one old aerial photo, the base line photo, with the

Table 2.1. Classification system developed for interpretation in CIR aerial photos in scale 1: 30,000 for objects of area cover (patches and matrix) in monitoring landscape and biotope diversity in Uppsalla County. The system contains several levels of different classifiers. (a) openland, grassland and arable fields, (b) forest, (c) built-up / paved land and other land. The Swedish names and terms are shown in italics.

(a) Open land, grassland and arable fields. *Öppen gräsbevuxen mark och åker.*

Level 1 Landuse <i>Markslag</i>	Level 2 Tree cover <i>Träddäckning</i>	Level 3 Tree sp. <i>Trädslag</i>	Level 4 Bush cover <i>Busktäckning</i>	Level 5 Bush sp. ¹ <i>Buskslag</i>	Level 6 Moisture ² <i>Fuktighet</i>	Level 7 Management <i>Hävd</i>
Grassland Pasture, regularly ploughed <i>Betesvall, fd åker</i>	Without trees 0%	Coniferous <i>Barrträd</i>	0%	Juniper bushes <i>Enbuskar och</i> <i>övriga barrbuskar</i>	Dry <i>Torr</i>	Without grazing/harvest <i>Hävd saknas</i>
Cultivated grassland <i>Kultiverad gräsmark</i>	1-10%	Common deciduous <i>Triviala lövträd</i>	1-10%	Thorny bushes <i>Taggbuskar</i>	Mesic <i>Frisk</i>	Weak <i>Svag – måttlig</i>
Ancient semi- natural grassland <i>Naturlig gräsmark</i>	10-25%	Hardwood deciduous <i>Ädellövträd</i>	10-25%	Willow <i>Vide</i>	Wet limnic <i>Fuktig- strandnära</i>	Good <i>Välhävdad</i>
	25-50%	Mixed <i>Blandskog</i>	25-50%	Brushwood <i>Övriga lövbuskar</i>		Tree plantation <i>Planterad</i>
	50-75%	Mixed deciduous <i>Blandlöv-skog</i>	50-70%			
			70-100%			
Arable field <i>Plöjd åker</i>	Crop type	Cultivation type <i>Gröda</i>				
	Annual <i>Ettårig gröda</i>	Crop rotation <i>Växelskifte/vall</i>				Newly planted trees <i>Ung plantering</i>
	Perennial <i>Flerårig gröda</i>	Energy forest <i>Energiskog</i>				Coniferous plantations >7years <i>Barrplantering</i>
	Fallow <i>Ej brukad</i>	Fruit trees/ Berry <i>Fruktträd, bärödling</i>				
	Tree plantation <i>Planterad</i>	Field for games <i>Viltåker</i>				Deciduous plantations >10 years <i>Lövplantering</i>

Common combinations occurring, with their own class are:

¹Juniper/thorny bushes, Juniper/brushwood, Thorny/brushwood bushes, Willow/brushwood
(*Enbuskar/lövbuskar, Taggbuskar/lövbuskar, Vide/övriga lövbuskar*)

²Dry/mesic, Mesic/dry, Mesic/moist, Moist/wet

(*Torr med inslag av frisk, Frisk med inslag av torr, Frisk med inslag av fuktig, Fuktig med inslag av våt*)

(b) Forest. Skog

Level 1 Vegetation type <i>Naturtyp</i>	Level 2 Moisture type <i>Fuktighetstyp</i>	Level 3 Management/Tree age <i>Hävd, ålder</i>	Level 4 Tree species <i>Trädslag</i>
Coniferous forest <i>Barrskog</i>	Extremely dry pine forest on bedrocks <i>Hällmarkstallskog</i>	Coniferous <i>Barträd</i>	Oak <i>Ek</i>
Mixed forest <i>Blandskog</i>	Dry/mesic coniferous <i>Torr/frisk barrskog</i>	Common deciduous <i>Triviala lövträd</i>	Birch <i>Björk</i>
Deciduous forest <i>Lövskog</i>	Wet coniferous <i>Barrsumpskog</i>	Hardwood deciduous <i>Ädellövträd</i>	Alder <i>Al</i>
	Wet mixed <i>Blandsumpskog</i>	Mixed <i>Blandskog</i>	
	Dry/mesic hardwood deciduous <i>Torr/frisk ädellövskog</i>	Mixed deciduous <i>Blandlövskog</i>	
	Dry/mesic mixed deciduous <i>Blandlövskog</i>		
	Dry/mesic common deciduous <i>Torr/frisk triviallövskog</i>		
	Wet deciduous <i>Lövsumpskog</i>		

(c) Built up / paved land and other land. Bebyggd och hårdgjord mark, samt övrig mark.

Level 1 Type of building <i>Bebyggelseslag</i>	Level 2 House type <i>Hustyp</i>	Level 3 Garden type/combination <i>Trädgårdstyp</i>	Level 4 Tree cover <i>Trätdäckning</i>	Level 5 Tree species <i>Trädslag</i>	Level 6 Moisture <i>Fuktighet</i>
Rural <i>Agrar</i>	Solitary farm <i>Ensamgård</i>	Economy building <i>Mark kring ekonomibygnad</i>	0% 1-10% 10-25% 25-50%	Coniferous <i>Barträd</i>	Dry <i>Torr</i>
Urban <i>icke-agrar</i>	Village <i>By</i>	Garden with lawn <i>Trädgård med gräsmark</i>		Common deciduous <i>Triviala lövträd</i>	Mesic <i>Frisk</i>
Roads, communications <i>Kommunikationsytor</i>	Manor, big estate <i>Herrgård, stor gård</i>	With fruit trees <i>Med fruktträd</i>		Hardwood deciduous <i>Ädellövträd</i>	Moist/wet <i>Fuktig</i>
	Castle <i>Slott</i>	With hedges <i>Med häckar</i>		Mixed <i>Blandskog</i>	
		With large solitary sunlit trees <i>Med stora solbelysta träd</i>		Mixed deciduous <i>Blandlöv-skog</i>	

Other land	Type	Tree cover <i>Trätdäckning</i>	Tree species <i>Trädslag</i>
Wetland <i>Våtmark</i>	Fen <i>Kärr</i>	0% 1-10% 10-25% 25-50% 50-70%	Birch <i>Björk</i>
Substrate & gravel pits <i>Substratmark och täkter</i>	Bog <i>Mosse</i>		Alder <i>Al</i>
Water <i>Vatten</i>	Bare bedrock <i>Hällmark</i>		Willow <i>Vide</i>
	Boulder <i>Blockdominerat</i>		Pine <i>Tall</i>
	Gravel / sand <i>Grus-sand</i>		Mixed deciduous <i>Blandlöv</i>
	Open water <i>Öppet vatten</i>		Mixed <i>Bland-barr-löv</i>
	Water vegetation <i>Högre vattenvegetation</i>		

Table 2.2a. The classification system developed for linear objects (corridors or barriers)

Level 0 Group of element	Level 1A Type of element / roadnet <i>Vägslag, typ av element</i>	Level 1B Type of element <i>Trädslag</i>	Level 2B Density of trees / bushes <i>Täthet av träd / buskar</i>	Level 3B Tree / bush species <i>Träd/ buskar arter</i>	Level 1C Type of boundary <i>Typ av kantzon / bryn</i>	Level 4B, C Field based <i>Fältdata</i>
A. Road net <i>Vägnät</i>	Farm gravel road without verges <i>Brukningsväg utan vägren</i>	Earth wall <i>Jordvall</i>	Open 0% <i>Öppen</i>	Coniferous trees <i>Barrträd</i>	Coniferous <i>Barrskogsbård</i>	Vegetation types <i>Vegetations typer</i>
B. Dry linear elements <i>Torra linje-element</i>	Farm gravel road with verges <i>Brukningväg med vägren</i>	Stone wall <i>Stenmur</i>	Solitary 1-10% <i>Enstaka</i>	Normal deciduous <i>Triviallövträd</i>	Deciduous <i>Lövskogsbård</i>	Species <i>Arter</i>
B. Wet linear elements <i>Våta linje-element</i>	Common/private gravel/paved road without verges <i>Allmän/enskild väg utan vägren</i>	Verge <i>Gräsrik ren</i>	Sparse 10-25% <i>Glesa</i>	Hardwood deciduous trees <i>Ädellövträd</i>	Mixed <i>Blandskogsbård</i>	
C. Forest boundary <i>Naturlig gräsmark</i>	Common/private gravel/paved road with verges <i>Allmän/enskild väg med vägren</i>	Tree row, coniferous <i>Trädrad av barrträd</i>	Dense 25-50% <i>Täta</i>	Juniper bushes <i>Enbuskar</i>	Wide crowned trees <i>Bård av bred-kroniga träd</i>	
		Tree row, deciduous <i>Trädrad av lövträd</i>	Very dense 50-100% <i>Mycket täta</i>	Thorny bushes <i>Taggiga buskar</i>		
		Hedges / bush row <i>Häck, buskrad</i>		Deciduous bushes <i>Lövbushkar</i>		
		Avenue <i>Allé</i>		Willow <i>Videbuskar</i>		
		Stream / rivulet <i>Å / bäck</i>				
		Water course / ditch <i>Vattendrag / dike</i>				

Table 2.2b. The classification system developed for point objects (stepping stones, small biotopes)

Level 0 Group of element <i>Typ av landskapselement</i>	Level 1 Type of element <i>Landskapselement</i>	Level 2 Density of trees / bushes <i>Täthet av träd o buskar</i>	Level 3B Tree / bush species <i>Träd / buskar</i>	Level 4 Field based <i>Fältdata</i>
Dry point elements <i>Torra punktelement</i>	Natural pool <i>Naturlig vattensamling</i>	Open 0% <i>Öppen</i>	Coniferous trees <i>Barrträd</i>	Vegetation types <i>Vegetations typer</i>
Wet point elements <i>Våta punktelement</i>	Artificial pool <i>Grävd damm</i>	Solitary 1-10% <i>Enstaka</i>	Normal deciduous trees <i>Triviallövträd</i>	Species <i>Arter</i>
Built point element <i>Byggt punkt element</i>	Inlet of trees <i>Åkerholme</i>	Sparse 10-25% <i>Glesa</i>	Hardwood deciduous trees <i>Ädellövträd</i>	
	Piles of stones <i>Stensampling (röse, etc.)</i>	Dense 25-50% <i>Täta</i>	Juniper bushes <i>Enbuskar</i>	
	Gravel pit <i>Täkter</i>	Very dense 50-100% <i>Mycket täta</i>	Thorny bushes <i>Taggiga buskar</i>	
	Solitary tree <i>Bredkronigt solitär träd</i>		Deciduous bushes <i>Lövbushkar</i>	
	Hay barn <i>Hölada</i>		Willow <i>Videbuskar</i>	
	Building <i>Byggnad</i>			
	Garden <i>Tomt</i>			

interpretation transparencies as an overlay, and one new aerial photo, the monitoring photo. To compare them we look at one photo with only one eye and close the other and then immediately afterwards look at the other photo with the other eye. In stereoscopic viewing the changes will show up in differing colours or patterns. The optimal period for monitoring seems to be at least five and preferably seven years. This limit is related to the possibilities of finding encroachment of bushes and ceased management on abandoned agricultural land, which are the most widespread changes.

The last step in the monitoring system, the analysis in the GIS system and the presentation in maps or pictures, the visualisation, is under development.

A further development of the classification system used here, as well as the selection of monitoring plots is to be undertaken too, to relate the regional monitoring to the national strategy NILS (National Inventory of Landscape in Sweden).

2.4 Conclusion

For regional monitoring of agricultural landscapes in Sweden for biodiversity we can conclude that:

- The whole landscape has to be mapped in a detailed scale in a monitoring plot with a base-line mapping according to content and structure. A plot size of 1 square km seems to be enough for content and structure description in the investigated landscape types.
- The landscape structure can be well described by a sub-division in patches, point and linear elements according to the PLP method
- Most importance must be put on biotopes belonging to the grasslands (meadows and pastures), the wetlands and the deciduous trees and woods.
- Factors that influence biotope quality and landscape structure must be included in the mapping. The classification system must be detailed, a shorter monitoring period requires a more detailed system. As well as vegetation types or plant associations, it should include ecological parameters such as moisture and nutrition, and anthropogenic parameters such as management type, management intensity, and disturbances, as well as management continuity.
- Mapping and monitoring of biotopes and landscape structure can be done by interpretation in CIR aerial photographs in scale 1: 30,000 quickly and with high accuracy, with only minor field-work. In the future the high spatial resolution image data from satellites, such as IKONOS holds important promise for this type of mapping and monitoring, but the costs are high.
- The developed approach of stratification into regions and randomly sampled monitoring plots seems to provide a good base for landscape monitoring. The counties can thus be subdivided, into regions, according to physical geographical factors, vegetation, actual and historical land-use and specific regional characteristics. The result from the monitoring plots can be applied to the whole landscape region.
- The developed approach has to be tested in further regions to be generally applicable in Sweden.

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3. Farmland biodiversity indicators and monitoring in Finland

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Summary

Four national level indicators of the state of farmland biodiversity indicate that Finnish farmland biodiversity is declining. The area of meadows has decreased to <1% of what it used to be in the beginning of the 20th century. The number of threatened farmland species has increased in all the five studied groups of organisms, and the rate of increase has been higher in farmland habitats than in any other habitat type in Finland. Dry meadows have the largest number of threatened species among farmland habitats. Some 40% of farmland butterflies have declined. The proportion of declined species is highest among meadow butterflies (71% declined). Some of the nationally useful biodiversity indicators may be too crude measures for detecting changes in biodiversity at smaller spatial scale. Therefore, and because of the needs in the monitoring of the effectiveness of the current Finnish agri-environmental support scheme to maintain farmland biodiversity, there is a need in Finland to develop farmland biodiversity indicators particularly at the landscape scale (an area of 0.25 - 1000 km²). Suitable information for this purpose was collected in summer 2001 in an extensive field survey of farmland biodiversity in 58 agricultural landscapes, which were selected for the study using stratified random sampling in four parts of southern Finland. The aim of the survey was to obtain quantitative information on (1) the amount of variation in plant, insect and bird biodiversity in ordinary Finnish farmland, (2) the key factors affecting species diversity at different spatial scales and (3) the relationship between landscape structure and biodiversity. First results on butterflies are shown. Landscape structure is quantified based on habitat maps digitised from aerial photographs and by using GIS methods and numerical indices of landscape structure. Results on the landscapes of five study areas are shown. It is concluded that both national and landscape level indicators of farmland biodiversity are needed, because the same indicators are not always useful at both spatial scales.

Key words: biodiversity survey; butterflies; threatened species; semi-natural habitats; grassland; habitat quality; landscape structure

3.1 Introduction

Agriculture in Finland has experienced very large changes during the last 50 years. The last big change happened in the year 1995 when Finland joined the European Union (EU) and adopted the common agricultural policy (CAP) of the EU. Agricultural intensification and loss of open semi-natural farmland habitats has caused large-scale losses of farmland biodiversity in Finland (Pitkänen & Tiainen 2001) as well as in other parts of Europe (Krebs *et al.* 1999). Because of the large changes there is a substantial need for useful indicators to measure the extent of change both at the national and landscape level. A preliminary set of indicators for the sustainable use of renewable resources at the national level was approved in Finland in February 1999 (Lahti & Nikkola 1999). At a smaller spatial scale indicators are particularly needed in the monitoring and further development of the effects of the Finnish agri-environmental support scheme, which is half-funded by EU.

The aim of this paper is to summarize some recent developments and on-going work on farmland biodiversity indicators and monitoring in Finland both at the national and at the landscape level. We start by showing recent results of four useful measures of the state of farmland biodiversity in Finland. After that we focus on the landscape level indicators and describe an on-going monitoring project, which was started in the 2000 in order to evaluate and further develop the effectiveness of the current Finnish agri-environmental support scheme to maintain farmland biodiversity. An additional aim of this project is to identify a set of the most useful indicators of Finnish farmland biodiversity. Finally, we compare the different needs that there are for useful farmland biodiversity indicators at the national and landscape levels.

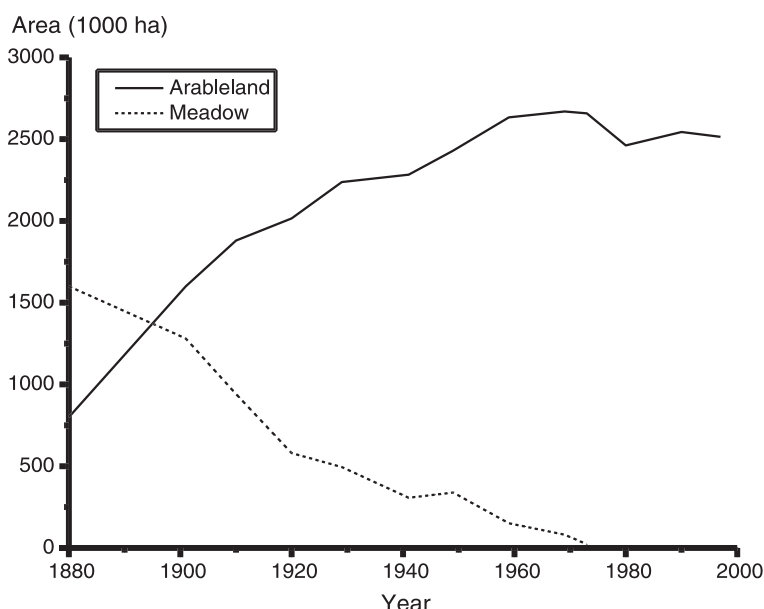
3.2 National level indicators

In this section we give a short overview of the recent trends and current state of farmland biodiversity in Finland by using four selected national level indicators: the trend in the amount of seminatural grasslands and the number of threatened species, threatened species in various farmland habitats and population trends in farmland butterflies.

3.2.1 Trend in the amount of semi-natural grasslands

During the last 100 years Finnish agriculture has gone through a change from small-scale traditional agriculture to much more efficient modern agriculture with increasing farm size and increasing specialization. Traditional Finnish agriculture involved animal husbandry in which it was typical to use extensive areas of semi-natural grasslands and forests for cattle-grazing. This type of agriculture was beneficial for a large amount of grassland-specialized species, especially for many plants and insects (Pykälä 2001). Presently, the large amount of different kinds of extensively used meadowland, which existed in Finland in the beginning of 20th century, has been mostly lost and converted to intensively used cultivated fields (Figure 3.1). During the last 100 years the amount of meadowland has decreased to less than 1% of what it used to be. Such a severe decline of suitable habitat is expected to cause a decline and regional extinctions of many meadow-associated species (Andrén 1997, Hanski 1999).

Figure 3.1. Decline of the area of semi-natural grasslands in Finland 1880-1997. Source: Soininen 1974, Finnish agricultural statistics.



3.2.2 Trend in the number of threatened species

A comprehensive evaluation of threatened species in Finland has been made for three times, in 1985, 1990 and 2000 (Rassi *et al.* 2001). Based on the existing three evaluations, it is possible to analyse trends in the amount of threatened species within different habitat types. Figure 3.2 summarizes the trends for five taxonomic groups in species which primarily occur in farmland habitats. In each of the five groups of organisms in Figure 3.2 there is an increasing trend. This trend is logically consistent with the observed long-term declining trend of suitable open seminatural habitats (Figure 3.1). However, a substantial amount of the increase in the numbers of threatened species is due to the increased knowledge of previously too poorly known groups of species. For example in Lepidoptera a substantial proportion of the currently threatened species belongs to Microlepidoptera, which could not be thoroughly classified in the previous evaluations before the year 2001 because of insufficient knowledge. Nevertheless, the increase of the amount of threatened species in the latest Finnish evaluation was higher in the species of farmland habitats than in any other habitat type (Rassi *et al.* 2001).

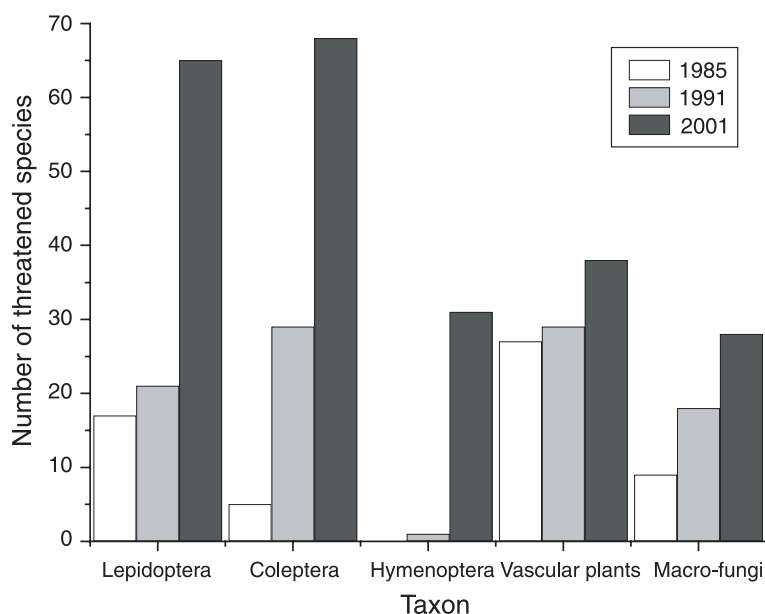


Figure 3.2. Increase of the number of threatened species associated with farmland habitats in Finland. Source: Rassi *et al.* 2001.

3.2.3 Threatened species in different farmland habitats

There is much variation in the numbers of threatened species among various kinds of farmland habitats. In Finland, almost half of the threatened farmland species are primarily species of dry meadows (Table 3.1). This is not surprising, because the area of dry meadows has decreased more severely than the area of any other grassland habitat type in Finnish agricultural landscapes (Heritage landscapes working group 2000). The amount of threatened farmland species is particularly high in butterflies and moths (Lepidoptera) as well as in beetles (Coleoptera; Table 3.1).

Table 3.1. Threatened species in different farmland habitats in Finland.

Habitat type	Lepidoptera	Coleoptera	Hymenoptera	Vascular plants	Macro-fungi	Total
Dry meadows	57	43	26	23	13	162
Fresh meadows	7	9	-	13	-	29
Margin habitats	58	25	11	1	-	95
Wooded pastures	7	16	8	10	17	58
Shores, river banks	11	19	1	14	2	47
Total	140	112	46	61	32	391

Source: Rassi *et al.* 2001.

3.2.4 Population trends in farmland butterflies

For the ecologically well-known groups of organisms it is possible to determine which species are primarily inhabitants of agricultural landscapes. In Finland this was recently done for butterflies. According to Pitkänen, Kuussaari & Pöyry (2001) 74 of the ca. 100 permanent butterfly species live in agricultural environments. These species were further classified into three categories according to their primary habitat type: species of (1) field margins and farmyards, (2) meadows (seminatural grassland) and (3) forest verges and clearings (Table 3.2). By combining information on observed population trends of each species and the habitat classification Pitkänen *et al.* (2001) found that the trends are distinctly different among the species of the three habitat types. While 71% of the meadow species had declined, the corresponding figure for the species of forest verges and clearings was only 25%, and none of the species of fields and farmyards had declined (Table 3.2).

Table 3.2. Population trends in Finnish farmland butterflies.

<i>Habitat type</i>	<i>(Number and % of species)</i>			
	<i>Decreased</i>	<i>No change</i>	<i>Increased</i>	<i>Threatened</i> ¹
Field margins, farmyards	0 0 %	7 88 %	1 12 %	1 12 %
Meadows	24 71 %	8 24 %	2 6 %	14 41 %
Forest verges and clearings	8 25 %	19 59 %	5 16 %	4 13 %
Total	32 43 %	34 46 %	8 11 %	19 26 %

¹ IUCN classification (Rassi *et al.* 2001).

Source: Pitkänen, Kuussaari & Pöyry 2001.

3.2.5 The trend in the national level farmland biodiversity indicators

All the above mentioned national level indicators of the state of farmland biodiversity indicate that Finnish farmland biodiversity has been declining. Eventhough the general trend has been a decline there are also exceptions, as shown for butterflies in Table 3.2. The situation is similar in Finnish farmland birds in which the population trends are known in detail (Tiainen & Pakkala 2001). While many farmland bird species have been severely declining, there are some others, which have become more common and increased in abundance (Tiainen & Pakkala 2001).

3.3 Landscape-level indicators

Agri-environmental support schemes aim at stopping and reversing the trend of environmental deterioration by providing economic support to farmers for applying environmentally friendly farming practices (Sutherland 2002). One of the aims of such schemes is maintaining and improving farmland biodiversity. Because an effective agri-environmental support scheme is a substantial economic investment from the society, there should also be effective means to measure the environmental benefits of such a scheme.

Measurement of changes in biodiversity may be complicated by several issues. For instance, the biodiversity impacts of changing farming practices may be weak and thereby difficult to detect. In addition, populations of many species react to environmental change with a time delay (Hanski 1997). Therefore, it may take some years before the positive impacts of beneficial changes in farming practices can be seen as increasing biodiversity.

National level biodiversity indicators may be too crude measures for detecting changes in biodiversity at smaller spatial scale. For example the number of threatened species may be a very useful indicator at the national level but almost useless at the level of an ordinary farmland landscape of 10 - 100 km². The occurrence of nationally threatened species at such a small spatial scale may be a too rare event in order to have practical applicability.

In Finland insufficient knowledge on farmland biodiversity has hindered the development of the Agri-environmental support scheme towards better taking into account farmland biodiversity. Quantitative information has been lacking on the existing variation of farmland biodiversity and the primary factors affecting it in ordinary Finnish farmland. To improve the level of knowledge and in order to monitor the biodiversity impacts of the current agri-environmental scheme an extensive biodiversity survey was organized in randomly selected Finnish agricultural landscapes.

3.3.1 Finnish farmland biodiversity survey

A pilot survey on Finnish farmland biodiversity was conducted in 15 farmland landscapes in summer 2000. In summer 2001 the same methodology was applied to 58 agricultural landscapes (Figure 3.3), which were selected using stratified random sampling in four parts of southern Finland (for details of the selection of study areas see the legend of Figure 3.3). The aim of the survey was to obtain quantitative information on (1) the amount of variation in plant, insect and bird biodiversity in ordinary Finnish farmland, (2) the key factors affecting species diversity at different spatial scales and (3) the relationship between landscape structure and biodiversity.

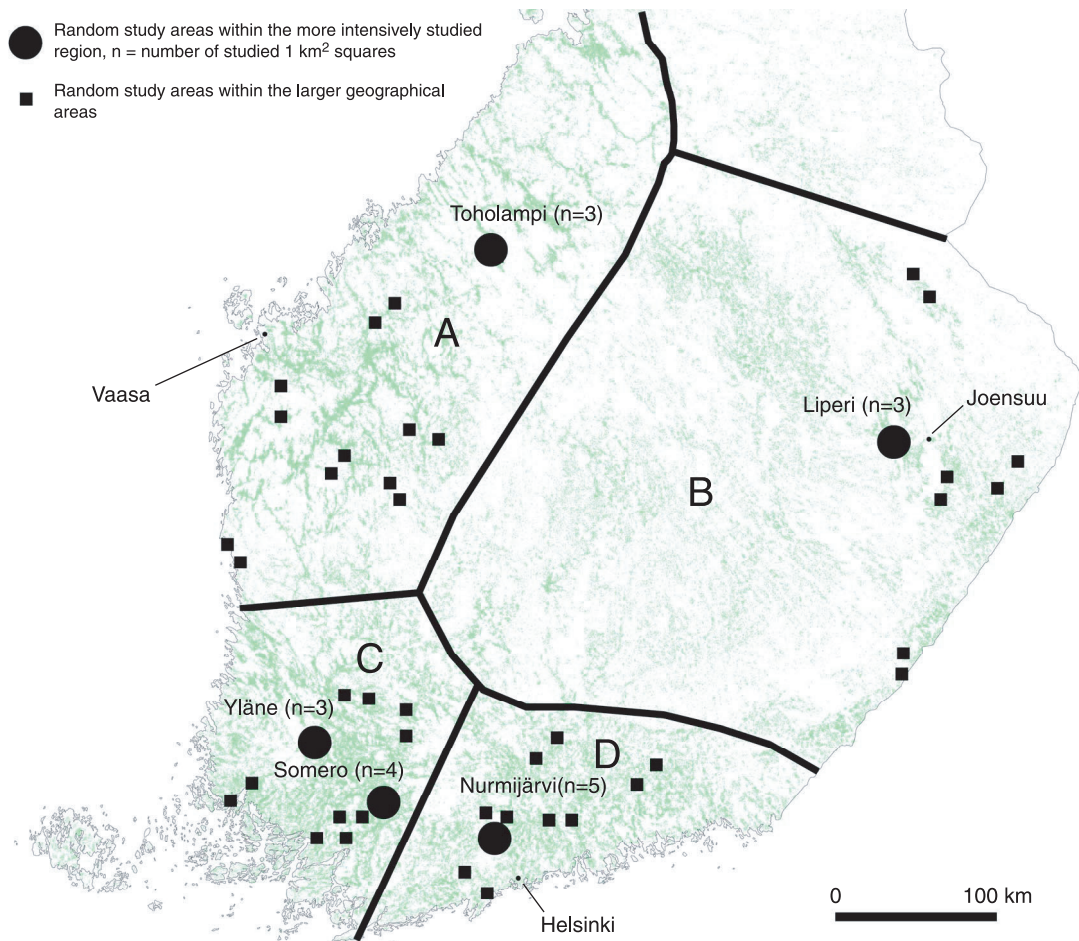


Figure 3.3. Location of the 58 studied 1 km² areas in the four parts (A-D) of southern Finland. Black dots = random study areas within the more intensively studied agricultural regions (Toholampi, Liperi, Yläne, Somero and Nurmijärvi), black squares = random study areas within the larger geographical areas (A-D). The distribution of cultivated fields is shown in green. Selection procedure of the 58 sampling areas: First, southern Finland was divided into three separate areas based on the geographic classification presented in Rikkinen (1994): the cultivated lowlands of Pohjanmaa in the western coast (area A in the above figure), the large and agriculturally less intensive lake district in the eastern and central Finland (area B), and the agriculturally most intensive areas of southern Finland along the southern coast. The southernmost district was further divided into two equally large areas (areas C and D) along a natural forest barrier between two agriculturally dominated regions. A total of 40 farmland areas were then randomly selected from the four larger areas using the following stratification based on the cover of cultivated fields: 12 sampling squares selected from area A, 8 squares from area B, and 10 squares from each of area C and D. Within the larger areas only 1 km² squares with >20% cover of cultivated fields were included in the selection procedure. In area A the selection was limited, because of practical sampling logistics, to the 150 km wide area surrounding the town of Vaasa and in area B to the 150 km wide area surrounding the town of Joensuu. In areas C and D there were no such distance limitations. In each of the areas A-D, the first sampling square was randomly selected. The second square was randomly selected within 10-20 km distance from the first square. This procedure was then repeated for as many pairs of study squares that there were within each of the larger area with the condition that the study squares were not allowed to be located closer than 10 km from each other. Additional more intensive sampling was carried out in five regions (Lestijoki in Toholampi, Taipaleenjoki in Liperi, Yläneenjoki in Yläne, Rekijoki in Somero and Lepsämäenjoki in Nurmijärvi), in which pilot studies on biodiversity and landscape structure had been conducted already during the first period of the Finnish agri-environmental program in years 1995-1999 (see Luoto 2000a, 2000b). Within each of these five earlier study regions five 1 km² study squares were randomly selected with the condition that the study squares were not allowed to be located closer than 1 km from each other. Again only 1 km² squares with >20% cover of cultivated fields were included in the selection procedure. Due to practical resource limitations the number of squares sampled within each region varied between three and five, totaling 18 one km² areas.

Vascular plants, butterflies, bumblebees and birds were quantitatively surveyed in a total of 58 one square kilometer study areas. In each 1 km² study area birds were counted from the whole farmland area, while the occurrence of plants and insects were sampled in 20 discrete 50 m long transects (altogether 1160 discrete transects) within two 0.25 km² subsquares (Figure 3.4). If possible, the two studied subsquares were selected in order to represent a contrast in landscape heterogeneity within the 1 km² area. The transects were located in all kinds of open and semi-open uncultivated farmland habitats available within each study square. In each subsquare we tried to find for the study two grassland patches as well as two replicates of each of the three types of field margins: margins located between cultivated fields and forest, margins completely surrounded by cultivated fields and road margins surrounded by cultivated fields.

Some 30 environmental variables (e.g. habitat type and location, vegetation height, amount of nectar flowers, type of habitat management) were recorded from each study transect to measure local habitat quality. Additional data on the details of farming practices in the study areas has been obtained from the farmland database of the Information Centre of the Ministry of Agriculture and Forestry and by interviewing the local farmers. Measures of landscape structure (see below) and the intensity of farming will be used to explain patterns of species diversity at different spatial scales.

Multiple regression methods are used to identify key factors affecting the diversity of various groups of organisms at different spatial scales. Additional interest is in examining the congruence of the variation of diversity among the four taxonomic groups. The results will be used in the evaluation and further development of the Finnish agro-environmental support scheme as well as in the identification of the most useful landscape level indicators of Finnish farmland biodiversity.

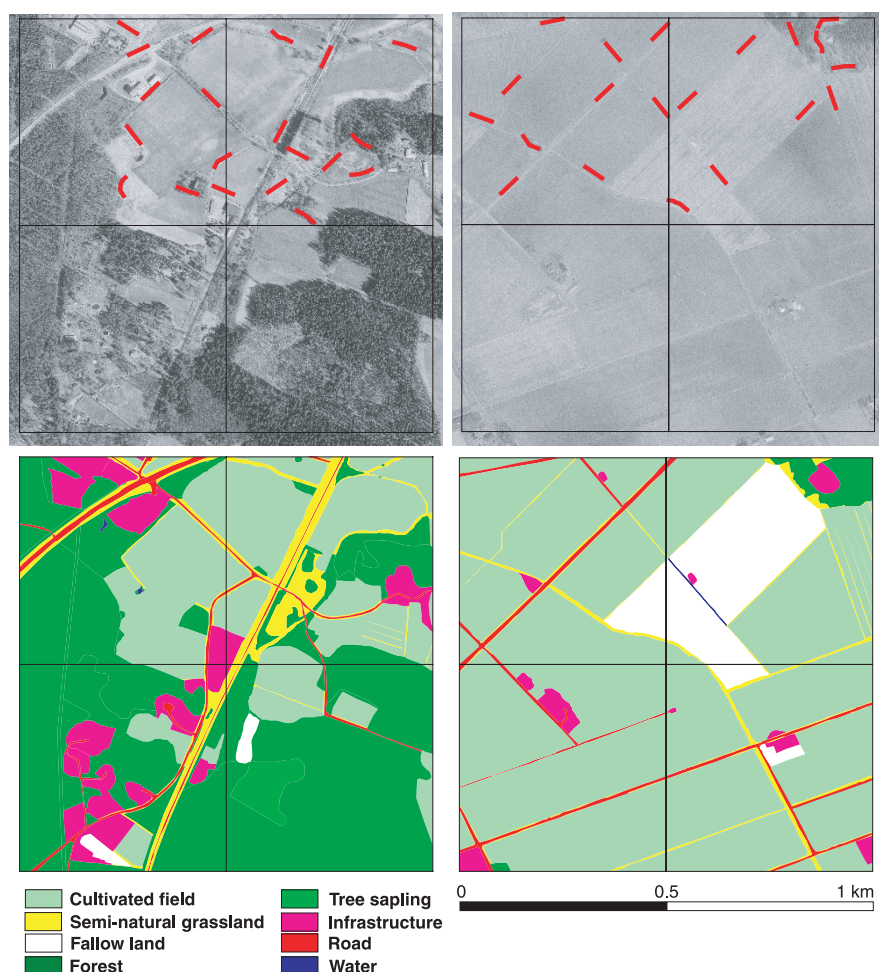


Figure 3.4. Two examples of 1 km² study squares. The upper figures show the location of the ten 50 m long plant and insect sampling transects within each of the 0.25 km² sampling sub-squares on a low altitude aerial photograph. Birds and habitat structure were surveyed from the whole 1 km² area. The lower figures show the digitised habitat maps corresponding the aerial photographs in the upper panels.

3.3.2 Landscape structure analysis using remote sensing data

Landscape analysis of 58 study landscapes (Figure 3.3) will be done for three different dates: 1990±2 years, 2000±2 years and 2005±2 years, to detect the recent changes of land use in agricultural landscapes. Habitat maps for the Finnish farmland biodiversity survey are derived from remote sensing data. Maps are digitized from low altitude black and white aerial photographs with a spatial resolution of 32 or 62 cm at the screen scale of ca 1:2,000 using Arc View 3.2. software. A total of ca. 20 different habitat types are identified and assigned (Table 3.3). The digitised habitat polygons are converted to raster images (cell size 1 m x 1 m) by the Arc/Info's Grid version using the polygrid function. In this process, the habitats which cover the largest share of the cell size are assigned to fill that grid totally. Each randomly sampled 1.0 km² study square is studied at three different scales: 1.0 km² (n=58) and 0.25 km² (n=232) squares and 50 m transects (n=1160). Each 1.0 km² study square consists of four 0.25 km² squares and 20 transects of 50 m (Figure 3.4).

Table 3.3. Habitat classification used in the Finnish farmland biodiversity survey. Habitat composition (cover of habitat) is calculated for all habitat types and subtypes.

1) Cultivated field	9) River or lake
2) Fallow land	10) Houseyard, garden
3) Semi-natural grassland habitats	11) Stockyard
a) Dry	12) Barn
b) Mesic	13) Road
c) Moist	14) Margin habitats
d) Hay meadow	a) Field/forest margin
4) Deciduous forest	b) Road/forest margin
5) Coniferous forest	c) Road/field margin
6) Mixed forest	d) Field/field margin
7) Tree sapling or felling	e) Field/lake (river) margin
8) Mire	

Habitat composition is analysed using the Arc/Info program (version 7.2.1). The absolute amount (m²) and the percentage coverage (%) of different habitats are calculated from polygon coverages by a frequency function. Habitat structure is analysed by calculating five landscape structure metrics from digital habitat maps of studied areas (Table 3.4). The habitat structure metrics 1-4 are analysed by the Fragstats program (version 2.0), which is a spatial pattern analysis program for quantifying landscape structure. In the Fragstats analysis the cell size is 1 x 1 m, and the core area distance and border zone is defined as 0 meters. Connectivity of grasslands (SI) is calculated using the SI program developed by Moilanen & Hanski (1998).

Table 3.4. Habitat structure variables calculated for the Finnish farmland biodiversity survey. For formulas 1-4 see McGarical & Marks (1994); formula 5 modified from Hanski (1994).

1) Habitat diversity (SHDI)	4) Habitat edge length (HEL)
2) Mean patch size (MPS)	5) Connectivity of grasslands (SI)
3) Mean patch shape (MSI)	

3.3.3 Results on biodiversity and landscape structure

In this section we show examples of the collected biodiversity and landscape structure data and their potential use.

Butterflies

Results of the large biodiversity survey conducted in summer 2001 are not yet available, but some results from the pilot study on butterflies (Kuussaari *et al.* 2001) and other pollinator insects conducted in summer 2000 can be shown. Table 3.5 summarizes the data on the occurrence of various insect groups that were gathered from the 1 km² squares. These data can be analysed either at the level of the 1 km² square, 0.25 km² square or at the level of the 50 m long sample transects.

Table 3.5. Summary of recorded insects in fifteen 1 km² study areas.

Insect group	All the 15 study areas		Number of species per study area			
	Individuals	Species	Mean	Sd	Min	Max
<i>Line transects¹</i>						
Butterflies	4776	51	30.5	3.2	24	35
Other day-active Macrolepidoptera	2814	69	23.7	3.2	18	30
<i>Yellow-traps²</i>						
Bumblebees	3956	20	12.6	2.8	6	17
Other bees	332	42	6.2	3.5	2	14
Hoverflies (Syrphidae)	11441	64	16.4	5.5	6	25

¹ Method described in Pollard and Yates (1993).

² Method described in Söderman (1997) and Söderman et al. (1999).

Figure 3.5 summarizes transect level data on the occurrence of butterflies in different seminatural habitats. Three noteworthy results emerge from the figure (Kuussaari *et al.* 2001, Kuussaari 2002). First, the highest numbers of butterfly species and individuals are observed in dry meadows. Second, butterfly density and species diversity are higher in meadows than in linear field margin habitats. Third, among the different kind of linear habitats, butterfly density and species diversity are higher in the open margins between field and forest than in the margins located between cultivated fields.

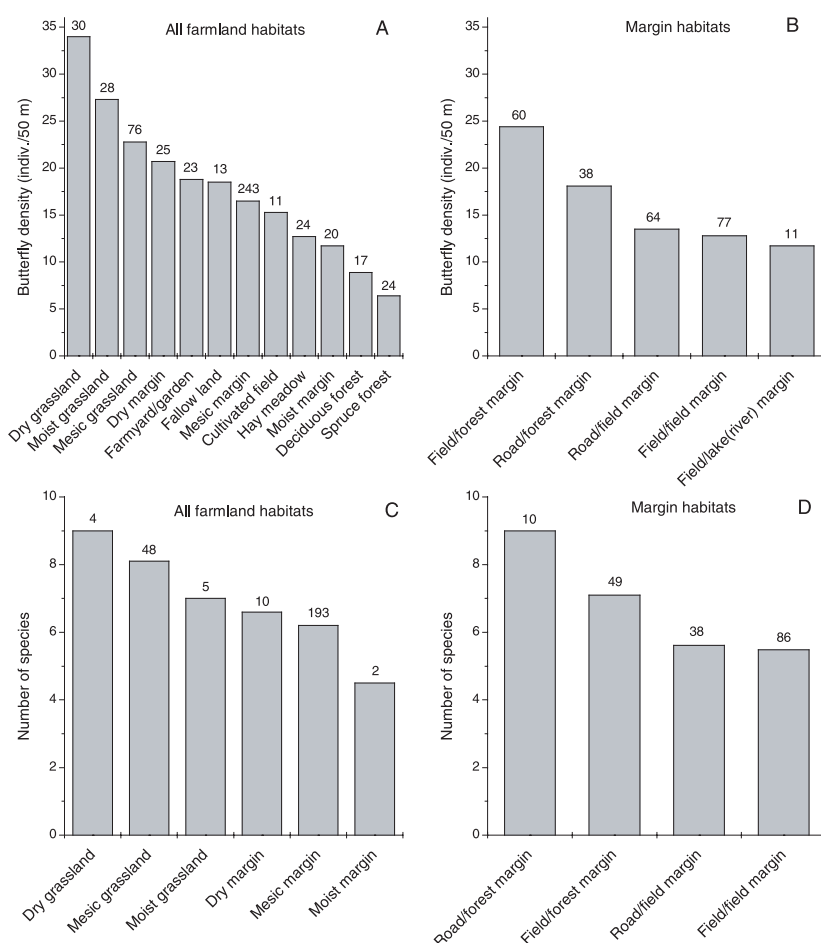


Figure 3.5. Average butterfly densities (individuals in 50 m transects: A and B) and number of species (in 50 m transects: C and D) in different agricultural habitats. Numbers above the bars indicate the number of subsections on which the mean value is based. Source: Kuussaari *et al.* 2001.

An analysis on the environmental factors affecting butterfly species richness in the linear margin habitats revealed that the most important three factors were nectar flower abundance, windiness of the site and the width of the margin. Increasing abundance of flowers and the width of the margin increased the number of butterfly species, whereas increasing windiness of the site decreased butterfly species richness (Figure 3.6).

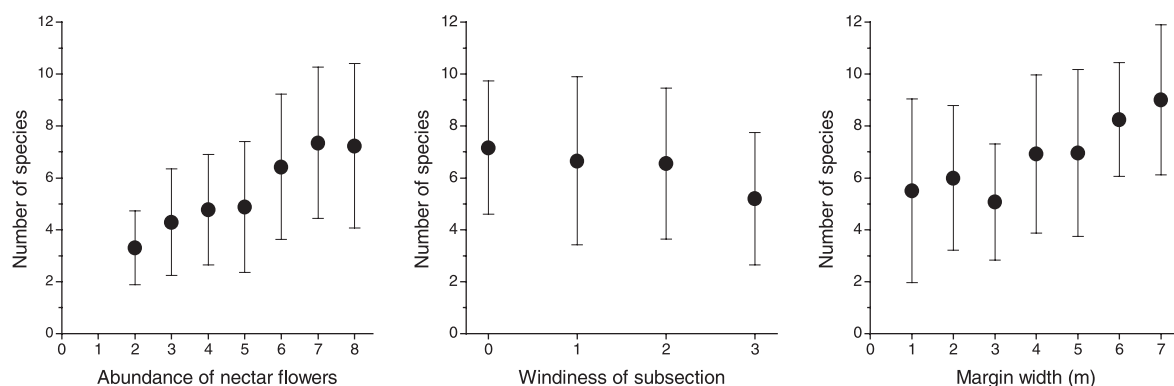


Figure 3.6. Factors affecting butterfly species richness in linear habitat elements (field and road margins). Means and standard deviation bars are shown. Source: Kuussaari et al. 2001

The first results of the Finnish biodiversity survey are encouraging, because they show that at least in the case of butterflies, local species richness can be explained to a substantial extent by a few easily measurable local environmental factors. However, the analysis of the extensive farmland biodiversity survey conducted in summer 2001 is just at its beginning. It will take some time before the most interesting analyses, which take into account both the local and regional environmental quality as well as the numbers of species in the different groups of study species, can be made. For example, in the forthcoming analyses an important question will be to analyse in what extent variation in biodiversity at the level of 0.25 - 1 km² can be explained only by measures of landscape structure (e.g. habitat diversity or the area of seminatural grassland).

Landscape structure

Here we show results on habitat composition and landscape structure in a subset of five different agricultural areas (i.e. the same five study areas shown in Figure 3.3), which were studied using aerial photographs and GIS techniques by Luoto (2000a). Landscape ecological characteristics of Lepsämäenjoki (S Finland), Lestijoki (W Finland), Rekijoki (SW Finland), Taipaleenjoki (E Finland) and Yläneenjoki (SW Finland) were quantified using habitat composition (Table 3.6) and five landscape indices: habitat diversity, mean patch size, mean patch shape, habitat edge length and connectivity of grasslands (Table

Table 3.6. Percentage coverage of the habitat types in the five study areas (Luoto 2000a). For a habitat map of the study areas see Luoto (2000a).

	Lepsämäenjoki %	Lestijoki %	Rekijoki %	Taipaleenjoki %	Yläneenjoki %
Agriculture	64.4	70.4	57.2	58.1	67.3
Semi-natural grassland	0.8	1.0	6.1	1.1	0.8
Stockyard	-	1.6	0.0	0.0	0.2
Deciduous forest	2.0	3.9	2.4	6.3	1.9
Coniferous forest	19.9	11.1	23.0	14.1	20.9
Mixed forest	0.5	5.1	1.9	0.5	1.0
Tree sapling or felling	5.3	1.2	4.1	11.6	1.3
Mire	0.0	0.4	0.0	0.0	2.2
Water course or lake	1.1	1.9	0.7	2.4	0.6
Houseyard, garden	4.5	1.8	3.6	4.0	2.7
Barn	0.6	0.5	0.2	0.3	0.3
Road	0.8	1.0	0.7	1.6	0.8

Table 3.7. Habitat structure in the five study areas studied at the scale of 0.25 km².

	Lepsämäenjoki	Lestijoki	Rekijoki	Taipaleenjoki	Yläneenjoki
Habitat diversity	0.69	0.74	0.85	0.89	0.67
Mean patch size (ha)	2.96	1.81	2.61	2.08	3.34
Mean patch shape	1.59	1.71	1.76	1.52	1.67
Habitat edge length (m)	2610	3860	3800	3310	2710

3.7). All the five areas were dominated by intensive agriculture. The most monotonous agricultural fields were in areas of extensive cultivated plains, with high mean patch size and low habitat diversity. In the cereal production areas, where the agricultural production capacity is high, the habitat pattern was less diverse than in areas of mixed farming. Habitat diversity was directly linked to topographical roughness. The most diverse areas were semi-open river valleys, with steep slopes and low agricultural input (Luoto 2000a).

Within each of the five areas three main types of agricultural landscape were found (see Ihse 1995): extensive cultivated plains, semi-open mixed landscape and enclosed, forested agricultural landscape (Table 3.8). Extensive cultivated plains are characterized by monotonous habitat structure and a small number of key habitats. They have the highest agricultural production. Semi-open mixed landscape is a landscape with great variety. Both topographically and by habitat pattern it is the most heterogeneous of the three types. It also has the highest number of ecologically valuable key habitats (semi-natural grassland, deciduous forests and water course). Enclosed, forested landscape is typical in agriculturally marginal areas with a low habitat diversity and a low cover of key habitats.

The prevailing trends in landscape development of agricultural areas are reduction and isolation of areas with high biodiversity, increasing uniformity of the spatial arrangement of habitats, and standardization created by large-scale homogeneous structures (Ihse 1995). In northern and eastern Europe, highly species-rich semi-natural grassland habitats occur with scattered distribution, albeit in a phase of continuous loss. The Finnish agri-environmental support scheme has been rather ineffective in supporting the management of semi-natural grasslands in Finland (Salminen & Kekäläinen 2000). The potential of the remaining network of semi-natural grasslands to preserve grassland-specialized flora and fauna seems insufficient in all the above five study areas except Rekijoki. The success of Rekijoki is based on special management projects, in which local people have participated actively, and on viable livestock husbandry in wide areas of grasslands.

Table 3.8. Characteristics of the three main types of agricultural landscapes in the studied five areas in Finland (Luoto 2000a).

Landscape type	Agricultural production	Habitat characteristics
Extensive cultivated plain	- cereal production - fodder crop cultivation - high cereal production	- low habitat diversity - large patch size - low amount of key habitats
Semi-open mixed agricultural landscape	- dairy production - fodder crop/cereal cultivation - abandoned fields	- great variety typical - high habitat diversity - high cover of key habitats
Enclosed, forested landscape	- abandoned fields - dairy production - marginalization	- low habitat diversity - large patch size - small agricultural fields

3.4 Conclusions

In this paper we have discussed the need for both national and landscape level (referring here to an area of the size of 0.25 - 1000 km²) indicators in monitoring of farmland biodiversity. We conclude that both kinds of indicators are needed, but that the same indicators are not always useful at both spatial scales. National level indicators are needed for comparisons among countries, while in many countries there is

an additional need to have landscape level indicators for example for monitoring the effectiveness of agri-environmental programs. Information on more specific landscape level indicators may help to explain and interpret observed patterns in the more crude measures of national level farmland biodiversity indicators.

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4. A classification system for landscape monitoring: Nordic and international perspectives

Workshop report, 11 - 12 October 2001, Tøne, Denmark

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Summary

As an activity under topic-1 (classification systems for landscape monitoring) of the NordLaM project, a workshop was held in October 2001 to examine the principles and practice of classification for landscape and related environmental and ecological mapping and monitoring. Presentations included examinations of the principles of classification, examples of international systems for landscape related classifications and examples of national classification systems including several from Nordic countries. The workshop also provided opportunity for group discussion across a range of classification issues. The meeting enabled a high level of interaction and concentration on the 'classification' issue, providing a broad common basis for future discussions and developments.

Keywords: classification, landscape monitoring, land cover

4.1 Introduction

There are currently numerous class sets used for environmental and ecological mapping and monitoring. For example, to name just a few of these, there are: CORINE-Land Cover, EUNIS, EU Habitats Directive Annex-1, Vegetation Types in the Nordic Region, the FAO Land Cover Classification System and the LUCAS Land Cover and Land Use systems. As this list indicates, the various systems reflect different interests, values and intentions.

At the same time, there is increasing development and implementation of programmes that have as their specific focus "landscape monitoring". These programmes, using a combination of image data and field survey, aim to describe the current status and changes for a wide range of ecological, and also cultural and socio-economic aspects of terrestrial environments, including the spatial arrangement of landscape elements. Nordic examples of such programmes include the NILS programme in Sweden (Inghe 2001), the 3Q and AR18x18 in Norway (Fjellstad *et al.* 2001) and the Small Biotop Monitoring Programme in Denmark (Brandt *et al.* 2001). Wider afield there are similar programmes underway or planned for several European countries, and indeed planned for Europe as a whole.

A major issue faced by Landscape Monitoring programmes is the set of classes that they should use. In many cases, existing legends for land cover, vegetation or habitat mapping, for example, do not fully meet the requirements for landscape monitoring. At the same time, these programmes wish to use class-sets such that their monitoring data are easily compatible with those from other programmes. Therefore the objectives of this workshop on this topic, were to:

- Increase understanding and generate discussion of issues relating to the development and use of classification systems, nomenclatures and legends in the monitoring of landscapes
- Explore the possibilities for the development of a classification system structured for and tuned to the requirements of landscape level monitoring for the Nordic area and Europe as a whole

The workshop, with 26 participants (Annex 4.A) comprised invited presentations and guided small group discussions. Seven of the nine presentations examined aspects of the needs for class sets and the satisfaction of these needs in various national and international contexts. The other two presentations examined general principles and concepts for mapping and monitoring classification systems and class sets in general, with detailed presentation of one example of a classification system that embodies these. Small group discussions built upon the material in the presentations exploring the purposes and principles of classification systems and their implementation.

4.2 Summaries of the presentations

Some general classification concepts and principles

With so many class sets in use, *e.g.* over 50 different land use information systems at the European level, there is clearly a need for understanding and dialogue on the principles and concepts of classification systems. These aspects of the workshop's remit seen from a generic, *i.e.* not necessarily environmental or ecological, perspective, were presented by Gerd Eiden. A working definition of 'classification system' is that they are "basic methods for ordering objects based on their relationships; the aim is to structure information, facilitating communication and exchange of information" (Sokal 1974). As such, a classification system has three core components:

- ◊ A systematic component, for hierarchical structuring of all objects – this can be considered as the 'classification system' itself.
- ◊ A nomenclature component, for naming and description of all objects and/or object-groups.
- ◊ An identification component, for assignment of an individual object to a specific class based on a set of criteria and rules.

As general rules classification systems should have:

- Spatial consistency (*i.e.* be comparable between different sites, regions or countries).
- Temporal consistency (*i.e.* they should reflect the current state, the 'stocks', at the time of observation).
- Completeness, in that no parts of the domain (the 'Universe of Discourse') are excluded.
- No overlap between classes (*i.e.* objects can be assigned to only one class and the use of mixed classes is avoided).
- Independence from observing tools (*i.e.* they should not be designed from the perspective of a specific data gathering method, such as image interpretation).
- Independence from scale.
- Rules for assignment of an object to a class.
- Rules for consistent naming of classes.
- Rules for inclusion of new objects.

Clearly, the development and application of good class sets is a pivotal, non-trivial and intellectually demanding part of mapping and monitoring work.

Nordic examples

Nordic examples of the requirements for high quality class sets in national mapping and monitoring activities were presented for Norway (Arnt Kristian Gjertsen; Jogeir Stokland) and Sweden (Göran Ståhl).

A key strategic activity in Norway is for a programme of area resource inventory at a landscape level, which covers all area types. This is being developed as the "AR18x18" (or "1000 places") project, as a systematic sampling (no pre-stratification) of 1000 1 x 1 km areas on an 18 km sampling grid. Aerial photographs, in scale 1: 13,000 are to be a primary source for inventory and mapping. This programme is driven by the need for a mapping programme that gives a total overview of Norwegian landscapes. In particular there is at present the lack of a mapping programme for Norway's alpine vegetation zone, which comprises 35% of Norway. In addition this programme will provide input ground reference data for national census of land cover derived by satellite image interpretation.

The classification system for the AR18x18 needs to be scientifically based, capable of delivering required information, practical and flexible to use and capable of correlation to many other national and international classification systems. As such, land cover is seen as a basis for the AR18x18 classification system: land cover criteria are central to many diverse mapping issues, such as vegetation type, land type, habitat type, the urban green structure. Towards this objective of using land cover as the basis of the AR18x18 classification system an examination was made of the correlation between the legend used in the Norwegian 3Q (agricultural areas) monitoring programme (Fjellstad *et al.* 2001) and land cover. This examination used the FAO/UNEP Land Cover Classification System (LCCS; see more regarding LCCS later in this workshop report) as the basis for correlation since LCCS classes are clearly stated. The main results of this exercise were that:

- The 3Q legend correlates well with the LCCS.
- There are some differences in the percent levels used for partition of cover, in particular for tree and shrub cover and in the definition of 'bare areas' (3Q: <25%; LCCS: <4%).
- 3Q makes use of a criterion for grazing that is used to add detail for classes describing areas that are

clearly being grazed by livestock.

The possibilities for a classification system for the AR18x18 are:

- ◊ a design that uses criteria that are provided implicitly by class definitions,
- ◊ a design that uses explicit criteria as interpretation keys, or
- ◊ a design where criteria are provided explicitly as independent, and individually observed and recorded classifiers.

Jogeir Stokland presented, from a Norwegian perspective also, a classificatory concept for the application of land cover and land use monitoring data as indicators of biodiversity change. In the 'environment' level of the DPSIR indicator model (*i.e.* the Pressures, States and Impacts components) it is necessary to consider the structure of information relating in particular to Pressures, *i.e.* human activities and State, *i.e.* environmental type and state. Rigorous hierarchical databasing of information, based upon classifiers is seen as the paradigm for this structuring. For Pressures, spatial units should be databased in terms of their land use type(s) and the associated land use activities. Structuring of State information is more complex, however it is proposed that spatial units can be databased in terms of their land cover, their habitat and their associated environmental state classifiers.

In Sweden the issue of classification systems is being actively explored in the context of development (2001 – 2003) and implementation (2004) of a national landscape monitoring programme, NILS (formerly known as SLÖ; Inghe 2001). Many aspects of monitoring are part of the overall NILS process, and the options available in relation to these are seen as part of the development of a classification system for NILS: NILS will have many, diverse users, and one question is the extent to which its classification system reflects such breadth, *i.e.* should its central classification system aim for versatility and general applicability or be rather more specific? Moreover, can a system based upon a core aspect of land such as land cover or habitat or vegetation type function in a general, open way or would it be specific and limiting? An option under consideration is a set of parallel specific systems. The answer to these question will influence how complex the resulting classification system is, and whether it accommodates "all" criteria or distinguishes between core criteria and "attached attributes".

A programme such as NILS has several distinct component purposes: production of maps, estimation of the current state and monitoring of changes. A further question asked therefore is, is the aim of the classification system to serve all of these purposes or is it necessary to focus on one or other of these purposes in order to develop a sound system?

As NILS will use field survey techniques to a large extent for its data collection it is important that the classification system provides the possibility for objective assessment of classes in the field. In many cases the basic data collection in NILS will involve the delineation of polygons. In some cases the extent on an object (its polygon) will be clear. In other cases the placement of lines will be less clear; indeed, in some situations it may only be possible to delineate "complex units". A question faced by NILS is therefore, to what extent should the classification system be part of the process of polygon delineation? Should the classification system explicitly include all the variables that are to be used to delineate polygons, even those used to delineate clear landscape objects? This question is complicated, since in the case of unclear polygons in particular, it is can be hard to divorce the issue of polygon delineation from its association with the mapping technique. An alternative position might be to consider all the variables of the classification system as variables to be applied in polygon delineation.

NILS aims for a classification system that will provide a good basis for analysis of its data and results with other of other related work, within and beyond Sweden. However, a further challenge it faces for achieving this goal, is how far should a country-specific programme go in developing for itself a classification system that can be related world-wide?

Experiences from Great Britain

In Great Britain landscape level monitoring has, in the form of the "Countryside Survey" been applied and refined through several rounds spanning several decades and the extension of such monitoring as a field mapping system for habitats and land cover across Europe is now being investigated and developed (Bunce 2001). The incorporation of classificatory aspects at several levels in this work was presented to the workshop by David Howard (representing R.G.H. Bunce). The complexity of such monitoring, and the resulting need for a robust field mapping system cannot be understated, with the innate complexity of landscape compounded by the difficulty of distinguishing real changes from background noise, and the need to detect both large and small changes. Clear vision in the matter of a classification system cannot be divorced from clear vision of the monitoring operation as a whole. Thus, it has been

found important to:

- Keep in mind: the clear objectives, the parts where compromise between practical and scientific issues is needed, the need to ensure there is data control such as in the use of control sites and the need to think long term.
- Work in terms of three clearly defined phases: design, field survey, analysis.

The Countryside Survey 'design' has followed four key principles: a clearly defined domain, objective sampling, spatial referencing of sample sites and a constant site size. 'Field survey' is built around use of a short time frame, consistent recording categories, use of relocation procedures and inclusion of quality control and assurance. 'Analysis' adheres to the use of appropriate statistical procedures, the checking of statistical assumptions, constant accuracy levels and the use of audit trails.

An overriding principle is the objective selection of survey sites and location of samples therein. The data collection made at these sites is the pivot-wheel of the whole operation, and the classificatory mapping procedures developed for this therefore lie at the core of the monitoring. Mapping is based upon a list of standard codes, with combinations of data codes used to annotate each category and at least one of the primary codes used for all features. The aim is to map recognisable different, yet mappable units. For Europe-wide monitoring a coding system has been proposed that comprises four fields: the general habitat, the land cover, the EUNIS habitat classification type and qualifiers.

An example from Germany

Classification for landscape level monitoring is also often involves making an effective land typology as the basis for area sampling. The presentation by Armin Benzler described one such example of landscape classification. Within the federal system in Germany the Länder are responsible for nature conservation and the Federal Government has only a frame competence. This results in a lot of different local monitoring programmes with different objectives, mostly focused on nature monitoring in special nature reserves, which do not fit together in any way on the national level. On a national level, the main emphasis in environmental monitoring in Germany is focused on the monitoring of chemicals and their impacts. There is – despite of the heavy impact of landuse on biodiversity - lack of statistical data on biodiversity on a national level. To change this situation, the Federal Statistical Office and the Federal Agency for Nature Conservation developed and tested the so called "Ecological Area Sampling", a method to get comprehensive and reliable information on the state and the development trends of landscape structure, biotope quality and biodiversity (Hoffman-Kroll *et al.* 2000). The Ecological Area Sampling (EAS) was tested in a pilot study in 1995. The EAS is designed as the basis for information and decision-

making in the field of nature conservation and biodiversity on the national level.

The EAS concept consists of two different steps (Figure 4.1). In step 1, on the landscape level, the inventory of random samples of one square kilometer each are surveyed (biotope mapping) all over Germany. Instruments are aerial photographs and field surveys. In step 2 animal and plant species are recorded in subsamples. The recording data together with secondary data sets like Ellenberg values or Red List data allow the evaluation of the quality of the biotope types, the trends in quality change and trends in species diversity.

The periodically monitored sites of the EAS are selected by stratified random sampling since the occurrence and shape of landscapes, habitats and species heavily depends on the local conditions. Stratification is based on land cover classes and land classes. The *land cover classes* are derived from the CORINE Land Cover map of Germany. These classes were aggregated to four main classes: open land, forests, urban and waters, with only open land and forests considered. (For urban and waters, different monitoring concepts are needed.) The *landclasses* are derived by hierarchical cluster analysis from mostly

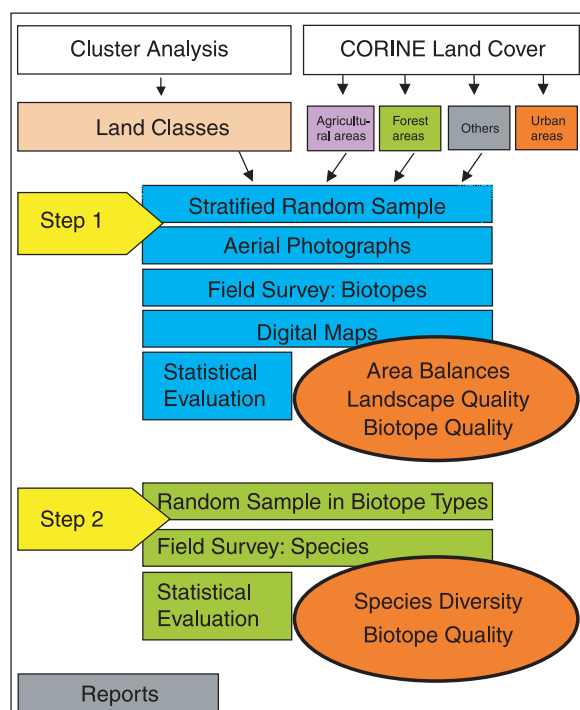


Figure 4.1. Ecological Area Sampling: survey design.

abiotic information using the CART algorithm (Schroeder & Schmidt 2001). 48 data layers used as variables for this classification:

- Mean monthly global radiation for the summer period (March to November)
- Soil texture
- Altitude
- The 12 mean monthly climate values of temperature, precipitation, evaporation
- Potential Natural Vegetation (PNV)

While the PNV serves as target variable, the other data layers are describing variables.

The cluster analysis leads to a division of the area into homogenous spatial land class clusters using the abiotic variables. From all possible divisions the one is chosen that fits best with the classes of the PNV. This way of acting has several advantages:

- Considering regions with homogenous quality leads to more differentiated information.
- Aggregation of the data in a hierarchical procedure created landclasses that allow work within several frames of reference (e.g. with main classes).
- The landclasses are units, which are not very liable to temporal change.
- The count of landclasses can be determined by the frame conditions of the concept.
- Using a target variable avoids shattering of the resulting land classes.

Disadvantages are:

- The resulting classes can be difficult to understand and to interpret. They are abstract and it is quite difficult to give them concrete names.
- The classification depends on the availability of datasets. Different data combinations lead to different classifications. So the selection of the data seems arbitrary.
- The quality depends on the quality of the data basis, and increasing quality needs require recalculation.

For describing habitat structure and for the records of step 2 the national system of biotope types, which comprises about 500 Biotope types similar to the habitat types of EUNIS classification, is used. Biotope types are units, characterized by homogenous geomorphological conditions like “rocks” or “sand dunes” or by occurrence of typical vegetation such as “grassland”. There are nine main classes and a hierarchical system.

Linking the data of mapping landscape features on the habitat scale with the species data and the use of secondary data on landuse, red lists etc. allows creation of a considerable set of indicators, expressing changes in landuse, landscape structure, habitat quality, diversity of habitats and species, state of threat and more. Unfortunately the implementation of the EAS on a national level in Germany is uncertain at the moment.

Classification and the EEA

The use of classifications is a central issue with the European Environment Agency (EEA), in particular in its role as the reporting agency on the state of the European environment to several international fora. Therefore, as Ulla Pinborg of the EEA noted in her presentation to the workshop, the scales for much EEA work are those of the European ‘use’ scale, *i.e.* those scales at which environmental data and information are used across the European countries. Much of this use of data and information is on a ‘landscape scale’. The Monitoring, Data, Information, Assessment and Reporting value chain and the Driving Forces, Pressures, States, Impacts, Responses framework are important concepts within EEA work.

The EEA’s principle activities concern environmental reporting to decision makers, based on targeted data collection and coordination of dataflow. Thus, EEA relies on ‘research’ and ‘monitoring’, but does not directly undertake such activities. A central task for the EEA is to provide the Environmental Signals Reports in time (June) before Commission preparation of EU Spring Councils, (February). EEA Reports related to evaluation of the EU Environmental Action Programmes and to the Environment for Europe process (next meeting in Kiev 2003) are also key aspects of EEA work. In making these reports, a crucial task is harmonisation of data. This relates to different spatial units, depending upon different conventions, *e.g.*:

- Bern Convention, EU Habitat Directive: biogeographical regions
- EU Water Directive: catchment area regions

CORINE Land Cover (CLC) is the most used EEA spatial data set. The CLC data are often used in analyses outside of the CLC’s own hierarchical class structure, providing maps of specific themes, such as ‘forest’ or ‘wooded’ areas, fragmentation of land and proximity of protected areas to pressure from land use. CLC is now entering its second data collection round, based on satellite images from 2000 (Image

2000). Possibilities for making the CLC classification more detailed are being tested. EUNIS is another important data system for the EEA. EUNIS represents a flat system in terms of its database, but has a hierarchical presentation in the form of a classification with definitions of class units. Thus, in terms of use of the EUNIS habitats database, different hierarchical and non-hierarchical class structures can be derived.

Current challenges for EEA data and its use of classification systems relate to the generation of environmental indicators. The EEA analysis and presentations in reports are based on indicators. A major focus of further development for the EEA spatial work is producing analyses and indicators based on combined CLC and EUNIS habitat classes: for example, to derive data for EUNIS grassland habitats and forest types aggregated from conversion of CLC data to habitat data or to provide a picture of CO₂ sink properties of the landscape, based on forest distribution.

CORINE Land Cover and classification beyond level-3

The theme of CORINE Land Cover was followed-up by the presentation from Jan Feranec. This examined the 4th level CORINE Land Cover nomenclature that has been elaborated for CLC work in the PHARE Countries (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia and Slovak Republic). Presentation was made of the considerations taken into account in delimiting the set of 105 CLC classes at the fourth level. A paper of this presentation, including the list of CLC fourth level classes is included as Annex 4.B of this chapter.

The FAO/UNEP LandCover Classification System

The focus on mapping of land cover was continued in the last presentation, by Louisa Jansen, which was an introduction to and demonstration of the Land Cover Classification System (LCCS) developed for the FAO/UNEP AfriCover Programme (Di Gregorio & Jansen 2000). The presentation discussed the significance of land cover as a mapping theme and the past present and future contexts of land cover mapping. The need for a new classification of land cover was examined and the context of the LCCS developments. Definitions and principles were discussed including those for land cover, classification (in general) and different ways of doing classification (e.g. a posteriori, a priori, hierarchical, non-hierarchical). Central to the LCCS approach is the concept of a 'legend' as distinct from the 'classification system'. The basic concept of the LCCS was described, showing how it can be considered as a 'new language' for land cover mapping, with its distinctive words, syntax and concepts – these were shown to enable it to be flexible whilst at the same time maintaining geographic accuracy. The basic principle of the LCCS is that a land cover class is defined by the combination of a set of independent diagnostic attributes, the so-called 'classifiers', which are arranged to assure a high degree of geographic accuracy. The technical aspects of the LCCS were presented, including its initial Dichotomous phase and the subsequent Modular-Hierarchical phase, and the use of pure land cover classifiers, environmental attributes and specific technical attributes to build classes. The resulting legend components, of a boolean formulation, a standard class name and a numerical code for built classes was demonstrated. Further demonstrations of LCCS showed the relationship between the four modules of the LCCS software suite: the core classification module, the legend module, the translation module and the field data module (under development). Examples of application of the LCCS for actual land cover map legend were presented and a demonstration of how it can provide a basis for change detection even when different classes have been used to map land cover. The presentation concluded with an examination of the wider implications of the LCCS for land information in general, with a review of land system classifications. A paper based upon this presentation is included as Annex 4.C of this chapter.

4.3 Small Group Discussion Session-1

The first of the two small group discussion sessions focused upon more general aspects of classification systems and their roles and applications in landscape monitoring. The discussion questions and associated notes presented to the groups are shown below, followed by reports of the resulting discussions within the three groups.

Qu.1) The first topic for discussion examined the function of classification systems for landscape monitoring:

- In what general ways are classification systems useful? For example, some generally accepted purposes served by classification are that it provides economy of memory, ease of communication and

analysis, and a way of describing structure and relationships among objects.

- In the traditional natural sciences (zoology, geology, medical science, etc.) the *raison d'être* of many classification systems is representation of the 'true relationships' between objects, such as living organisms, rock types, etc. To what extent is it, by contrast, the case in many areas of environmental science and ecology, that classification systems are primarily used as tools to facilitate data gathering, modeling, interpretation in terms of indicators and reporting?

Qu.2) The second discussion topic of this session focused on the general design of classification systems for landscape monitoring. Two specific design issues were suggested for discussion, relating to (a) the influence that purpose has over design, and (b) the use of hierarchical and flat structures for classification.

- Different purposes, working upon the same set of features, will develop classification systems that use different characteristics of landscape features as their classifiers. For example, a monitoring programme that is concerned with hydrological issues will require use of classifiers or classes that register different types of irrigation upon cultivated land, rather than just different major types of land cover such as 'forest', 'permanent pasture' and 'arable land' (example taken from Di Gregorio & Jansen 2000, page 7). How should we create a classification system that is truly multi-purpose? To what extent does land cover provide a basis for a multi-purpose classification system of landscape features? Does 'a multi-purpose system' imply that it is fully scale independent, since only a scale independent system can be truly multi-user orientated? A system that is fully scale independent could be applied at very large scales and at very small scales on a uniform basis, making it possible to easily combine information from a sample survey with information from a census (whole coverage) survey. (How does 'scale independence' influence system design? - as, for example, in avoidance of classes such as 'Buildings with >50% vegetation cover' that mix different categories due to association with a certain mapping scale.) So, should a scale-independent land cover classification system function as a basis of a multi-purpose landscape level monitoring system? - how then should other elements (land use, vegetation type, topography, climate, geology) be integrated?
- Often classification systems are based upon hierarchical structures, either, as in EUNIS and CORINE Land Cover in terms of their classes, or as in the LCCS in terms of their use of classifiers. Some reports (such as the 'Manual of Concepts' of the Eurostat Land Use Statistics working group) have discussed the possibility of non-hierarchical classification systems, noting that the 'hierarchical aspect of [a nomenclature] is an artificial construction applied upon a complex web of relationships, likenesses, affinities, neighbourhoods'. Furthermore, disadvantages of hierarchical systems have been noted, such as their general inflexibility to modifications, and the problems of ensuring that, across a complex hierarchy, all possibilities for objects requiring classification are represented once and only once (*i.e.* without 'gaps' or 'overlaps'). Alternatives to the hierarchical structure include flat 'combinational' approaches. It has been suggested that, given the wide range of aspects that the study of landscapes should consider (land use, land cover, vegetation, habitat, etc.) a non-hierarchical combinational approach represents a valid and potentially significant classification system for landscape monitoring. What are some of the significant advantages and disadvantages associated with development of hierarchical and non-hierarchical classification systems? In what circumstances, for what purposes, in landscape monitoring might a non-hierarchical system be more useful than a hierarchical system?

4.3.1 Group Reporting:

Group 1:

- It was noted that 'purpose' often has the following pattern:
Predefined Purpose Classification System $\Rightarrow$ Product $\Rightarrow$ New Purposes / Uses
- 'Purpose', along with 'Scale' & 'Method' are the three fundamental decisions that have to be made in the classical tradition of mapping, such as in production of topographic maps.
- A classification system should carry with it information on its purpose, including what it should be used for, and what it should not be used for.
- It was felt that there cannot be a general multi-purpose classification design for mapping, so for example if the purpose is vegetation mapping then a vegetation classification system should be used. One Swedish experience was that even if the design was for multi-purpose monitoring, with those with interests in different themes combining forces for monitoring work, it was not possible to find a

logical way of putting together the information on different themes in one system.

- On the other hand, Landscape Monitoring does have to be multi-faceted, taking into consideration issues of culture, history, biodiversity and the relationship of biodiversity to ecosystems.
- A distinction was noted between the impact of the Landscape Monitoring objectives upon the design of a classification system and the impact that these requirements also have upon the sampling design. Hence, there may be a danger of mixing-up these two design issues. Some of the 'multi-purpose' demands require use of a purposeful sampling design more than merely use of a purposeful classification system. (The latter implies attention to the aspect of 'classification' within landscape monitoring concerning derivation of a map of delineated landscape types.)
- It may also be the case that monitoring data are collected for one purpose, but then they are also used for a second purpose, as new questions arise. To enable the possibility for this type of multi-purpose use it is important that the initial data recording is done in terms of good definitions, so that the interpretation of the data for a new purpose can be made clearly.
- It was noted that there are many, many on-going classification systems in the field of 'land' mapping and monitoring - some are still in development and some are now rather rigid. It is important to appreciate that all systems will change over time in some ways - this is, for example, true of the FAO Classification of World Soils, which may sometimes be regarded as an example of a fixed classification
- It was noted that the only truly truly scale-independent system implies mapping in a scale of 1:1. The 'Landscape Scale', meaning variation over 1 - 10 km was seen as a scale that is highly intrinsic to most people.
- With respect to whether classification systems should be hierarchical, it was noted that in some well-known cases, classifications have become presented as hierarchical 'by accident'. Both the EUNIS and the CORINE Land Cover are examples of this process. EUNIS began as a database, and as a system was developed to use the database this became increasingly structured and hierarchical. This suggests a usefulness for approaches that enable a set of classifiers to be used in different mixtures depending upon the information available, which is an important aspect of the use of EUNIS - 'a halfway-house to a hierarchical system'.
- A general point is that a non-hierarchical approach enables re-grouping.

Group 2:

The question has to be asked whether (a) the intrinsic order of the subject and/or (b) the audience involved in a situation drives the purpose behind a classification system. These can present very different perspectives on how a classification system should be. This point is linked to that of the importance of keeping separate those issues concerning the primary data (that is vital to retain the integrity of the monitoring) and the inventory data (used in reporting). Having this distinction clear can move some difficult questions concerning the classification system and the analysis to the post data collection stage. Classification is purpose driven. Furthermore, purpose must be clear from the outset, without too many constraints, leaving the monitoring open and flexible for later use from different perspectives.

The question of classification systems does matter because they 'show value'.

Values:

- ◇ provide meaningful synthesis from large datasets
- ◇ lead to objective linkage to synthetic groupings
- ◇ start to provide the bases for variable measures that are to be chosen and lead to the gathering of inventory information and wider extrapolation of information from other data sets
- ◇ they are the bases for monitoring and change / trend detection.

Classification:

- Imposes the choice of parameters to include in a monitoring operation. For most purposes it is possible to recognise biological and anthropogenic/cultural parameters for basic data collection.
- Imposes the criteria of scales (nominal, ordinal, interval, ratio) - this depends upon the parameters or classifiers and the source of data.

Classification is seen as important for:

- ◇ Organising a morass of data.
- ◇ As a communication tool.
- ◇ Providing a time-line for monitoring / reporting
- ◇ Providing a basis to impose order upon changes

- ◇ For modelling and hypothesis testing.
- ◇ Providing a chance to use available funding by imposing practical limits.

Land cover provides a good starting position for a truly multi-purpose classification system. It should, ideally, be scale independent. However, the degree to which it is multipurpose will depend upon what is included under 'land cover'. Thus, land cover was seen as been 'classifically multipurpose', but this implies the need to enumerate it in terms of classifiers and/or categories, relating to edaphics/hydrology, lithology, geomorphology/topography, climate/microclimates, cultural practices (e.g. grazing), altitude. Thus, 'full multi-purposeness' is seen as possible – it just implies including a lot of classifiers and/or categories.

It was also noted that classifiers are scale-affected, i.e. the break-points used in classifiers will be affected by scale and purpose – this situation may lead to mixed classes.

A 'pros and cons' evaluation was made of hierarchical and non-hierarchical classification systems:

HIERARCHICAL CLASSIFICATION SYSTEM

- | 'pros' | 'cons' |
|---|--|
| • easier to collate / summate / aggregate | • aggregations are pre-determined |
| • simpler / intuitive / culturally accustomed | • classes do not represent "real" entities in nature |
| • sequential | • end users can find classes unnatural |
| • enable logical aggregation for end uses of information, such as politicians | • can be non sequential "artificial" and non-intuitive |

NON-HIERARCHICAL CLASSIFICATION SYSTEM

- | 'pros' | 'cons' |
|--|---|
| • can be used in a non pre-determined way* | • not intuitive |
| • are flexible, enabling pragmatism* | • potentially complex to use |
| • can use binary approaches, enabling creativity | • can require more data than a hier. system |
| • can enable addition of more classifiers | • potentially hard to write routines for |
| • relate well to changing environment* | • the audit trail needs to be strict |
| • can aggregate in different ways* | • needs good use-guidance |
| • reflects well the 'dirty' nature of environment* | |
- (* =when this approach works well)

Group 3:

Usefulness of classification systems?:

- First it is necessary to decide what we want from Landscape Monitoring ... how do we want to use the information ? then we can decide how to develop the classification system.
- It was also noted that there will often be a situation of wanting to aggregate data in different ways.

Multi-purpose classification systems?:

- Landscape individuality needs to be recognised, and landscapes will not be the same in different regions or countries – this suggests a need for different 'purpose' classification systems. Tied in with this is the fact that comparison of landscape function becomes more difficult as distance increases.
- There is a case for thinking in terms of 'Primitives' i.e. items on the lowest data level. However, this implies:
 - a need to agree on their definition, and
 - a need for flexibility to include new primitives
- It is important to recognise that the resolution of the resulting map is determined by the nature of the data (primitive) capture.

Hierarchical or non-hierarchical?:

- There is a need for both.
- A flat system is appropriate for data (primitive) capture.
- A hierarchical system is appropriate for nesting of the data.

In summary:

- We should recognise the detail and then summarise it using classifications.
- We can then use each other's data by aggregating according to our own specific Landscape objectives, using our own classifications.

4.4 Small Group Discussion Session-2

In contrast to the more general topics discussed in Session-1, this second discussion session addressed three specific issues related to problems encountered or foreseen in the development of classification systems for the monitoring of landscape features. This session also asks groups to consider what topics and issues require further and particular focus for the greater development of the use of classifications systems in landscape level monitoring.

Qu. 3) A key principle of Landscape Ecology / Landscape Study is that landscapes are composed of Areal, Linear and Point (ALP) features. (N.B. 'Point' is not used in the strict geometric / Cartesian sense of a 1-dimensional spot, but may mean, as in the Swedish Standard Nomenclature for Landscape Monitoring, a feature of up to 0.25 ha in area.) This principle raises a number of issues in relation to the design and use of classification systems:

- Should a single legend or different legends be used for the Area, Line and Point features?
- In some situations it is interesting to classify Line and Point features in terms of the characteristics of their surroundings (*e.g.* "is the vicinity of a road vegetated?"). Is it desirable with regard to the operation of a classification system to consider the 'surroundings' of features in their classification?
- The ALP principle is related to the handling of mosaics by a classification system: for example, an area of grassland with some small clumps of bushes could either (a) rather simply be classified as 'grassland + bushes', (b) simply classified in terms of the character of the grassland part, omitting the bushes since these will be treated independently as Point features, or (c) more complexly classified in terms of a mosaic feature. What are appropriate and inappropriate courses of action in such a situation?

Qu. 4) Some existing classification systems that relate to aspects of landscapes include geographical and bio-geographical concepts in their sets of classifiers or keys (such as climate, as in the US Federal Geographic Data Committee's National Vegetation Classification System, or bio-geographical regions in EUNIS). How and to what extent should a classification system for use in landscape level monitoring include classifiers relating to geographical or bio-geographical aspects?

Qu. 5) Height is the third dimension of landscape features and can be highly relevant for some users, but less so for others. The classification system should be able in a flexible manner to address these different situations. The issue of height is also related to the issue of layering, and similarly information of layering might be of high interest for some users and not for others. How, in the best way, can a classification system design allow for the different user demands for height and layering information? Furthermore, depending upon the method used, height and layering information is not highly mappable, and is difficult to collect. Thus, should it be possible within a classification system to leave-out this classifier or to include it on only a very general level.

Qu. 6) What are important questions for development of a concept of a classification system for use in landscape level monitoring? Please identify 2 - 4 issues that the group thinks are most in need of further discussion, such as via an Internet discussion forum and/or other development work.

4.4.1 Group Reporting:

Group 1:

Q3.:

- Question-3 is important since in some monitoring situations it is important that monitoring follows the expectations ('mandate') of particular academic interest groups. Thus, as is the case from a landscape ecology perspective, 'area – line – point' is an important conceptual mandate.
- The historical context of the emphasis on Area-Line-Point in landscape monitoring is that early programmes for 'landscape monitoring' focused, in their data recording and reporting on just areal features. This was seen as inadequate for landscape ecology, requiring particular focus to then be placed upon the lines and points in the landscape. Moreover, 'A-L-P' has always been a pin-wheel within classical topographic mapping.
- One solution might be to monitor in terms of 'composite area features' that include information on line and point elements that they contain, plus a distinct layer for line elements in order to derive their lengths, plus a layer for point elements, in order to derive the number of these. – However this was seen as requiring considerable extra effort.
- An alternative approach, along the lines of the LCCS, might be to 'define' the area part, the line part

and the point part separately and then combine these, as appropriate, in the legend classes.

- It was noted that in Swedish experience, it was found to be easier and beneficial in general to include information about the surroundings of line and point features as part of their classification in the field – rather than seeing this as an issue for post-hoc GIS analysis. However, the ease of making such field recording was also seen as related to the scale at which the monitoring is done, since if a finer, more detailed scale is used the effort could be considerable greater. Also, the ‘in the field’ approach was seen as requiring very complex protocols in order to determine, for example, ‘under this classification system for linear features, where does this hedge feature stop and the next one start?’
- The nature of the surroundings of a line or point feature was seen as vitally important in biological terms (i.e. if the purpose of the monitoring is biological) – the nature of the surroundings very much determines the biological function and value of line and point features.
- Some ‘real world’ situation were considered, in which the recording of area, line or point features, and the surroundings of line and point features as part of their classification system raises interesting pragmatic questions. The case of a road crossing an area of semi-natural vegetation (such as moorland) was considered: how wide is the surrounding area? The case of forest edges was found to be particularly taxing: is a forest edge a linear feature or merely a line between area features? When is it an edge and when is it a transition zone representing a distinct vegetation type? Should such decisions involve a species composition or a structural approach?

Q5:

- It was noted that height should not be seen as a surrogate of tree age. The Swedish SLÖ experience is that the question ‘is this a tree or a shrub layer’ should be determined on the basis of species, not on height or form (e.g. presence of an apical point). If height is used for this discrimination there is a danger of getting distorted distributions of tree height.
- Another solution to the layering issue might be to consider ‘woody species’ irrespective of what layer they constitute.

Group 2:

Q3:

- It was noted that it should be possible to include additional information in the recording for landscape level monitoring, without this information being a part of the classification system. This additional information could also be added as additional qualifiers to the classification later on.
- Linear features have important landscape and biological value. Thus, there is functional use for retaining these features.
- The degree to which line and point features are recorded will depend upon the scale of the mapping. This is not quite the same as the relationship between scale and the mapping of area features, which is more determined by issues of role and rationale.

Q4:

- Biogeography should not influence classifiers used in landscape level monitoring. This information should be brought in to analysis and reporting from elsewhere and used through superimposition upon the monitoring information.

Q5:

- Vegetation, such as forest, involves issues of both height and layering.
- Buildings and technical constructions involve just issues of height.
- Topography should not be used in a classification system.

Q6:

Future focus should include:

- Work on attributes that relate to ‘environmental state’, such as age, integrity and the quality of habitats.
- The recognition of values for specific functions land use
- How to translate land cover into aspects with meaning for biodiversity, i.e. targeted functional questions
- Additional environmental information is needed

Group 3:

Q3:

- The recording of information on area, line and point features is necessary in the sense that it is important to record as much as possible.

- But it is important to apply standardisation in whatever method is used for the monitoring of landscape features - such as monitoring in terms of ecotones, gradients or mosaics. This should also involve use of a rule set that is defined on the basis of agreed objectives, in terms of scale and the minimum mappable units.
- Information about surrounding areas ('vicinities') to line and point features should fall out from the GIS associated with a monitoring programme.

Q4:

- In consideration of the associated biogeography of landscape features there may be concerns over the resolution of data relating to biogeographical themes – typically such data sets tend to be rather coarse (regional / national) scale. Furthermore, some biogeographic data may be out of date compared to changes in say climate or vegetation zones.
- Landscape ecology may represent a holistic approach, but the question still has to be asked of 'how much do we include?' Rules may be needed to answer such a question.
- It may be possible to record landscape structure by the recording of land cover, and then use biogeography to link this information to drivers of change.

Q5:

- The recording and inclusion of height in a classification system depends on the data collection method that is involved. Thus, its recording might be considered as easier for monitoring by field survey than for monitoring that is using image data (of some type) as its primary data source.
- If height is considered important, maybe we have to think in terms of GIS that adequately accommodate X, Y and Z.

Q6:

- Need for agreement on nomenclatures and labels for landscape monitoring.
- Thresholds need to be standardised, in particular with respect to polygon delineation and mosaics.
- The Objectives, the classification and the Methods of a monitoring programme should all be considered together and equally.
- Data collection must be defined and should be undertaken in as fine detail as is possible.
- Consider development of a classification system for Nordic areas along the lines of the LCCS.

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Annex 4.A - Workshop participants (with affiliations at time of workshop)

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Annex 4.B - The 4th level CORINE land cover nomenclature for the Phare Countries

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4.B.1 Introduction

Land cover is a material manifestation of natural and socio-economic processes (land use) on the Earth's surface. It is spatially differentiated by its physiognomic and morphostructural attributes, and indicates the intensity of the processes and changes within the landscape. Identification of land cover is a prerequisite for analysing causes and consequences, assessing the human impact on landscape, and solving the problems of ecological stability in the spheres of decision making and planning.

Identification and mapping of land cover (*e.g.* using the CORINE Land Cover Project nomenclature at scale 1:100,000, Heymann *et al.* 1994) generalise the actual image of the landscape in time of acquisition of the satellite data. These data constitute a source of information on land cover (*e.g.* at different scales). The cited CORINE land cover (CLC) nomenclature at scale 1:100,000 – ranging from urban (industrial), agricultural, forest and semi-natural areas to categories such as alpine meadows, wetlands, *etc.* – also indicates the rate of human impact (Feranec *et al.* 1998).

Elaboration of a more detailed land cover nomenclature at scale 1:50,000 was one of the PTL/LC (EEA Phare Topic Link on Land Cover) activities (Feranec & Otahel 1998). This scale is more adequate for precise observation of the regional and local peculiarities of land cover than 1:100,000 scale. However, an important condition of the work was the respect for the logic of the structure of CLC classes, observation of the proceeding level, in this case the level three.

4.B.2 Characteristics of the third level of CLC classes allowing for a more detailed delimitation in the fourth level – scale 1:50 000

For the itemisation of CLC classes it is necessary to know which characteristics are the determining ones for the delimitation of the 4th level classes at scale 1:50,000. We suggest the following characteristics:

➤ Mapping size (the smallest unit mapped) of land cover objects:

Heterogeneity of many CLC classes at scale 1:100,000 was caused by the fact that they contain objects

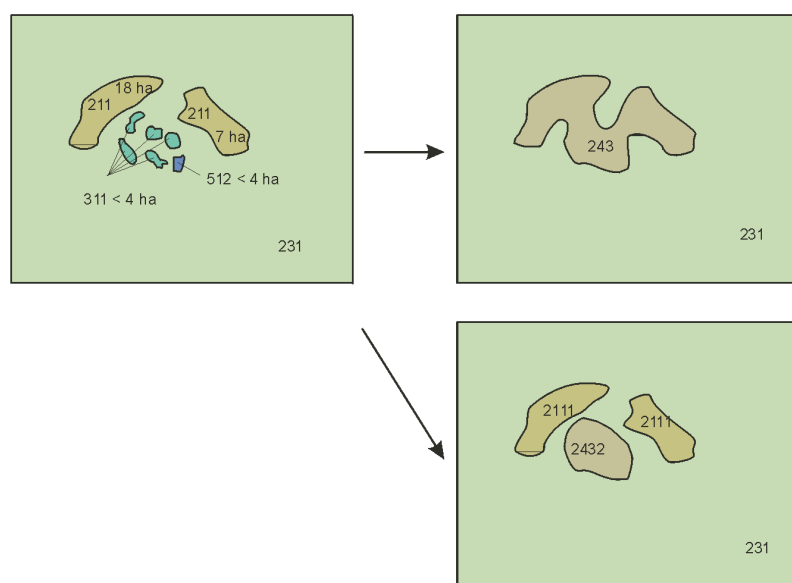


Figure 4.B.1. Sample of class 243 (Land principally occupied by agriculture with significant areas of natural vegetation) from which the characteristic "the minimum size of identified polygon 4 ha" new class 2111 can be delimited.

"Developments in Strategic Landscape Monitoring for the Nordic Countries." Groom, G. (ed) Nordic Council of Ministers. ANP 2004:705, pp 54-63. (This paper was published in *Geograficky casopis*, 51, 1999, 1, pp. 19-44. The Editorial Board of *Geograficky casopis* approves its publishing in the NordLaM publication.)

smaller and larger than 25 ha. If we use a new criterion “the minimum size of identified polygon 4 ha” it will be possible to formulate new classes in terms of proposed definitions of CLC nomenclature 1:50,000 which will be relatively more homogeneous from the viewpoint of the contents (Figure 4.B.1).

➤ Morphostructural and physiognomic characteristics of land cover objects:

Inner heterogeneity of land cover classes at scale 1:100 000 manifested in satellite images by means of physiognomic characteristics (for instance alternation of single trees or stands of trees – broad-leaved or coniferous, crown coverage within class 313) allows for more detailed itemisation of this class at scale 1:50,000 (Figure 4.B.2).

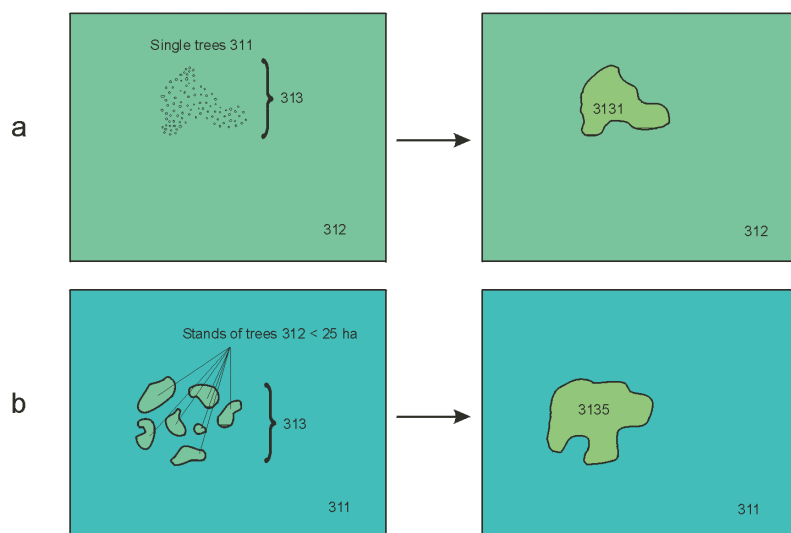


Figure 4.B.2. Mixed forest (class 313) where the distinguishing characteristic is whether it is (a) alternation of dispersed single trees (broadleaved - coniferous) or (b) stands of trees (broadleaved - coniferous).

➤ Territorial (national) peculiarities of the land cover objects:

Acceptance of territorial (national) peculiarities will facilitate delimitation of new land cover classes at scale 1:50,000 characteristic for various geographic areas of PHARE countries (Figure 4.B.3).

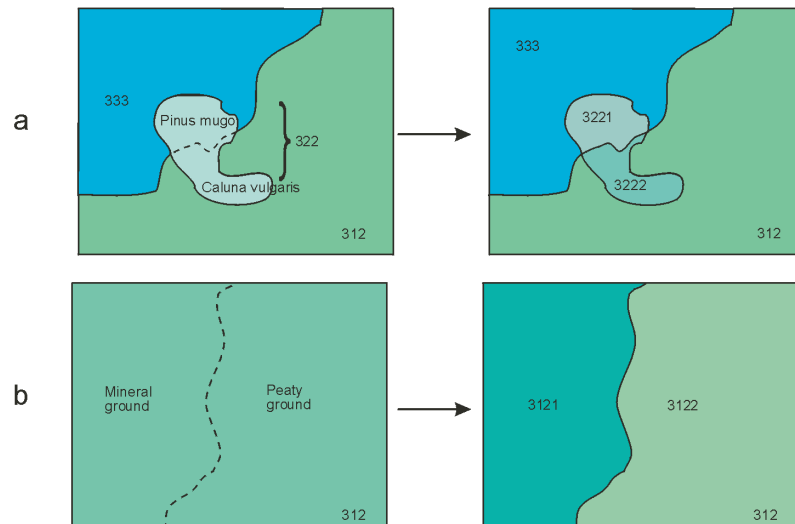


Figure 4.B.3. Demonstration of the division of class 322: (a) - (Moors and heathland) to 3221 (Areas of dwarf mountain pine) and to 3222 (Heathlands and moorlands) and to 312: (b) - class (Coniferous forests) to 3121 (Coniferous forests with continuous canopy not on mire) and to 3122 (Coniferous forests with continuous canopy on mire).

4.B.2.1 Characteristics used for the delimitation of CLC classes of the fourth level:

- ⇒ the size limit (4 ha) at the smallest unit (polygon),
- ⇒ morphostructural and physiognomic characteristics distinguishing the inner heterogeneity of the 3rd level classes:

- 111: Density of urban fabric, size and shape of the buildings, share of supplementing parts of the class (square, width of the streets, parking lots)
- 112: Size and shape of the buildings, arrangement and character of supplementing parts of the class (gardens, urban greenery)
- 121: Share of buildings and areas of special infrastructure in urban fabric

- 122: Character of transport network
 - 123: Size and character of neighbouring water areas, arrangement of infrastructure, size of quays
 - 124: Character of the runway surfaces
 - 131: Situation and character of sites
 - 132: State of the dumps
 - 141: Arrangement and share of anthropogenic parts of the class
 - 142: Arrangement and share of playgrounds and sport halls
 - 211: Share of dispersed greenery
 - 222: Arrangement and share of areas of permanent crops
 - 231: Share of dispersed greenery
 - 242: Occurrence of dispersed houses (cottages)
 - 243: Arrangement and share of single objects of the class
 - 321: Share of dispersed greenery
 - 324: Character (developmental stage) and arrangement of vegetation
 - 331: Character of the neighbouring classes
 - 333: Character of substrate
 - 411: Character of substrate, water and vegetation
 - 412: Character and share of vegetation or water
 - 421: Character and share of vegetation
 - 511: Character (origin) of flowing waters
 - 512: Character (origin) of standing water
- ⇒ *territorial (national) peculiarities as well as morphostructural and physiognomic characteristics, distinguishing the inner heterogeneity of the 3rd level classes:*
- 311: Character of substrate, canopy, special plantation of vegetation
 - 312: Character of substrate, canopy, special plantation of vegetation
 - 313: Character of substrate, character of alternation (mixture), canopy
 - 322: Character (composition) of vegetation

4.B.3 The new nomenclature proposal

The Smolenice version of the CORINE land cover nomenclature at scale 1:50,000 (Feranec *et al.* 1995) was prepared by J. Feranec and J. Otahel, completed and approved by the team of the following experts: M. Baranowski, M. Bossard, G. Büttner, A. Ciolkocz, J. Kolář and Ch. Steenmans (during meeting in Smolenice, Slovak Republic, January 1995). It was used for elaboration of new version of nomenclature. Following, all national CORINE land cover teams – from Bulgaria (D. Kontardjiev), the Czech Republic (D. Zdenková), Estonia (K. Aaviksoo), Hungary (G. Büttner), Latvia (H. Baranovs), Lithuania (R. Kaulakys et al.), Slovenia (A. Kobler, B. Vrščaj), Poland (M. Baranowski), Romania (V. Vajdea), and the Slovak Republic (J. Feranec, J. Otahel) – participated on preparation of proposal for names and definitions of the 4th level nomenclature.

1 ARTIFICIAL SURFACES

1.1 Urban fabric

1.1.1 Continuous urban fabric

1.1.1.1 Areas of urban centres

Areas of urban centres with public, administrative and commercial buildings, roads, parking lots and artificial surfaces (e.g. cemeteries without vegetation) cover more than 80% of the total surface. Urban greenery is exceptional.

1.1.1.2 Areas of ancient cores

Dense ancient cores (mainly residential buildings) with roads, parking lots, etc. Urban greenery is exceptional.

1.1.2 Discontinuous urban fabric

1.1.2.1 Discontinuous built-up areas with multiflat houses prevailingly without gardens

Areas, substantial part of which are formed mainly by houses without more distinct representation of gardens. Also lawns and tree and shrub urban greenery, communications, parking lots, in lesser extent service buildings, cemeteries without vegetation, private family houses can be part of them. They are represented mainly by urban settlement with multistoreyed houses.

1.1.2.2 Discontinuous built-up areas with family houses with gardens

Areas, substantial part of which are formed mainly by family houses connected with gardens and lawns. There are fruit trees, vegetable, eventually agricultural crops. Other elements of the class are communications, various service buildings, parking lots, small squares reaching the area of approx. 20-50% of the pattern area, cemeteries without vegetation. They are represented mainly by rural settlements and parts of urban settlements.

1.1.2.3 Discontinuous built-up areas with greenery

Areas mostly consisting of houses in forestland (dispersed houses in forest environment, e.g. Tapiola "Garden city").

1.2 Industrial, commercial and transport units

1.2.1 Industrial or commercial units

1.2.1.1 Industrial and commercial units

Areas of industrial enterprises, store houses, shops, agricultural farms (e.g. cattle-, pig-, poultry-, etc.), fair sites, exposition sites, power plants and unbuilt areas associated to industrial units, hospitals, university or school campus, etc.

1.2.1.2 Areas of special installations

Areas of technical infrastructure e.g. sewage plants, transformers, test fields of civil and military production industry, military base houses, etc.

1.2.2 Road and rail networks and associated land

1.2.2.1 Road network and associated land

Road network and associated areas. Lines of roads of minimum width 50 m with associated transport facilities (parking lots along the motorways, maintenance activities for roads, trenches, etc.).

1.2.2.2 Rail network and associated land

Rail network and associated areas. Lines of rail roads of minimum width 50 m with associated transport facilities (station buildings, maintenance activities for trains, trenches, etc.).

1.2.3 Port areas

1.2.3.1 Sea commercial, fishing and naval ports

Areas of commercial, fishery and naval ports with piers and associated infrastructure.

1.2.3.2 River and lake ports

Areas of ports situated on the lake shores or river banks with associated infrastructure of buildings and communications.

1.2.3.3 Shipyards

Areas formed by infrastructure of production and assembly halls with the associated water surface and communications.

1.2.3.4 Sport and recreation ports

Areas of sport and recreation ports with piers and associated infrastructure.

1.2.4 Airports

1.2.4.1 Airports with artificial surfaces of runways

Areas of airports with artificial surface of runways with associated grass areas and infrastructure of airport buildings.

1.2.4.2 Airports with grass surfaces of runways

Areas of airports with grass surface of runways with associated airport buildings.

1.3 Mine, dump and constructions sites

1.3.1 Mineral extraction sites

1.3.1.1 Open cast mines

Areas of open cast coal mines, oil-shale mines, gravel, sand, and clay pits.

1.3.1.2 Quarries

Areas of quarries.

1.3.2 Dump sites

1.3.2.1 Solid waste dump sites

Areas of public and industrial waste and dump sites of raw materials.

1.3.2.2 Liquid waste dumps

Areas of dump sites of liquid waste originating in mainly chemical industry.

1.3.3 Construction sites

1.3.3.1 Construction sites

Areas under construction development for which earthworks and different stages of building constructions are typical.

1.4 Artificial, non agricultural vegetated areas

1.4.1 Green urban areas

1.4.1.1 Parks

Areas of parks occurring within the settlements and formed mainly by lawns, tree and shrub greenery, strips of lanes and paths.

1.4.1.2 Cemeteries

Areas of cemeteries with vegetation.

1.4.2 Sport and leisure facilities

1.4.2.1 Sport facilities

Areas of playgrounds within or outside the urban fabric, running tracks, race-courses, ski resorts, golf grounds, etc.

1.4.2.2 Leisure areas

Areas of leisure and recreation with cottages, spa buildings with parks, castle parks, zoo-gardens, forest-parks not surrounded by urban areas, historical open-air museums, skanzens, open-air theatres, etc.

2 AGRICULTURAL AREAS

2.1 Arable land

2.1.1 Non-irrigated arable land

2.1.1.1 Arable land prevailingly without dispersed (line and point) vegetation

Plots of arable land (where cereals, legumes, industrial crops, root crops and fodder crops, semi-permanent crops as strawberries, market gardens, kitchen gardens, flowers and trees nursery-gardens - non-forestry nurseries, are cultivated), with rare occurrence of scattered (line and point) greenery. This class includes also fallow lands (3-4 years abandoned). They can be seasonally irrigated.

2.1.1.2 Arable land with scattered (line and point) vegetation

Plots of arable land (where cereals, legumes, industrial crops, root crops and fodder crops, semi-permanent crops as strawberries, market gardens, kitchen gardens, flowers and trees nursery-gardens - non-forestry nurseries, are cultivated), with sporadic occurrence of scattered (line and point) greenery - less than 15%. This class includes also fallow lands (3-4 years abandoned). They can be seasonally irrigated.

2.1.1.3 Greenhouses

Areas of glass and plastic greenhouses.

2.1.2 Permanently irrigated land

2.1.2.1 Permanently irrigated land

The same definition than for the 3rd level.

2.1.3 Rice fields

2.1.3.1 Rice fields

Areas of rice fields.

2.2 Permanent crops

2.2.1 Vineyards

2.2.1.1 Vineyards

Areas of vineyards (single vineyard plots with area of 4 ha and more; if single vineyard plots smaller than 4 ha each, in total exceeding 60% of the area are mixed with e.g. fruit trees, arable land, meadows, priority will be given to 2211).

2.2.2 Fruit trees and berry plantations

2.2.2.1 Orchards

Areas of fruit orchards (apples, plums, pears, cherries, peaches, apricots, etc.) and ligneous crops (walnut, chestnut, hazel, almond, etc.).

2.2.2.2 Berry fruit plantations

Areas of plantations of berry fruits (black and red currants, raspberries, gooseberries, etc.).

2.2.2.3 Hop plantations

Areas of hop plantations.

2.2.2.4 Kiwi plantations

Plots planted with kiwi.

2.2.2.5 Oil-bearing rose plantations

Parcels planted with oil-bearing rose.

2.2.2.6 Wild willow plantations

Areas of wild willow plantations.

2.2.3 Olive groves

2.2.3.1 Olive groves

Areas of olive groves.

2.3 Pastures

2.3.1 Pastures

2.3.1.1 Grassland (pastures and meadows) prevailingly without trees and shrubs

Areas of grassland prevailingly without trees and shrubs (less than 15%).

2.3.1.2 Grassland (pastures and meadows) with trees and shrubs

Areas of grassland with trees and shrubs (between 15-40%).

2.4 Heterogeneous agricultural areas

2.4.1 Annual crops associated with permanent crops

2.4.1.1 Annual crops associated with permanent crops

The same definition as for the 3rd level.

2.4.2 Complex cultivation patterns

2.4.2.1 Complex cultivation patterns without scattered houses

Juxtaposition of small plots of diverse annual crops, pastures and/or permanent crops (fruit trees, vineyards and berry plantations) without scattered houses (settlements).

2.4.2.2 Complex cultivation patterns with scattered houses

Juxtaposition of small plots of diverse annual crops, pastures and/or permanent crops (fruit trees, vineyards and berry plantations) with scattered houses (settlements).

2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation

2.4.3.1 Agricultural areas with significant share of natural vegetation, and with prevalence of arable land

Agriculturally cultivated areas with prevalence of arable land (over 50%) with a pronounced representation of natural vegetation, especially strips and patches of forest, grasslands and sporadic occurrence of water areas (artificial and natural).

2.4.3.2 Agricultural areas with significant share of natural vegetation, and with prevalence of grasslands

Agriculturally cultivated areas with prevalence of grasslands (over 50%) with representation of arable land, strips and patches of forest, grass communities and water areas (artificial and natural).

2.4.3.3 Agricultural areas with significant share of natural vegetation, and with prevalence of scattered vegetation

Agriculturally cultivated areas with prevalence of scattered greenery (woodland patches and bushes over 50%) with representation of arable land, grasslands and water areas.

2.4.3.4 Agricultural areas with significant share of ponds, and with presence of scattered vegetation

Agriculturally cultivated areas with prevalence of ponds (over 50%) with representation of arable land, grassland, strips and patches of forests.

2.4.3.5 Agricultural areas with significant share of permanent crops, and with presence of scattered vegetation

Agricultural areas with vineyards and orchards (to 50%) with representation of grasslands and strips of forests.

2.4.4 Agro-forestry areas

2.4.4.1 Agro-forestry areas

Areas of annual crops or grazing land under the wooded cover of forestry species.

3 FOREST AND SEMI-NATURAL AREAS

3.1 Forests

3.1.1 Broad-leaved forests

3.1.1.1 Broad-leaved forests with continuous canopy, not on mire

Areas of broad-leaved woods forming continuous canopy (crown of trees overlap one another - continuous canopy is more than 80%).

3.1.1.2 Broad-leaved forests with continuous canopy on mire

Areas of broad-leaved woods forming continuous canopy (crown of trees overlap one another - continuous canopy is more than 80%).

3.1.1.3 Broad-leaved forests with discontinuous canopy, not on mire

Areas of broad-leaved woods forming discontinuous canopy (crown of trees do not overlap one another - continuous canopy is less than 80%).

3.1.1.4 Broad-leaved forests with discontinuous canopy on mire

Areas of broad-leaved woods forming discontinuous canopy (crown of trees do not overlap one another - continuous canopy is less than 80%).

3.1.1.5 Plantation of broad-leaved forests

Artificially planted areas of the same species of broad-leaved wood, e.g. poplar, etc. These plantations are cleared and replanted in regular intervals.

3.1.2 Coniferous forests

3.1.2.1 Coniferous forests with continuous canopy, not on mire

Areas of coniferous woods forming continuous canopy (crown of trees overlap one another - continuous canopy is more than 80%).

3.1.2.2 Coniferous forests with continuous canopy on mire

Areas of coniferous woods forming continuous canopy (crown of trees overlap one another - continuous canopy is more than 80%).

3.1.2.3 Coniferous forests with discontinuous canopy, not on mire

Areas of coniferous woods forming discontinuous canopy (crown of trees do not overlap one another - continuous canopy is less than 80%).

3.1.2.4 Coniferous forests with discontinuous canopy on mire

Areas of coniferous woods forming discontinuous canopy (crown of trees do not overlap one another - continuous canopy is less than 80%).

3.1.2.5 Plantation of coniferous forests

Artificially planted areas of the same species of coniferous woods, e.g. pine, larch, spruce, etc. These plantations are cleared and replanted in regular intervals.

3.1.3 Mixed forests

3.1.3.1 Mixed forests created by alternation of single trees with continuous canopy, not on mire

Areas of forest formed by alternation of the broad-leaved and coniferous woods (crown of trees overlap one another - continuous canopy is more than 80%).

3.1.3.2 Mixed forests created by alternation of single trees with continuous canopy on mire

Areas of forest formed by alternation of the broad-leaved and coniferous woods (crown of trees overlap one another - continuous canopy is more than 80%).

3.1.3.3 Mixed forest created by alternation of single trees with discontinuous canopy, not on mire

Areas of forest formed by alternation of the broad-leaved and coniferous woods (crown of trees do not overlap one another - continuous canopy is less than 80%).

3.1.3.4 Mixed forest created by alternation of single trees with discontinuous canopy on mire

Areas of forest formed by alternation of the broad-leaved and coniferous woods (crown of trees do not overlap one another - continuous canopy is less than 80%).

3.1.3.5 Mixed forests created by alternation of stands of trees with continuous canopy, not on mire

Areas of forest formed by alternation of the groups of broad-leaved and coniferous woods (crown of trees overlap one another - continuous canopy is more than 80%).

3.1.3.6 Mixed forests created by alternation of stands of trees with continuous canopy on mire

Areas of forest formed by alternation of the groups of broad-leaved and coniferous woods (crown of trees overlap one another - continuous canopy is more than 80%).

3.1.3.7 Mixed forests created by alternation of stands of trees with discontinuous canopy, not on mire

Areas of forest formed by alternation of the groups of broad-leaved and coniferous woods (crown of trees do not overlap one another - continuous canopy is less than 80%).

3.1.3.8 Mixed forests created by alternation of stands of trees with discontinuous canopy on mire

Areas of forest formed by alternation of the groups of broad-leaved and coniferous woods (crown of trees do not overlap one another - continuous canopy is less than 80%).

3.2 Scrub and/or herbaceous vegetation associations

3.2.1 Natural grasslands

3.2.1.1 Natural grassland prevailingly without trees and shrubs

Areas of natural grasslands without trees and shrubs (less than 15%). They are formed by grasslands of protected areas, alpine grasslands, military training area and abandoned low productivity grassland (e.g. karstic poljes meadows, etc.).

3.2.1.2 Natural grassland with trees and shrubs

Areas of natural grassland with trees and shrubs (between 15-40%). They are formed by grasslands of protected areas, military training areas, alpine grasslands and abandoned low productivity grassland with trees and shrubs.

3.2.2 Moors and heathland

3.2.2.1 Heathlands and moorlands

*Areas of heathlands, moorlands and transitory peat-bogs represented mainly by dense shrubs and herbaceous plants (*Calluna vulgaris*, *Erica* sp., *Vaccinium* sp., *Genista* sp., *Rubus* sp., *Juniperus* sp., etc.).*

3.2.2.2 Dwarf pine

*Areas of mountain dwarf pine (*Pinus mugo* ssp. *mughus*) or dwarf pine planted on dunes and mires (*Pinus mugo* ssp. *uncinata*).*

3.2.3 Sclerophyllous vegetation

3.2.3.1 Sclerophyllous vegetation

Bushy sclerophyllous vegetation, including maquis and garrique.

3.2.4 Transitional woodland-scrub

3.2.4.1 Young stands after cutting (and/or clear cuts)

Areas of young stands planted by man after cutting, fire or natural disaster without vegetation.

3.2.4.2 Natural young stands

Areas of natural forest regeneration/recolonization.

3.2.4.3 Bushy woodlands

Areas formed by shrubs (Juniperus, Cisteegus, Rosa, etc.) along with dispersed trees and grassland. Crowns of shrubs and trees do not form a continuous canopy.

3.2.4.4 Forest nurseries

Areas of forest nurseries (production areas of young forest trees).

3.2.4.5 Damaged forests

Areas of forests strongly affected by air pollution, biotical injurious agents or natural disasters.

3.3 Open spaces with little or no vegetation

3.3.1 Beaches, dunes, sands

3.3.1.1 Beaches

Areas of bank sand plains prevailing without vegetation. They are adjacent to 5.2.3.

3.3.1.2 Dunes

Areas of dunes almost without vegetation or with sporadic occurrence of mainly thin grasses (occur in coastal zone as well as in inland).

3.3.1.3 River banks

Belts of river banks formed mainly by deposits of sands and gravel prevailing without vegetation.

3.3.2 Bare rocks

3.3.2.1 Bare rocks

Areas of different rock outcrops, e.g. cliffs, screes, rock-face surfaces, etc.

3.3.2.2. Products of recent volcanism

Areas of recent lava streams and mud without vegetation

3.3.3 Sparsely vegetated areas

3.3.3.1 Sparse vegetation on sands

Areas of sand plains (dunes, glaciofluvial terraces) covered by sparse vegetation.

3.3.3.2 Sparse vegetation on rocks

Areas of xerothermic grasses and shrubs of karstic terrain, or areas of discontinuous alpine grasslands and partially dwarf mountain pine.

3.3.3.3 Sparse vegetation on salines

Areas of salines covered by sparse halophilic vegetation.

3.3.4 Burnt areas

3.3.4.1 Burnt areas

Areas (mainly forest and heathlands and moorlands) after recent fires.

3.3.5 Glaciers and perpetual snow

3.3.5.1 Glaciers and perpetual snow

Areas covered by glaciers or permanent snow.

4 WETLANDS

4.1 Inland wetlands

4.1.1 Inland marshes

4.1.1.1 Fresh-water marshes with reeds

Areas of swamps with reed beds (more than 80%) and other water plants without peat deposition (peat layer is less than 30 cm thick) seasonally or permanently waterlogged with low mineral content.

4.1.1.2 Fresh-water marshes without reeds

Areas of swamps without reed beds (to 20%) and with other water plants without peat deposition (peat layer is less than 30 cm thick) seasonally or permanently waterlogged with low mineral content.

4.1.1.3 Saline (alkali) inland marshes with reeds

Areas of swamps with reed beds (more than 80%) and other water plants without peat deposition (peat layer is less than 30 cm thick) seasonally or permanently waterlogged (prevailing arheic) with higher mineral content.

4.1.1.4 Saline (alkali) inland marshes without reeds

Areas of swamps without reed beds (to 20%) and with other water plants without peat deposition (peat layer is less than 30 cm thick) seasonally or permanently waterlogged (prevailing arctic) with higher mineral content.

4.1.2 Peat bogs

4.1.2.1 Explored peat bogs

Areas of peat-bogs with extraction.

4.1.2.2 Natural peat bogs with scattered trees and shrubs, without pools

Characteristic for higher stage of bog development where conditions for pool formation are created (peat deposit more than 30 cm thick).

4.1.2.3 Natural peat bogs with pools communities

Areas of convex (raised) bog where zones of pools are perpendicular to water movement (peat deposit more than 30 cm thick).

4.1.2.4 Natural dwarf shrub bogs

*Vegetation composed of shrubs (*Calluna vulgaris*, *Ledum palustre*, *Empetrum nigrum*, *Andromeda polifolia*, *Oxycoccus* sp.) and scattered pines and birches. Situated mainly in the margin zones of bogs (peat deposit more than 30 cm thick).*

4.2 Maritime wetlands

4.2.1 Salt marshes

4.2.1.1 Salt marshes without reeds

Areas of coastal plains seasonally or permanently waterlogged covered by sparse halophilic vegetation.

4.2.1.2 Salt marshes with reeds

*Areas flooded by sea water and colonized by *Phragmites communis*.*

4.2.2 Salines

4.2.2.1 Salines

The same definition as for 3rd level.

4.2.3 Intertidal flats

4.2.3.1 Intertidal flats

The same definition as for the 3rd level.

5 WATER BODIES

5.1 Inland waters

5.1.1 Water courses

5.1.1.1 Rivers

Natural water streams of minimum width of 50 m with meanders, usually without longer straight spells of banks which are often formed by deposits of gravel, sand or trees and shrubs.

5.1.1.2 Channels

Artificial water channels or regulated water streams of minimum width of 50 m, prevailing straight.

5.1.2 Water bodies

5.1.2.1 Natural water bodies

Water areas of natural origin.

5.1.2.2 Artificial reservoirs

Water areas created by man with prevailing regular shape.

5.2 Marine waters

5.2.1 Coastal lagoons

5.2.1.1 Coastal lagoons

The same definition as for the 3rd level.

5.2.2 Estuaries

5.2.2.1 Estuaries

The same definition as for the 3rd level.

5.2.3 Sea and ocean

5.2.3.1 Sea and ocean

The same definition as for the 3rd level.

4.B.4 Conclusions

The CLC nomenclature of the 4th level at scale 1:50,000 was elaborated on the basis of proposals of the national teams of Phare countries (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Po-

land, Romania, Slovenia and Slovak Republic).

The elaboration of nomenclature was based on the morphostructural and physiognomic characteristics of the land cover classes of the 3rd level. These characteristics differentiated also landscape-ecological and functional properties of land cover and pointed at the significance of real landscape structure. Characteristics of territorial peculiarities increased the importance of land cover at national scale. More detailed knowing of land cover at scale 1:50,000 represents a suitable data for future scientific and applied research. Pattern analysis of land cover accompanied by the analysis of natural conditions and function priorities facilitates solution of ecological conflicts and risks and proposition the optimal spatial organisation of landscape. In this sense land cover data represent one of the decisive source material for environmental planning.

The CLC nomenclature 1:50,000 will support the trend of more geometric and thematic details of land cover mapping by using satellite data for practical, as well as gnoseological aims mainly at regional and partly local level policies (it will be more suitable to the needs of national users).

Land cover classes at scale 1:50,000 will be much more appropriate for the cross-reference with *e.g.* EUNIS habitats, CORINE biotopes, different statistics, etc.

Proposed land cover classes can be used as basis of the uniform European 4th level CLC nomenclature.

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Annex 4.C - Land Cover Classification System: basic concepts, main software functions and overview of the “land system” approach

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4.C.1 Introduction

People have reshaped the earth continually but the present magnitude and rate of change is unprecedented. We need to know how land cover has changed over time in order to assess the changes that may occur in future and the impact that these changes will have on people's lives. Changes in land cover affect the atmosphere, climate and sea level (Meyer & Turner 1992). The sustainable management of land resources has become more important with time since the most suitable land areas are in use for agriculture and supply of new lands is limited to marginal areas or areas with a high value concerning biodiversity or history (*e.g.*, cultural landscapes such as certain heath lands).

The main resource controlling primary production for terrestrial ecosystems can be defined in terms of land: the area of land available and its quality. Land cover is the easiest detectable indicator in the landscape that can be used to estimate the spatial extent, duration and time of vegetative cover, as well as a measure for land cover change and correlation with land-use pressure. Especially in combination with land-use an increased understanding of agriculture and environmental sustainability might be gained.

Land cover data forms a baseline data set for applications ranging from forest and rangeland monitoring, production of statistics for planning and investment, biodiversity, climate change to desertification control (Di Gregorio & Jansen 2000). However, land cover changes quickly over time and data need to be updated at regular intervals in order to monitor changes and to predict future trajectories.

In the past natural resources information was collected by each individual discipline with methodologies that allowed limited spatial analysis. Today many disciplines are still producing their own data sets but in future the trend will move towards data sharing between technical disciplines, organisations and institutes, as well as countries. This data sharing will be an essential step in the evaluation and management of (cross-boundary) environmental resources, in addition to making the most effective use of human and financial investment in data collection. In order to facilitate data sharing it will be important that these data are being harmonised, *i.e.* being brought to the level of a “common language”.

4.C.2 LCCS Concepts

Despite the importance of land cover, there is no internationally accepted reference classification. Many classifications and legends exist that are heterogeneous with respect to quality, scale, criteria used and resulting nomenclature. Class definitions are imprecise, ambiguous and/or absent. Most existing systems are very limited to accommodation of the whole range of potential land cover classes, *i.e.* they are dedicated to either vegetation or cultivated areas or built-up areas (Di Gregorio & Jansen 2000).

LCCS was created as response to a need for harmonised data collection in different environmental settings, the availability of the resulting data for a range of applications and the need for comparison of land cover types (*e.g.*, in time-series analyses and cross-boundary environmental problems).

The challenge while developing LCCS was to create a comprehensive classification system that can accommodate any occurring land cover anywhere in the world independent of scale. The methodology developed has been structured with the guiding principle that criteria used at the higher levels of the classification system can be more easily detected and described than those at lower levels, *i.e.* with a high geographic accuracy (Di Gregorio & Jansen 2000). The use of explicit criteria assures the internal consistency of the system.

LCCS defines *land cover* as “the observed biophysical cover on the earth's surface” (Di Gregorio &

“Developments in Strategic Landscape Monitoring for the Nordic Countries.” Groom, G. (ed) Nordic Council of Ministers. ANP 2004:705, pp 64-73

Jansen 2000) and classification as “the ordering or arrangement of objects into groups or sets on the basis of their relationships” (Sokal 1974). Classification is an abstract presentation of the situation in the field using a set of well-defined criteria. In theory two types of classification can be distinguished:

- a priori classification: in which the criteria and classes are predefined, *i.e.* prior to data collection.
- a posteriori classification: in which the criteria and classes are defined after data collection.

The first type of classification has the advantages that criteria and classes can be ordered in order to achieve data harmonisation between different users of the system. The disadvantage is the implicit rigidity of the approach because a certain field situation may not be present in the classification and therefore a class needs to be selected that assures a “best fit” with the actual sample site. The second classification type depends on the area where the data has been collected and allows a very good fit between the classes of the classification and the samples. However, the approach cannot readily be used by different users working in different areas because it is area-dependent. Data harmonisation is extremely hard to achieve and would require covering the largest area possible. However, the advantage is the greater flexibility of the approach.

In LCCS legend is defined as “the application of a classification in a particular geographic area” (Di Gregorio & Jansen 1998, 2000). It will depend on the geographic area which of the classes in the classification will be present. Usually only a sub-set of the classes of the classification will be found (Figure 4.C.1).

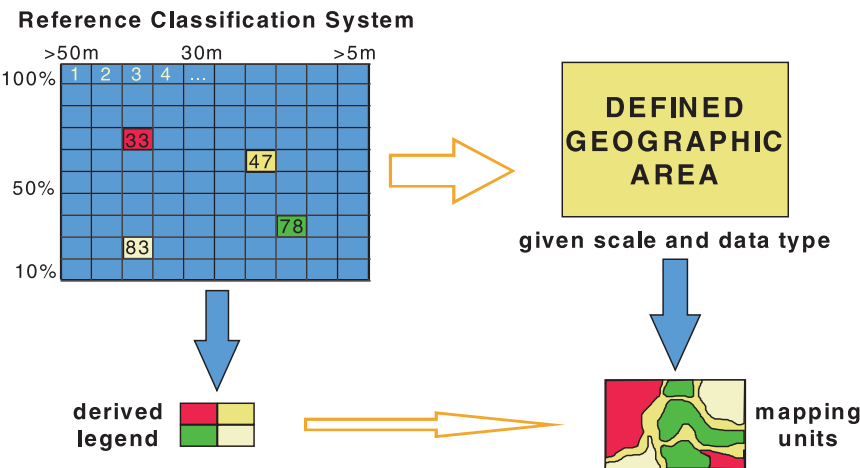


Figure 4.C.1. Legend as application of a classification in a defined geographic area (Di Gregorio & Jansen 2000).

In order to develop a classification system that combines two seemingly contradictory requirements, *i.e.* allow harmonisation -and possibly standardisation- while at the same time being highly flexible, one has to match an a priori classification containing enough classes to cope with the real world and at the same time adhere to strict and unambiguous class boundaries to assure the geographic accuracy (Figure 4.C.2). The basic principle adopted in LCCS is that a land cover class is defined by a set of independent diagnostic criteria, the so-called classifiers, which are arranged in a logical and functional order to assure a high degree of geographic accuracy. This principle seems to be impeded by the fact that land cover

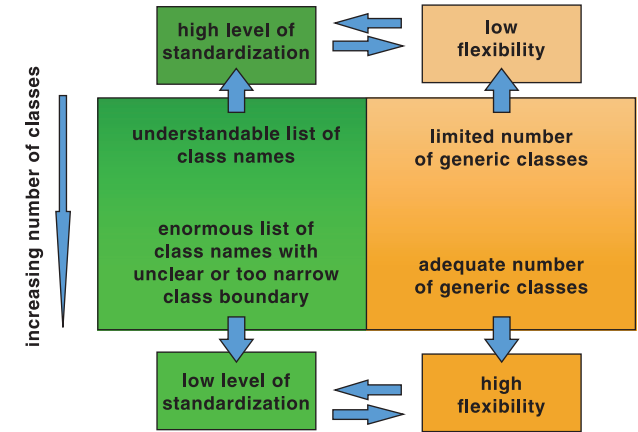


Figure 4.C.2. A priori classification in relation to flexibility and ability to accommodate numerous classes (Di Gregorio & Jansen 2000).

deals with a heterogeneous set of features (*e.g.*, from cultivated areas to vegetation to built-up areas or water surfaces). To avoid meaningless combinations of classifiers, these have been tailored to the main land cover features.

Furthermore, with the aim of achieving a logical and functional hierarchical arrangement of the classifiers certain design criteria have been applied. The classification contain two phases (Figure 4.C.3):

- an initial *Dichotomous Phase* where eight major land cover types are distinguished with three classifiers “presence of vegetation”, “edaphic condition” and “artificiality of cover”:
 - Cultivated and Managed Terrestrial Areas
 - Natural and Semi-Natural Terrestrial Vegetation
 - Cultivated Aquatic or Regularly Flooded Areas
 - Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation
 - Artificial Surfaces and Associated Areas
 - Bare Areas
 - Artificial Waterbodies, Snow and Ice, and
 - Natural Waterbodies, Snow and Ice.
- this phase is followed by a lower *Modular-Hierarchical Phase* where the set of classifiers and their hierarchical arrangement are tailored to the major land cover type.

A land cover class is created by a stepwise selection of classifier options that will generate the following elements (Table 4.C.1):

- a string of codes, the so-called *Boolean Formula*;
- a *Standard Class Name*; and
- a unique *Numerical*, or *GIS, Code*.

Table 4.C.1. Illustration of the elements of a LCCS land cover class (from Jansen & Di Gregorio 2000)

<i>Classifiers</i>	Example “Natural and Semi-natural Terrestrial Vegetation” (A12)		
	<i>Boolean Formula</i>	<i>Standard Class Name</i>	<i>GIS Code</i>
A. Life Form & Cover	A3A10	Closed Forest	20005
B. Height	A3A10B2	Closed Forest	20006
C. Spatial Distribution	A3A10B2C1	Continuous Closed Forest	20007
D. Leaf Type	A3A10B2C1D1	Broadleaved Closed Forest	20095
E. Leaf Phenology	A3A10B2C1D1E2	Broadleaved Deciduous Forest	20097
F. 2 nd layer: Life Form, Cover & G. Height	A3A10B2C1D1E2F2F5F7G2	Multi-layered Broadleaved Deciduous Forest	20628
F. 3 rd layer: Life Form, Cover & G. Height	A3A10B2C1D1E2F2F5F7G2 F2F5F10G2	Multi-layered Broadleaved Deciduous Forest with Emergents	20630

In addition, the user can optionally add two types of attributes:

- *Environmental Attributes*: these are attributes that are not inherent features of land cover but may influence land cover (*e.g.*, landform, lithology, soils, climate, altitude, erosion, *etc.*). They can be added to the land cover class as a further characterisation of the environment in which the land cover occurs, rather than to add a new data layer.
- *Specific Technical Attributes*: these attributes refer to the technical discipline of the major land cover type (*e.g.*, Floristic Aspect for (Semi) Natural Vegetation, Crop Type for Cultivated Areas and Salinity for Waterbodies.

Because of the complexity of the classification and the need for harmonisation, and possibly standardisation, a software application has been developed to assist the interpretation process and facilitate the consistency of applications.

4.C.3 Software application

Because of the complexity of the classification and the need for standardization, a software program has been developed to assist the interpretation process. This software program facilitates not only the standardization of the interpretation process but, also, contributes to its consistency. Despite the huge number of classes that can be generated, an interpreter is dealing only with one classifier at a time and each class is built up by stepwise selection of each classifier, aggregating a number of classifiers to derive

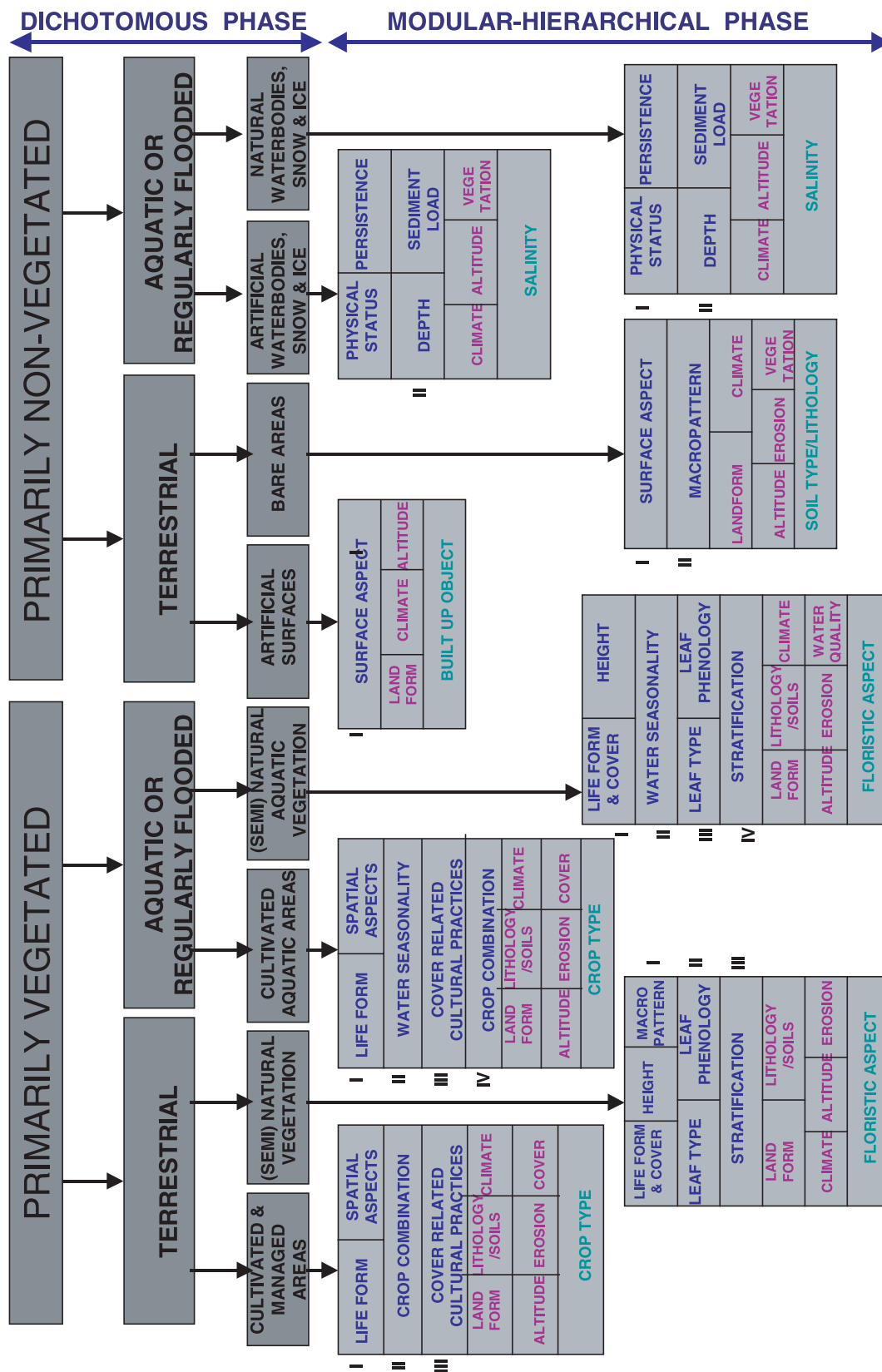


Figure 4.C.3. Schematic presentation of LCCS with the eight major land cover categories of the Dichotomous Phase and the arrangement of classifiers in the Modular-hierarchical Phase (in dark blue), the environmental attributes (in purple) and the specific technical attributes (in green) tailored to the major land cover type (Di Gregorio & Jansen 1998, 2000).

the class. This will assist in reducing variation between interpreters and with interpretations over time. The LCCS software consists of four modules (Figure 4.C.4):

- *Classification* provides a standardised approach for classifying land cover classes as described above and with the option to add environmental and/or specific technical attributes;
- *Legend* provides storage of the land cover classes according to the domains to which these classes belong, storage of the standardised class descriptions and list of classifiers used. This module allows export of data in commonly used file formats and allows users to add user-defined attributes to the land cover classes;
- *Field Data* provides storage of the detailed field survey information and automated classification of these data (this module is not available in version 1.0);
- *Translator* provides the possibility to compare classifications and legends using LCCS as a reference base. Comparison is possible at the level of the class and at the level of the classifiers.

The LCCS software program has been developed by FAO under the AFRICOVER Project with support

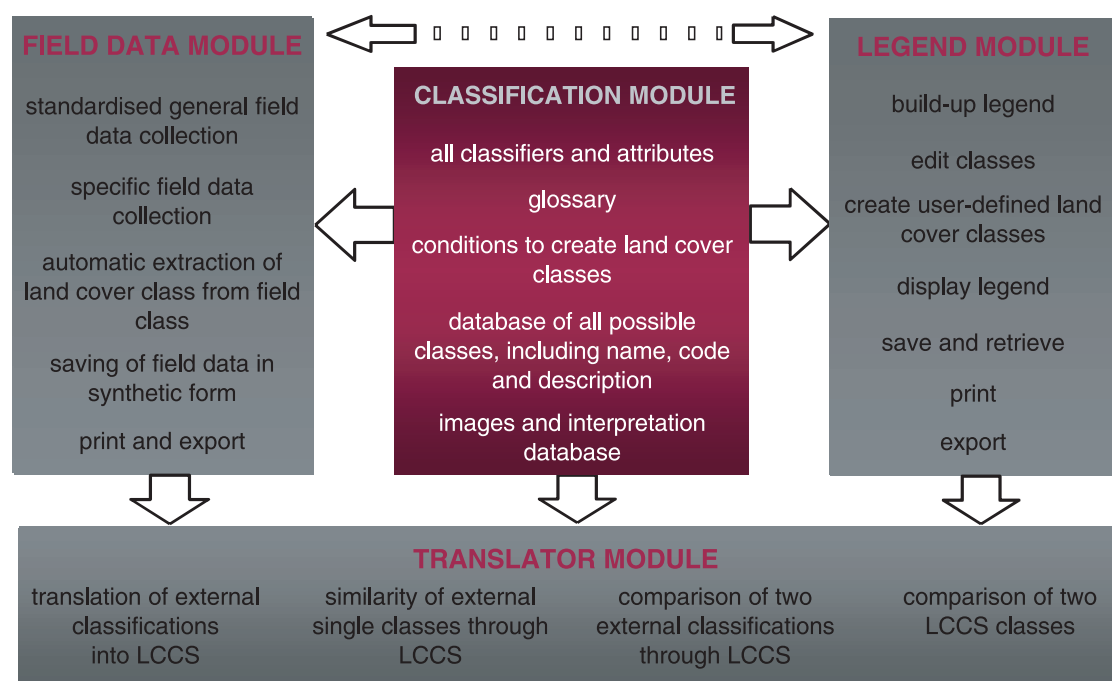


Figure 4.C.4. Overview of the LCCS software applications functions (Jansen & Di Gregorio 2000).

from UNEP. At present, it is in operational use by the Eastern Africa Module of the AFRICOVER Project, which is collecting land cover data in 11 countries. The program has been tested by members of the EC LANES concerted action on the development of a framework for a multi-purpose land cover and land use information system (LANES 1998). Furthermore, it has been applied in Bulgaria for the preparation of a land cover database to strengthen the country's capacity in agricultural development (Travaglia *et al.*, 2001), for data translation and class comparisons using existing legends (Jansen *et al.* 2003; Jansen & Di Gregorio 2003; McConnell & Moran 2001), in FAO projects in Yemen and Azerbaijan, for land cover change studies (Jansen *et al.* 2003) and at the Istituto Agronomico per l'Oltremare in Florence for the Italian Cooperation programme with the Regional Centre Agrhymet, Niamey, on management of natural resources and food security (Mahamadou 2001). The methodology has been endorsed by FAO and UNEP, as well as by the joint International Geosphere Biosphere Programme and International Human Dimensions Programme on Land Use Land Cover Change (LUCC) (McConnell & Moran 2001).

LCCS is released on CD-ROM with the accompanying documentation on the classification concepts and use of the software application. It is also available through downloading via the Internet at the addresses www.africover.org and www.lccs-org.com.

4.C.4 Application of LCCS for environmental change

Not only is there need for improved land cover data but also there is also need for compatibility between data sets in order to monitor, evaluate and analyse processes concerning land surfaces (Di Gregorio 1991, Reichert & Di Gregorio 1995, Thompson 1996, FAO 1997). A parametric land cover classification such as LCCS can facilitate environmental change studies because the criteria used to define classes function at the same time as the parameters to be observed over time (Jansen & Di Gregorio 2002).

Most existing classifications and legends in Europe (*e.g.* ECE-UN 1989; CEC 1995) are based upon class names thereby not facilitating the use of these systems for monitoring purposes. It is more difficult to interpret a change in class names than comparing two sets of parameters. Land cover change detection has to recognise that changes take two forms: conversion from one land cover category to another (*e.g.* from pine forest to grassland), and modification within one category (*e.g.*, from rainfed cultivated area to irrigated cultivated area). These two forms of change have implications for the methodology used to describe and classify land cover. Conversion implies an evident change, whereas modifications are much less apparent. The latter requires a greater level of detail to be accommodated (Jansen & Di Gregorio 2002).

With a system based upon class names the latter type of land cover change cannot be captured unless the system contains an ample set of classes. LCCS can capture both types of land cover changes at a great level of detail as is shown by a series of examples.

The first example (Table 4.C.2) shows a land cover conversion from vegetation into a cultivated area type of class. The set of parameters is different except for the first classifier “Life form” that both classes contain and that can be compared. However the options of the “Life form” are not identical. This type of change is evident in the field as well as by the different set of criteria used to define the class.

Table 4.C.2. Example of land cover conversion.

Classifier	Classifier option	Classifier	Classifier option
<i>Land cover conversion from one land cover type to another type: from “Multi-layered needleleaved evergreen forest” (left) to “Rainfed herbaceous crops – rye (Secale cereale L.)” (right)</i>			
A. Life Form of Main Layer:	Trees	A. Life Form of Main Crop:	Herbaceous
A. Cover:	Closed	B. Field Size:	Large to medium
B. Height:	> 30-3m	B. Field Distribution:	Continuous
C. Macropattern:	Continuous	C. Crop Combination:	Single crop
D. Leaf Type:	Needleleaved	D. Cover-Related Cultural Practices: Water Supply	Rainfed
E. Leaf Phenology:	Evergreen	D. Cover-Related Cultural Practices: Cultivation	-
F. 2 nd layer Life Form:	Trees	Time Factor	
F. 2 nd layer Cover:	Closed to open		
G. 2 nd layer Height:	> 30-3m		
T. Floristic Aspect:	-	S. Crop Type:	Rye (<i>Secale cereale L.</i>)

The second set of examples (Table 4.C.3) show two type of land cover modification. The first example shows a modification within the domain of “Graminoid crops”. The change is related to “Field size”, “Water supply” and “Crop type”. This type of change could be linked to a change in land-use, *i.e.* intensification of the cropping system with possibly a use of large agricultural machinery that can only be used in large-sized fields. The second example show a modification within the major land cover type “Vegetation” but a shift in domain, *i.e.* from a “Forest” land cover to a “Woodland” due to a change in the classifier “Cover”. The classifier “Macropattern” may indicate that an original continuous forest has been used for logging purposes resulting in a fragmentation of the trees.

The interpretation of observed land cover changes in land-use terminology should be substantiated by further proof from ground observation or interviews with land-users.

LCCS also contains the possibility to calculate the similarity between land cover classes. This type of analysis is useful in order to analyse which classes are more similar and therefore more difficult to distin-

Table 4.C.3. Examples of land cover modification.

Classifier	Classifier option	Classifier	Classifier option
<i>Land cover modification within the land cover domain: from “Small-sized field(s) of rainfed graminoid crop(s)” (left) to “Large-sized field(s) of irrigated graminoid crop(s)” (right)</i>			
A. Life Form of Main Crop:	Graminoids	A. Life Form of Main Crop:	Graminoids
B. Field Size:	Small	B. Field Size:	Large
B. Field Distribution:	Continuous	B. Field Distribution:	Continuous
C. Crop Combination:	Single crop	C. Crop Combination:	Single crop
D. Cover-Related Cultural Practices: Water Supply	Rainfed	D. Cover-Related Cultural Practices:	Irrigated
D. Cover-Related Cultural Practices: Cultivation Time Factor	-		
S. Crop Type:	Rye (<i>Secale cereale</i> L.)	S. Crop Type:	Maize (<i>Zea mays</i> L.)
<i>Land cover modification within the major land cover type: from “Needleleaved evergreen forest” (left) to “Fragmented open forest (Woodland)” (right)</i>			
A. Life Form of Main Layer:	Trees	A. Life Form of Main Layer:	Trees
A. Cover:	Closed	A. Cover:	Open
B. Height:	> 30-3m	B. Height:	> 30-3m
C. Macropattern:	Continuous	C. Macropattern:	Fragmented
D. Leaf Type:	Needleleaved	D. Leaf Type:	-
E. Leaf Phenology:	Evergreen	E. Leaf Phenology:	-
F. 2 nd layer Life Form:	-	F. 2 nd layer Life Form:	-
F. 2 nd layer Cover:	-	F. 2 nd layer Cover:	-
G. 2 nd layer Height	-	G. 2 nd layer Height	-
T. Floristic Aspect:	-	T. Floristic Aspect:	-

guish than classes that are dissimilar. In this way, the user can identify which type of distinction should be made with caution because it is being based upon minor differences between land cover features (*e.g.*, the same set of classifier with identical options selected save for one classifier). Furthermore, such class distinctions should be supported by a significant validation effort to substantiate their separation. This type of analysis also provides an insight in the determining characteristics for class separation and whether or not such a criterion can be detected on any of the materials available for interpretation (*e.g.*, field observations, aerial photography and/or satellite imagery) (Jansen *et al.* 2003).

4.C.5 Land System approach

The term “land unit” is regarded as a general term to be used when referring to a homogenous unit of land of any size, whilst “land system” is identified as homogenous according to certain preconceived criteria.

Land system is primarily a major geomorphic unit having a predominantly uniform geology, climate, vegetation and a characteristic soil association. The Australian CSIRO Division of Land Research devised a first approach to a land system classification in 1947.

If a portion of the earth is not examined in its single elements but as a synthetic result of the interrelations between land cover, landform, geology, soils, climate, land-use, etc., one cannot speak of an analytical approach but one speaks of a “holistic” one. In scientific terms “holistic” means that an element is observed in its structural and functional dimensions, *i.e.* the element is more than the sum of its single components. Different levels are distinguished in the “land system” approach, these are:

- Complex land system, related to physical geography. This unit has a distinctive topography with an equally distinctive vegetation structure associated at the level of plant sub formation. Local land-uses usually fit.
- Land system, related to geomorphology. This unit shows a recurrent landform pattern and geomorphologic related smaller units, so-called “land facets”, as well as distinctive vegetation and local land-use patterns.
- Land facet, related to geomorphology and botany. This level exists of a major physiographic unit with a distinctive assemblage of landforms and uniform fit of the natural vegetation (*e.g.* plant formations).
- Site, related to botany. This level exists of the simplest part of the landscape, *i.e.* uniform in vegetation

(e.g. plant associations), landform, climate, geology, hydrology and soils (e.g. contains a characteristic soil phase/soil type).

Different types of land classifications have evolved over time in different countries. Table 4.C.4 gives an overview of the most common land classifications.

A major constraint of the current land classifications is that they do not consider the problem of standardisation of the individual disciplines used to create a land classification. The land system concept in its current form is an “ordering/arrangement of portions of the earth surface in predefined macro (e.g. land province) or micro (e.g. land system, land facet, etc.) units”. In order to create the system, the user does not have at his or her disposal a systematic list of geological, geomorphologic, vegetation, etc., classes that are ordered in a comprehensive classification system. Different users can use different land cover (or other) classifications to obtain results. This creates an obvious “incomparability” between users in different parts of the world or even within the same country. The hierarchical arrangement of the land classification leads to “subjectivity” and imposes an inflexible mapping approach (i.e. from small to large scales). The different levels of land classification are difficult to harmonise. The placement of a particular area in one of the land system classes can be very subjective. The relation scale/type of land units cannot be used in a rigid way. Moreover, more than the scale the inherent characteristics of the area determine the type of land unit. In order to rationalise this situation, the user is obliged to map the whole region, progressively going from small to large scales. However, even with this not very pragmatic approach a high degree of “subjectivity” remains.

4.C.6 Conclusions

LCCS is a true parametric classification system in which the criteria used to define classes are explicit and quantifiable. The arrangement of the parameters is guided by the principle of geographic accuracy. However, from a database point of view the hierarchically presented structure does not impose any problems when querying the resulting classes. One could speak therefore of a flat database structure.

The same set of criteria can be used for monitoring purposes. Comparison of two land cover descriptions of the same area at two different moments in time leads to a comparison of classifiers used and the selected options. This methodology allows detection of land cover conversions as well as the less easily detected land cover modifications. In addition to comparisons of two classes for time series analyses, the user can also calculate the similarity between classes. The values help in understanding how similar classes are and where the differences between classes are based upon a difference in classifier option or in the occurrence of an additional classifier. This type of distinction between classes should be based upon a sound field validation approach.

Land classifications have been developed in different parts of the world in order to describe the landscape in a holistic manner. However, since there has been no attempt made to harmonise and standardise the various systems used to describe the different elements in the landscape, the results are very subjective. Furthermore, the current land system approaches require description from small to large scales, which seems rather non-pragmatic.

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Table 4.C.4. Overview of the most common land classifications.

Scale	Main discipline	Main types of terrain classes per land classification*									
		FAO	Australia CSIRO	UK DOS	Netherlands Van Zuidam ITC	Netherlands Zonneveld ITC	Russia S.G.	Canada CFS	USA USFS		
< 1:250 000	Physical geography	Land province	Complex land system	Land region	Terrain Province	Major landscape	Mestnosti	Land district	Land subregion		
> 1:250 000	Geomorphology	Land system	Land system	Land system	Land system	Land system	Mestnosti Urochischa	Land	Land types System ass.		
> 1:50 000	Geomorphology /Botany	Land facet	Land facet	Land facet	Terrain units	Land unit (facet)	Urochischa	Land types	Land type		
> 1:10 000	Botany	Land element	Site	-	Terrain elements	Ecotope	Facies	-	Habitat type		

* FAO Food and Agriculture Organization of the United Nations, CSIRO Commonwealth Scientific and Industrial Research Organization, DOS Directorate of Overseas Survey, ITC International Institute for Aerospace Surveys and Earth Sciences, S.G. Survey Geographic, CFS Canada Forest Service, USFS United States Forestry Service.

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5. Global land cover harmonisation: report of the UNEP/FAO expert consultation on strategies for land cover mapping and monitoring, 6 - 8 May 2002, Artimino, Italy

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Summary

Mapping and monitoring of land cover contributes to a better understanding of the environment and its dynamics. Increasingly remote sensing is used as tool to collect such land cover data. In order to be able to integrate and harmonise data on regional and global scales harmonisation of approaches and standardisation of methodologies is needed. The proposed establishment of a Global Land Cover Network would play a key role in the strategies to be followed for harmonisation and standardisation. FAO and UNEP organised an Expert Consultation to draw on the collective knowledge of the participants for advice on the development of an operational strategy for the proposed network. Furthermore, a contribution to the increased awareness to the Land Cover Classification System was made as the methodology with the potential of becoming the referential standard: it provides a neutral terminology, is flexible and can be used as a system to bridge between existing nomenclatures.

keywords: land cover; classification; mapping; FAO; UNEP; LCCS

5.1 Introduction

Land cover is globally one of the major Earth surface parameters that is mapped and monitored in order to better understand, use and manage the environment and its associated ecology. Acquisition of land cover data has made great use of remote sensing, including work undertaken in numerous landscape level mapping and monitoring programmes of the Nordic countries. However, differences in the way land cover data have been produced and processed have led to the need for specific efforts towards its integration and harmonisation on regional and global scales. Following significant developments and experiences in land cover data production and harmonisation in recent years, the FAO and UNEP agencies of the UN have proposed establishment of a Global Land Cover Network (GLCN). As a step towards this aim, an expert consultation meeting for Strategies on Land Cover Mapping and Monitoring was held with 60 delegates (Annex 5.A) at Artimino (Italy) in May 2002 (Annex 5.B; FAO/UNEP 2002). The NordLaM project participated in this meeting, which is reported here by the project's representative at Artimino.

5.2 Objectives

5.2.1 Objectives of the meeting

The principles of sustainable development set out in the United Nations Conference on Environment and Development (UNCED) Agenda 21 have been reaffirmed by the Millennium Declaration of the United Nations General Assembly. The assessment of land cover and the monitoring of its dynamics are essential requirements for sustainable management of natural resources and environmental protection. Land cover is a baseline dataset for fulfilling the Framework Convention on Climate Change (UNFCCC), Convention to Combat Desertification (UNCCD), Convention on Biodiversity (UNCBD) and the United Nations Forest Forum (UNFF). The implementation of a programme to harmonise the approach to land cover in monitoring programmes is an essential step in providing reliable land cover information to a large user-community.

In 2000, the United Nations Environment Programme (UNEP) and the Food and Agriculture Organization of the United Nations (FAO) laid the foundations for a cooperative programme by adopting the FAO/UNEP Land Cover Classification System (LCCS) (Di Gregorio & Jansen 2000). The FAO Africover

"Developments in Strategic Landscape Monitoring for the Nordic Countries." Groom, G. (ed) Nordic Council of Ministers. ANP 2004:705, pp 75-81 + 3 Annexes

Project is the first regional land cover project that has applied LCCS in the eastern African sub region. In central and east Europe and former Soviet republics the methodology has been applied at national level, for example in Bulgaria (Travaglia *et al.* 2001) and Azerbaijan.

The main objective of the meeting was the usage of the collective knowledge of the participants for advice on an operational strategy for the establishment of a Global Land Cover Network (GLCN). Furthermore, the meeting would contribute increased awareness of LCCS as the most advanced methodology to date with the potential of becoming a referential standard.

5.2.2 Objectives of the NordLaM participation

Within the NordLaM activity “Theme 1 – The inter-relation of Nordic monitoring classification systems and nomenclatures” the participation of the Nordic Landscape Monitoring (NordLaM) Project in the meeting focussed on the capacity of LCCS as a tool to achieve class correspondence, *i.e.* thematic harmonisation, between existing legends and classifications used by the various national operational landscape-level monitoring programmes in the Nordic countries (Groom & Reed 2001). Furthermore, the results of the ongoing discussion within the NordLaM – LCCS activity would feed back into the general discussion of the appropriateness of LCCS as a bridging language between existing land cover nomenclatures.

The meeting provided opportunities for discussion and exchange of information and experiences, the examination of current status of various (sub) regional land cover activities and further developments in the Africover land cover mapping methodology. In addition, the role of Europe and CORINE land cover in the GLCN to be established could be evaluated, as well as the role of individual European countries.

5.3 Findings

5.3.1 Global user requirements and status (Plenary session, 6 May)

The emphasis in this first plenary session was mainly on global land cover activities and data collection efforts under way. Presentations were made on the Land Use and Land Cover Change project (LUCC) of the IGBP, the Global Land Cover 2000 (GLC2000) project, the Global Terrestrial Observing System (GTOS) and GOF/C/GOLD network and the Japanese Global Land Cover Mapping Project. Points noted in these presentations included:

- existing evaluation of LCCS has been made, but further testing should also be made (LUCC)
- a parallel land use system would be welcome (LUCC)
- the LCCS has been adopted as a basis for global LC mapping activities (GLC2000)
- compatibility of the LCCS with other LC applications is essential (GLC2000)
- production of a high quality map product does not necessarily result from standardisation (GLC2000).

5.3.2 The UN Land Cover Classification System (Plenary session, 6 May)

The meeting was reminded of the origins of LCCS for Africover as a result of realised limitations of alternative classification systems based on predefined classes for regional and continental application. Different presenters in this session noted the features of LCCS, such as its flexibility in LC mapping of different degrees of detail, the clear meaning of its derived classes. Its application potential as a bridging system between non-standardised legends, and also between statistical census data and mapping programme data was noted.

Recent developments in the Africover methodology were presented as well as various existing and developing UNEP and FAO networks. These were seen as also related to and relevant to the GLCN, the core ideas and design of which were presented next. The network itself and establishment of the LCCS global database are seen as key GLCN elements. The importance of the GLCN as a technical forum was noted. Other comments from the presenters and meeting participants noted the need for pilot studies using LCCS, the need for balance between harmonisation and local problems and solutions, and the need for quality assessment processes.

5.3.3 Regional Round Table

Expert contributions from six regions worldwide were made via a “Regional Round Table” panel discussion session. The NordLaM representative was one of the two experts from Europe that sat at this Table. The purposes of the RRT were to create awareness of regional LC mapping activities and priorities, and to obtain regional advice on strategies and common standards for global LC mapping. Annex 5.C provides a comprehensive overview of the presentation of the land cover activities in Europe during the RRT. In summary:

- In EU Member States the standard used for land cover mapping and monitoring is CORINE Land Cover (CEC 1995). The European Environmental Agency and EUROSTAT have a mandate on provision of land cover data/statistics within the European Union. (It should be noted that the EEA was not represented at the meeting.)
- In accession countries, the CORINE approach has been implemented in several nations. However, in central and eastern Europe the CORINE land cover approach is being used in parallel with LCCS depending on whom is executing and/or financing (within the UN context LCCS is used, within the European Commission CORINE-LC). Therefore, this sub region could be identified as a priority area for harmonisation of approaches.

The findings of the RRT overall included:

- Land cover data is mainly used for crop and forest inventory surveys at national or sometimes regional level. Recent developments show that these data are also being used for other environmental, industrial and food security purposes.
- Lack of standardisation at country, regional and global levels was felt to be an important impediment for integration of data sets and consequently a constraint on well-informed decision-making.
- Success stories and problems identified by operational networks should be analysed and the lessons learned integrated in the cooperative program to establish the global network on land cover.

5.3.4 Working Group discussions

A set of three Working Groups, involving all participants developed further the consultation. These three WGs were focussed on: (1) the LCCS, (2) methodologies for an LCCS-based Global Land Cover Database, and (3) the strategic framework for development of an FAO/UNEP GLCN. Within the context of the NordLaM Theme 1 interest in the operational use of the LCCS tool for thematic harmonisation, in particular the Translator Module, participation in the WG-1 was the logical choice.

Working Group 1 – the FAO/UNEP Land Cover Classification System (LCCS)

The discussion within WG-1, which was co-chaired by the NordLaM representative centred on the following issues:

1. Assessment of LCCS’s appropriateness to meet a broad range of users from different technical disciplines.
2. Overview of the experiences with the use of LCCS, its applicability, compatibility with existing nomenclatures and harmonisation options.
3. To derive a number of principles from which recommendations could be derived considering the technical level involved in further development and use of LCCS.

The main issue addressed was that adoption of LCCS is a process in which the users are involved in order to meet their requirements, thus representing a bottom-up approach. Furthermore, the establishment of a technical panel to guide the process of feedback and changes to be adopted is seen as a crucial element to ensure that LCCS remains a technically sound methodology. Based upon its discussion this WG formulated three principles:

- LCCS is an innovative land cover classification system which meets the needs of a wide multi-user community and in this sense is a truly multi-user oriented methodology which can be used to compare LC information collected at common scales from various land observing systems, including *in situ* observations and measurements, aerial photographs and satellite data.

- LCCS is an open, transparent and evolving system based on users' participation.
- LCCS has the basic prerequisites to become the international referential standard for land cover classification (e.g. being technically sound, acceptable by the user-community).

From these principles the following recommendations are derived:

- 1.1 To promote among the LC community awareness of LCCS potentialities and participation in the development of applications.
 - 1.2 To analyse and evaluate feedback from a wide range of applications/users.
 - 1.3 To develop pilot studies of nested LC systems (e.g., up and downscaling of LC data).
- 2.1 A user-community network should be set up to allow and facilitate:
 - dialogue, interaction and exchange of experiences; and
 - training, including the development of training tools such as tutorials, distance learning, guidelines and FAQ.
 - 2.2 A technical panel should be set up to:
 - evaluate feedback from users;
 - propose upgrades of LCCS to the user-community; and
 - implement, document and disseminate the upgraded versions of LCCS.
 - 2.3 Sub regional workshops should be organised to promote the use of LCCS and to encourage participation in the network.
- An *ad hoc* working group should be set up to explore and pursue certification of LCCS under ISO.
 - LCCS users should produce metadata.
 - Populate the LCCS Translator Module with translation of existing legends, in particular global, regional, sub regional and national legends, involving the authorities responsible for those legends, to be certified by the technical panel in 2.2 above.

Who and when (with the "when" shown in parenthesis)?

Within the overall framework of the network the following should be located:

- facilitator (immediate)
- user-community (within several months)
- technical panel (within a year)
- ad hoc working group (ISO) (to be determined).

All of them within the overall network (subcomponents of this network).

Working Group 2 - Methodologies for establishment of LCCS-based global land cover database

The objective of a LCCS-based global land cover database is to satisfy the requirements of UNEP and FAO programmes and projects. These products will also be useful to other users such as other UN agencies and programmes, government organisations, bi-lateral co-operations, NGOs, private sector and researchers. The design of the LCCS-based methodology for the establishment of the global LC database consists of two tracks:

1. Fast track methodology: a short cut solution based on translation of existing land cover databases into LCCS nomenclature (e.g., in the European context CORINE LC); and
2. Standard track methodology: based on the application of the Africover methodology.

The justification of the fast track methodology is to supply land cover information to ongoing UNEP and FAO programmes as soon as possible. It consists of the following tasks:

- Inventory of existing land cover databases;
- Review of their legends, class definitions, accuracy and dates;
- Selection of compatible databases, at least on an interim basis, with UNEP and FAO LC requirements;
- Screening of the LC classes;
- LCCS translation;
- Editing, formatting and labelling of translated LC classes;
- Inclusion of fast track LC classes in the LCCS global LC database; and

- Inclusion of information on the fast track LC classes in the meta database and its dissemination through the GLCN.

The standard track methodology will be used in new land cover mapping activities following the Africover methodology that is based on the following principles:

- New coverage by high-resolution earth observation satellites (*e.g.*, 10 - 50 m ground resolution) will be the primary source for input data. In areas with persistent cloud cover SAR data will be used.
- Uniform geodetic framework for global LCCS LC database will have the following parameters:
 - Reference ellipsoid: Geodetic Reference System 1980 (GRS 80);
 - Geodetic datum: World Geodetic System 1984 (WGS 84);
 - Cartographic projection: Universal Transverse Mercator (UTM) ; and
 - Planimetric accuracy: 50 m (dominant base map features) to 100 m (land cover polygons).
 - The global Earthsat GeoOrtho product, which is in the public domain and has planimetric accuracy of less than 50 m, will be used as the base map for the global LCCS-based LC products.
- Interpretation of satellite images will be supported by the software packages developed by the Africover Project, *i.e.* GeoVis and AIMS (note by the reporter: this s/w is not operational).
- Content and architecture of the LCCS-based global LC database will provide flexibility for generation of multi-level and multi-application LC products corresponding to UNEP and FAO LC requirements. Its geometric accuracy will be compatible with requirements of LC mapping at up to 1:100,000 scale and related GIS data integration, processing and modelling.
- The main product will be GIS-based LCCS-based global LC database. After project completion, the LCCS database will become part of the UNEP/FAO GLCN. Its component regional (=continental) and national LC databases will be maintained by regional and national organisations that participated in the Africover project implementation (note by reporter: the risk is that the end product will be fully controlled by UNEP/FAO).
- Development of a meta database to be available on the UNEP/FAO GLCN web site.

The WG-2 envisaged that the methodology will be user-friendly to facilitate capacity building for LC classification and mapping based on the LCCS and Africover methodology. However, the approach as presented seems rather top-down and not based upon identified user-requirements but rather on specific institutional requirements.

The WG-2 further specified three requirements for the output products:

- Accessibility: products will be accessible to all qualified users (this term is not further specified);
- Consistency: production, storage and distribution of LCCS-based LC products will follow the same specifications for all countries; and
- Quality and reliability field validation of interpreted LC classes will assure the thematic accuracy of LC polygons over 75 percent globally (note that the accuracy of current Africover LC products has not been evaluated).

The WG-2 also addressed LC as being one of the baseline data sets in environmental databases. The data itself is an element in a larger database system. In any application LC data will be combined with other types of thematic data, spatial and non-spatial data, etc.

Working Group 3 - Strategic framework for development of FAO/UNEP global land cover network

This WG concentrated on the more institutional and organisational aspects of setting up a GLCN. The relationship with space programmes and other relevant organisations that may contribute to the UNEP/FAO GLCN was analysed. Linkages with existing networks were considered and protocols for LC data transfer and dissemination policies discussed.

The GLCN was seen as an operational programme driven by the users and their requirements. Its benefits will be realised mainly at national level tailored to the specific country requirements (*e.g.*, training and institutional strengthening). The central role of FAO and UNEP in arrangements, outreach and communication with participants and potential donors of the GLCN was implicit.

Whereas the WG-1 emphasised the users and their requirements and the technical level within the network, WG-2 emphasised the methodologies to be followed and products to be generated from co-operation with multiple partners through the network, and WG-3 concentrated on the institutional framework within which the network will be set up and function. These three WGs show a shift from a bottom-up towards a more top-down approach.

5.4 Conclusions and recommendations

5.4.1 Global context

A drafted statement, the “Artimino Declaration on Global Land Cover Network”, was presented to the participants for finalisation. In the statement the objectives and goals are formulated to establish the GLCN in response to user needs and operational applications with a focus on national perspectives and distributed responsibilities. The network will provide information on land cover and its dynamics in order to support decision-making. The final text will be included in the report of the meeting. The statement is made by the participants of the meeting, not by the institutions they represented.

5.4.2 European and Nordic context

The NordLaM Project is seen by many participants as an example of how a network could be set up that addresses key issues in a flexible networking sub regional approach. The shared interest in a specific subject and the need to address the identified issue are instrumental in making a network function at longer term. Furthermore, a network consists of several components, for example at institutional and technical levels. Some participants saw such components of a network as a potential cause for conflict, by others as essential elements to make a large network practically and logically functioning.

It would have been a suitable occasion to present the NordLaM Project in more detail to the participants but the participation of the project was confirmed at a very late stage and the programme of the meeting already set. The focus of the meeting was more on LC products, especially at global level, than on the organisation of a network.

In the European context it should be noted that EEA was absent, the CLC2000 effort was not presented and other than a single representative from the EC Joint Research Centre, presenting a global effort that has adopted LCCS, no European institution was present. (IIASA is an institute established to strengthen east-west relations and the work of the institute has mainly focussed on Asia). As the European Union is the world largest donor, the absence of such an important player at the Expert Consultation can be considered significant.

5.5 Commentary on the Artimino meeting

The emphasis on global land cover data may be important in the UN context but for many countries or group of countries the national level data sets are of prime importance in order to enable the country to report on conventions and directives by monitoring habitats, agricultural surfaces, ecologically important landscape elements, etc. The importance of the having readily available national land cover data was not sufficiently stressed. A number of questions arise in the context of European and especially Nordic countries that were not addressed during the meeting:

1. How will the CLC2000 activities fit in the outlined strategy and specified methodologies and classification system?
2. What benefits could the EU Member states derive from participating in a GLCN that promotes a methodology and classification that is different?
3. Should the possibility of the co-existence of CORINE LC and LCCS within the EC be examined?
4. Within the near future no technical body will exist that could officially validate the thematic translation of existing nomenclatures of monitoring projects participating in NordLaM. Is this a limitation or an opportunity to set up a set of rules to be followed in any translation exercise?

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Annex 5.A - Participants of the UNEP/FAO Expert Consultation

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Annex 5.B - Agenda of the UNEP/FAO Expert Consultation

Facilitating Team:

Leo Sayn-Wittgenstein (consultant), Denny Kalensky (consultant), Tim Foresman (UNEP Early Warning and Assessment Division), John Latham (FAO Environment and Natural Resources Service), René Verduijn (FAO Environment and Natural Resources Service), Luca Alinovi (FAO Africover Project)

6 May 2002 - Monday

08:30 - 09:00 Registration

Opening and orientation (Chair Sayn-Wittgenstein)

09:00 - 09:45 Welcome address by:

He Changchui, FAO Environment and Natural Resources Service

Tim Foresman, UNEP Early Warning and Assessment Division, Department of Co-operation, Ministry of Foreign Affairs

Alice Perlini, Director Istituto Agronomico per l'Oltremare (IAO), Regione Toscana

09:45 - 10:00 Break

10:00 - 10:15 Round Table Introductions

10:15 - 10:30 Overview of the consultation (Sayn-Wittgenstein)

10:30 - 11:00 Overview of goals and objectives of the meeting; introducing the concepts for an operational FAO/UNEP Global Land Cover Co-operative Programme (Foresman and He)

11:00 - 11:30 Coffee Break

Overview of Global User Requirements and Status (Chair Kalensky)

11:30 - 11:50 IGBP assessment of users' requirements for global land cover information (McConnell)

11:50 - 12:15 Status of the Global Land Cover (Global Land Cover 2000), results achieved and future requirements (Bartholomé)

12:15 - 12:35 GTOS and GOF/GOLD requirements for global land cover information (Schole)

12:35 - 12:50 UNEP Requirements for Using Global Land Cover for integrated global assessment, early warning and future initiatives (Foresman)

12:50 - 13:10 The Global Mapping Project (Tateishi)

13:10 - 14:15 Lunch

Presentation of the UN Land Cover Classification System (Chair Ryerson)

14:15 - 14:40 FAO Requirements for Integration and Approach to Land Cover Classification; Requirements and Progress (Latham)

14:40 - 15:00 Overview of alternate systems for Land Cover Classification (Kalensky)

15:00 - 15:30 Methodology, approach and existing tools to be used for harmonization of data and new datasets using the FAO/UNEP Land Cover Classification System (Di Gregorio)

15:30 - 16:00 Coffee break

16:00 - 16:30 FAO existing networks, outreach and advocacy programme (Alinovi)

16:30 - 17:00 UNEP existing networks, and operational capacities (Foresman)

17:00 - 17:30 Process design for delivering LCCS global database (Sayn-Wittgenstein/Kalensky)

17:30 - 18:00 Plenary discussion

18:00 Adjourn

7 May 2002 - Tuesday

Utility of FAO/UNEP methodologies for regions and countries (Chair Verduijn)

09:00 - 09:30 Plenary review of the FAO/UNEP Global Land Cover Design (Foresman/Alinovi)

09:30 - 11:00 Regional Round Table: Experts from five regions to respond to a set of questions regarding the utility and applicability of the proposed design strategy:

Experts from the regions:

Africa, North and Middle East: Muftah Unis and Sami Abdel Rahman

Africa, Sub-Saharan: Alhassane Adama Giallo, Mark Thompson and Yemane Tekleyohannis

America, Central/South: Dalton de Morrison Valeriano and Stella Navone

America, North: Bob Ryerson and Mathew Fladeland

Asia: Ravoori Nagaraja and Dirk van der Stichelen

Europe: Günther Fischer and Louisa Jansen

11:00 - 11:30 Coffee break

11:30 - 12:00 Regional Round Table: discussion on panel response

Working Groups organization and assignments (Chair Sayn-Wittgenstein)

12:00 - 13:00 Three working groups were formed. Review of Guidelines for Working Groups.

WG-1 UNEP/FAO Land Cover Classification System (LCCS)

Co-chairs: Paolo Sarfatti and Louisa Jansen

Overview of lessons learned from the application of LCCS, its global applicability, compatibility with other LC classification systems, and harmonization options among LC classification systems. Review of LCCS distance-learning software packages and their user-friendliness. Formulating a requirement for development of LCCS-based international LC classification standard acceptable to ISO.

W-2 Methodologies for Establishment of LCCS-based Global LC Database

Co-chairs: Mark Thompson and Denny Kalensky

Recommendation of appropriate methodologies for the establishment of a LCCS-based global land cover database compatible with information requirements of FAO and UNEP programmes. They include methodologies for conversion of existing land cover databases to LCCS standards, as well as methodologies for land cover mapping and monitoring (remote sensing input data, mapping scales, minimum mapping areas, validation of results, formats of LC products).

W-3 Strategic Framework for Development of FAO/UNEP Global LC Network

Co-chairs: Leo Sayn-Wittgenstein, Luca Alinovi and John Latham

Drafting a strategic framework for cooperation with space agencies and other relevant organizations in development of the FAO/UNEP Global Land Cover Network (GLCN). Specific tasks to be considered are the GLCN institutional infrastructure, linkages with existing LC databases, LC data transfer protocols, dissemination policy for LC data products and their cost, global LC meta-database, and LC capacity building in developing countries.

13:00 - 14:00	Lunch
14:00 - 15:00	Working Group discussions
15:00 - 15:30	Coffee break
15:30 - 17:30	Working Group discussions
17:30 - 18:00	Plenary discussion on preliminary WG issues (Chair Leo Sayn-Wittgenstein)
18:00	Adjourn

8 May 2002 - Wednesday

Deliberations by Working Groups and preparation of the WG report

09:00 - 11:00	Working Group discussions
11:00 - 11:30	Coffee break
11:30 - 13:00	Preparation of Working Group reports and recommendations
13:00 - 14:30	Lunch
14:30 - 15:30	Reports to plenary by the Working Groups (Chair Sayn-Wittgenstein)
15:30 - 16:00	Coffee Break
16:00 - 16:30	Roadmap for operational implementation (Chair Sayn-Wittgenstein)
16:30 - 17:00	Finalization declaration/statement of the participants
17:00 - 17:30	Closing remarks
18:00	Adjourn

Annex 5.C - Contribution to Regional Round Table - Europe

Prepared by

Günther Fischer, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

Louisa J.M. Jansen, consultant, NordLaM Project, NERI, Kalø, Denmark

- A. The starting point in Europe was a fairly heterogeneous picture with inconsistency and incomparability of land cover (LC) products across countries due to differences in projections used, nomenclatures and classifications applied, updating frequencies and procedures, and accessibility of products.
- B. During the last ten years several EU-funded projects and Concerted Actions were initiated to review and attempt issues of standardization, harmonized classification, integration of geo-information with statistical data.
- C. A Geographical Information System unit (GISCO) was set up within the European Commission (only) in 1991 to cater for geo-data requirements of DGs and the Commission.
- D. The main use of LC products in EU and Member States is as a basic layer for spatial analysis within integrated environmental assessments. Important examples are:
 - Territorial impact assessment in support of regional planning (*i.e.*, related to Structural Funds, European Spatial Development Perspective),
 - Impacts of the Common Agricultural Policy (CAP) changes on the environment,
 - Strategic environmental assessments of TEN (transport network),
 - Ecological assessments of nature sites (*e.g.*, Natura2000),
 - Impact assessments in support of Convention on Long-range Transboundary Air Pollution,
 - Watershed management in support of Water framework directives,
 - Integrated coastal zone management,
 - Spatial impact studies of EU-enlargement.
- E. A review of pan-European land cover data sets was carried out by the Coordination Center for Effects in support of scientific work within the Effects Programme of the UN/ECE Convention on long-range transboundary air pollution. The review involved three phases: (i) define criteria by which to evaluate, (ii) inventory of available LC databases, and (iii) evaluate and intercompare databases. Five LC products were identified: CORINE Land Cover, SEI Land Cover Map of Europe, PELCOM land cover map, IGBP-DIS land cover product and Olson Global Ecosystems (the latter two based on the same NOAA AVHRR data of 1992/93). Some characteristics of the 5 data sets are listed in Table 5.C.1. Three products (CORINE, SEI, PELCOM) were retained for a more detailed comparison. It was concluded that CORINE, for the countries where available, was the most adequate database for the specific environmental analysis of the long-range transboundary air pollution impacts assessment.
- F. Updating of CORINE Land Cover to year 2000 (CLC2000) is currently ongoing, driven by the needs of the European Commission and the Member States. The main data input for CLC2000 is Landsat 7 remote sensing images of the period 1999 to 2001.
- G. An EU-wide mosaic of ortho-rectified images, designed as a multi-purpose product (called IMAGE2000), is a key data set for CLC2000.
- H. Main outputs of CLC2000 will be:
 - An updated European consistent land cover database for the year 2000, fully compatible with the first CORINE land cover inventory,
 - A European database on land cover changes of 1990 – 2000,
 - A basic satellite image reference layer for the year 2000 at 25 m ground resolution.
- I. At national level, large monitoring programmes exist (*e.g.*, often sample based field surveys) at the

landscape level where limited use of remote sensing is being made due to the required level of detail. In the Nordic monitoring programmes especially additional possibilities for increased use of RS is recognized. Advancement of the use of image data in monitoring should include both systematic developments and increased coordination within monitoring itself.

- J. Relevance of LCCS: In addition to the internal requirements of the EU and Member States, harmonized global and regional LC products are important for a number of assessments and international obligations. Examples are: reporting to international conventions and treaties; aid programs to foster food security and sustainable development; global change research including impact studies, vulnerability studies, Earth system studies (climate modeling, carbon cycle, GHG mitigation studies, carbon sinks, *etc.*).
- K. In Central and Eastern Europe two major LC classifications are in use, *i.e.* CORINE LC and LCCS. In some countries both methods have been applied (*e.g.* Bulgaria). This sub-region could be considered an important area for LC harmonization efforts.
- L. In the Nordic region, including EU and non-EU states, the recognition of the need for increased coordination between monitoring activities has led to a harmonization activity in which class correspondence between nomenclatures is being analysed. Building upon increased knowledge and understanding of classifications currently used, LCCS has been selected as the method for thematic harmonization.
- M. The international obligations of EU and Member States require LC products, which are:
 - Technically sound,
 - Reliable and accurate,
 - Appropriate in detail to the range of applications intended,
 - Consistent, compatible, flexible and validable across countries/regions,
 - With adequate updating frequency (and ability to be reproduced),
 - With a high likelihood of acceptance by many countries,
 - Carefully constructed to allow consistent linkage to other information, in particular international statistics and assessments on land use.
- N. LCCS appears to be technically sound. It is flexible in accommodating various levels of detail within a consistent system and hence LCCS-based products can cater to a range of applications. Standardization procedures and harmonized land cover products would probably have a high likelihood of acceptance by many countries if supported and organized by UN organizations.

Table 5.C.1 Selected LC databases with their specifications derived from their documentation and the Internet.

	CORINE Land Cover	SEI Land Cover Map of Europe	PELCOM (Pan-European Land Cover Monitoring)	IGBP-DISCover	Olson-Global Ecosystems
Characteristics					
Ownership / financier	European Environment Agency, Copenhagen, DK	Stockholm Environment Institute, York, UK	Alterra, Wageningen, The Netherlands	IGBP-DIS	USGS – EROS Data Center
Availability / copyright	EEA agrees to grant to the customer the non-exclusive and non-transferable right to use and process the dataset (http://natlan.eea.eu.int/termsfuse.htm)	Contact SEI	Free distribution, registra- tion of use requested (http://cgi.girs.wageningen-ur.nl/cgi/siteguide)	Freely available (http://www.ngdc.noaa.gov/paleo/igbp-dis and http://edcdaac/usgs.gov)	EROS Data center (http://edcgaac.usgs.gov)
Source dates	1985-1997	1970-1996	DLR: 1997, IGBP: 1995	1992-1993	1992-1993
Special coverage	EU countries, EU accession states and several eastern European States	Pan-Europe	Pan-Europe	Global	Global
Spatial resolution	250m cells	< 1:2.000.000	1100m cells	1100m cells	1100m cells
Sources	Landsat/SPOT XS at a scale of 1:100,000 with simultane- ous consultation of ancil- lary data.	FAO Land Use Map of Europe (1:2,500,000), Land Use of the Former USSR (1:4,000,000) ESA Forest Map of Europe (1:2,000,000), Forests of the USSR (1:2,500,000), CORINE Soil Map of the EC (1:1,000,000), FAO/ UNESCO Soil Map of the World (1:5,000,000).	NOAA/AVHRR images from DLR, IGBP maximum value composites and from the Lannion database.	Unsupervised clustering of monthly NDVI maximum value composites NOAA/ AVHRR on a continental basis	Same as IGBP.
Classes	44 level-3, 16 level-2 and 7 level 1 classes (Austria and Switzerland compatible with level-2 only; Finland not fully compatible with level-2 classification).	7 main classes, 25 main subclasses and 129 sub-subclasses.	12 classes	17 general cover types	94 classes
Accuracy	No specific accuracy information available	Overall accuracy undeter- mined, accuracy of some input products known.	Overall accuracy of 69.2% based on an assessment of 40 interpreted high- resolution images.	-	-

6. Thematic harmonisation and analyses of Nordic data sets into Land Cover Classification System (LCCS) terminology

Development of remote sensing in Nordic terrestrial landscape monitoring Nordic Landscape Monitoring (NordLaM) Project

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Summary

In the Nordic landscape monitoring programmes remote sensing data are widely used for interpretation of land cover with each country having established a particular legend. Five Nordic legends have been translated into LCCS terminology in order to be able to make comparisons. These translations revealed several problems related to differences in definitions and threshold values, use of land-use terminology, and use of mixed classes when a range is described in the class definition that does not correspond to a particular LCCS classifier. The use of classifiers was analysed showing that the specific-purpose legends use more land cover classifiers than the more general-purpose land cover legends. The comparison of classes within a single legend reveals that classes are similar in their structural-physiognomic description and consequently how difficult class separation may be. Comparison between legends shows that the highest similarity values are found within a single land cover category and lower values may occur between categories that share a number of classifiers.

Keywords: land cover; classification; mapping; LCCS; landscape monitoring

6.1 Introduction

With the growing interest in environmental change, it is important to re-examine existing data sets and attempt to harmonise them, both thematically and geospatially, in order to make comparisons between neighbouring countries and to compile time series with which to analyse environmental changes and detect trends (Jansen *et al.* 2003). The need for an integrated approach to all aspects of land cover, the growing importance of environmental modelling and the development of computerised applications have increased the need for a common approach and thus harmonisation and standardisation (UNEP/FAO 1994; LANES 1998). However, it is unrealistic to work with new standardised class sets often because major financial and intellectual investments have been made in existing class sets and established methods of classification. The need to be able to work with both old and new class sets for environmental change monitoring requires harmonisation between data sets. Furthermore, it is probable that there will always be a need for specialised classifications for particular purposes (Wyatt *et al.* 1997; Wyatt & Gerard 2001).

Current land cover classifications and legends are based upon an approach that is characterised by class names and class descriptions that do not consistently use a set of criteria to make class distinctions. In general one can state that such land cover nomenclatures (Jansen & Di Gregorio 2002):

- are inconsistent in the application of inherent criteria;
- are inconsistent in the use of criteria at the same level of classification;
- use different criteria between classes; and
- use non-inherent characteristics (e.g., landform and land-use).

Although the underlying reasons for making subdivisions based upon different criteria may be valid, they show that criteria do not always have the same weight in making distinctions. Such decisions are usually not well documented in the accompanying reports of the classifications. It will be difficult for any user to trace back the origins of these unsystematic descriptions and to re-interpret the class descriptions and criteria used in the absence of sufficient documentation. This hampers thematic harmonisation of classification results, as these interpretations are likely to differ between persons within one country

and between countries (Jansen & Di Gregorio 2002).

The FAO/UNEP Land Cover Classification System (LCCS) (Di Gregorio & Jansen 1998, 2000) not only provides a systematic method to classification based upon the classifier approach, but also a systematic procedure for the comparison of land cover classes in the so-called Translator Module. Existing classifications and legends can be translated using LCCS as the reference classification. By translating classes into LCCS, the system acts as a “bridge” between nomenclatures at the level of thematic harmonisation. Furthermore, there is a clear distinction between inherent (*i.e.* the land cover classifiers and modifiers) and non-inherent criteria (*i.e.* the environmental and specific technical attributes).

In the Nordic countries remote sensing data are widely used for interpretation of land cover, both for general wide-area mapping and for detailed sample area mapping as part of landscape monitoring programmes. The objectives of the NordLaM translation of five Nordic data sets into LCCS terminology are examination of the usefulness of LCCS as a bridging system and thematic harmonisation tool, and analysis of the type of problems encountered while translating classes used in different countries with similar types of landscapes but different approaches to land cover classification. At the same time the consistency of and use of criteria in the Nordic data sets can be examined and the similarity between classes within a legend or between legends is illustrated with a number of examples.

6.2 Materials provided

The five translated legends worked with (AIS-LCM for Denmark, EELC for Estonia, 3Q and DMK for Norway, and SMD for Sweden) focus on different aspects of land cover. Some of these five legends are focussed on agricultural land-uses, others on (semi-) natural vegetation description or on giving a more general picture of land cover/land-uses, especially for agriculture and/or forestry. The focus of these legends determines the type of classes present and the criteria used to distinguish these.

The individual classes in these legends were expressed, using the LCCS software’s Classification and Legend Modules, in terms of the LCCS classifiers and states by those who have been involved in the development of and mapping with the particular legends:

- AIS-LCM (Denmark) – Geoff Groom, NERI;
- EELC (Estonia) – Kiira Aaviksoo, EEIC;
- 3Q (Norway) – Wendy Fjellstad, NIJOS;
- DMK (Norway) – Arnt Kristian Gjertsen, NIJOS; and
- SMD (Sweden) – Eva Ahlcrona, Metria Miljöanalys.

The legends were then provided to the author as MS-ACCESS database files generated by the LCCS Legend module (Export function). These files contained the original class names and/or codes as well as the LCCS class, Boolean formula, codes and associated LCCS class name. In many cases the description boxes in the Legend Module were also used for making additional comments on the classes and/or their LCCS translation. The legends comprised a total of 152 classes that are presented with descriptive information and resulting translated LCCS class in Annex 6. A.

6.3 Legend preparation for LCCS Translator Module

Before being able to analyse the translated legends two steps are required in LCCS: (1) import into the Legend Module and (2) export of the legends and their classes into the Translator Module. These two preparatory steps are described in more detail below.

6.3.1 Import into and preparation in the Legend Module

The first step was the import of the five legends into the LCCS Legend Module. Two options are available: import as EXCEL97 file or external ACCESS97 database file. The latter option was adopted. The *Display* option can be used to see the contents of the legend after successful completion of the import. One should note that an imported file becomes the active legend in the Legend Module but that this file still needs to be saved in order to store it within LCCS and to be able to retrieve it at a later stage. All files were imported successfully and saved under their original names.

In order to be able to export classes from the Legend to the Translator Module each legend was examined for any inconsistencies or other discrepancies that were discussed with the translators and when needed small adjustments to the class translations were made.

The LCCS Legend Module allows for creation of mixed classes, comprising up to three components. Several of the translated classes had been expressed as mixed classes. Mixed classes require a different procedure for export to the Translator Module than single classes. The first two components of each mixed class need to be recreated as single classes. In the Translator Module a mixed class cannot contain more than two elements. Therefore, any mixed class containing three elements lost its third component in the Translator Module.

A problem occurred with those classes containing a specific classifier option that is linked to the concept of mixed classes as adopted in LCCS. This presented itself in the case of the 3Q legend class "2Aa1", which consists of the LCCS codes 11149/11149: the use of the Cultivated and Managed Terrestrial Areas (A11) "Spatial Aspect-Distribution" classifier option "Scattered clustered" forces the user deliberately to create a mixed class because this classifier obliges the user to select a mixed class from the *Save to legend* option. A class containing this classifier option can never occur as a single class and hence cannot be prepared for export to the Translator Module. The same situation applies for the options "Scattered clustered" and "Scattered isolated" of the classifier "Spatial distribution" in the (Semi-) Natural Terrestrial Vegetation" (A12) category. However, these classifier options were not used in any of the translated legends. The impossibility to import such a class is thus due to the concept adopted in LCCS.

6.3.2 Import to Translator Module

The prepared legends containing all the single classes and the separated components of mixed classes were exported one by one to the Translator Module. The active legend can be imported class-by-class using the methodology described below; in the case of mixed units the class was recomposed. The import/export procedure is quite time-consuming, as the following steps need to be followed for each individual class if the option *Retrieve from Legend* is selected from the Import menu of the Translator Module; *Retrieve from Legend* will cause a new window called *Legend Export to Translator* to be displayed:

1. All classes present in the active legend are displayed and the relevant class is selected using *Select as 1st* to display the class in the *Classes Identified* frame.
2. Type a user-defined numerical ID, code and the legend's name ('Ext. Classification Name') in the relevant boxes (if the class has a user-defined name this name appears automatically in the 'Class Name in Legend' box).
3. Select *Export*, this will bring the user back to the Import window.
4. In the next window select *Process Class1*, which will fill the relevant boxes with the LCCS code and class name and add an ID.
5. Save the class in the Translator Module using the *Save Class* option.

In case of a mixed unit it is necessary to add the following steps:

- After step 1, select the second class using *Select as 2nd* option.
- In step 2, a username will not appear in the relevant box unless already added in the Legend Module so this box should be filled. Automatically a slash will appear to indicate that it is a mixed class. If this slash is not needed in the name it should be deleted from the box.
- In step 4, one will need to select *Process Class2* before saving.

The two IDs available in the main TM Import window can be used to store the order of the classes. The first ID (in the upper left corner, in yellow) can store the order of the classes in the original legend, whereas the second ID (to be typed by the user) can be used to record the LCCS Legend class order. In this way both the original class order and the LCCS grouping can be stored. For the five imported legends the second ID is identical to the first and both represent the LCCS Legend order. That is because some original class IDs were too long for recording by LCCS and most of the five translated legends (with the exception of DMK) had the original codes stored in the class names.

Classes that were cloned, i.e. classes containing a user-defined Z-code, with an attribute related to a classifier code caused problems when importing them into the Translator Module. The category to which the classes belonged can be identified but the Boolean formula and class name do not appear in the boxes when processed and hence cannot be saved. This concerned the following classes:

- AIS-LCM legend: "18 Sæsonbestemt arealdække" and "07 Afgræsset eller slået græs";
- 3Q legend: "U4ha", "U4go", "U4ca" and "U4id";
- DMK legend: "Jordbruksareal (Agricultural area)" and "Innmarksbeite (Fertilized pasture)";
- SMD legend: "211 Arable land", "231 Pastures", "3242 Cleared-felled areas (before woody vegetation)", "334 Burned areas (before woody vegetation)", "1122 Discontinuous urban fabric with less than 200 inhabitants", "1123 Rural fabric with open plots", "1312 Other mineral extraction sites" and

“1311 Sand and gravel pits”.

An attempt to remove the cloning and user-defined codes (e.g. (1)Z2) and adding them after processing of the class worked well but the classes as such could not be further used in the similarity assessment because an error message was generated informing the user of the “Invalid use of Null”. Therefore the codes for cloning and user-defined attributes were moved manually into the environmental attributes boxes where they could not cause further problems since the attributes are not considered in the computation of the similarities. The decision to move these codes was based upon trial and error as the user is not supposed to move manually any of the codes from one box to another.

Import of classes having a cloned attribute (e.g. Floristic aspect in the EELC legend) did not cause any problems in the Translator import. All attributes, whether cloned or not, will be ignored in the similarity assessment and thus do not cause any problems.

6.4 Difficulties encountered

The translation of the five legends into LCCS terminology forced the translators at times to make compromises from among the choices and options available within LCCS. Although LCCS contained in general more options than the criteria used in the original legends, the correspondence between original criteria and the LCCS classifiers was not 100 percent. The main problems encountered are discussed below as well as the solutions adopted. Some of the solutions may require discussion and would, more importantly, require consensus between translators of different countries.

6.4.1 Differences in thresholds

In general it was possible to find the corresponding LCCS class for all classes of the five legends although this correspondence, more often than not, was not 100 percent. The main problems included differences in thresholds, especially crown cover. For instance 3Q uses 25 percent and the value used in SMD is presented in Table 6.1. LCCS contains more options for indication of crown cover than most existing legends but differences of 5 - 10 percent occur between the placing of the LCCS thresholds and those used by the five legends.

Table 6.1. Differences in crown cover thresholds between LCCS and SMD (source: Eva Ahlcróna)

Land cover type	Crown density (in %)	
	LCCS	SMD
Closed forest	>65	
Open forest / Woodland	40 - 65	
	15 - 40	>30
Sparse trees	1 - 15	

Different thresholds also exist for artificial surfaces such as urban areas. Table 6.2 provides an overview of the minor differences that exist between LCCS and SMD and that have been neglected in the translation of relevant classes, since a difference of five percent is difficult to establish in practise.

Table 6.2. Differences in densities of urban areas between LCCS and SMD (source: Eva Ahlcróna)

Density classes	Density (in %)	
	LCCS	SMD
High density / continuous urban fabric	>75	>80
Medium density / discontinuous urban fabric	50 - 75	50 - 80
Low density / discontinuous urban fabric	<50	30 - 50

Furthermore, differences exist between tree heights used in the various legends. Table 6.3 shows the differences between LCCS and SMD and shows that certain tree heights would lead to a different class (e.g., 6m).

Table 6.3. Differences in tree height between LCCS and SMD (source: Eva Ahlcrona)

Distinguished tree height classes	Height (in m)	
	LCCS	SMD
High / Coniferous forest >15 m	>14 - 30	>15
Medium forest	40 - 65	>5
Low / Young forest	3 - 7	2 - 5

In the DMK legend the thresholds for “Mixed forest” are unusual, with 20 percent cover as the lower limit and 50 percent cover as the higher limit for needleleaved trees; thus a forest area with 40 percent broadleaved trees is classified as needleleaved forest. In LCCS the thresholds follow the UNESCO vegetation classification (Di Gregorio & Jansen, 2000).

In the DMK legend an area is called “forest” also when it is for the time being without trees. This situation is analogue to the description of cultivated areas without crops in LCCS. Furthermore, if an area is covered with needleleaved trees under a canopy of broadleaved trees, it is classified as needleleaved. This is probably due to the larger economic value of needleleaved trees and therefore of prime interest to the forester. A cultivated area where also trees are present is described as “forest” in the DMK legend whereas this would be a mixed class in LCCS.

A class such as “Other soil covered land” in the DMK legend was impossible to translate, because this class does not describe the actual land cover. The same with the class “Land with shallow topsoil”. These classes have therefore not been included in the translation.

An important difference in threshold values occurs between LCCS and 3Q for determination whether a class belongs to vegetated or non-vegetated land cover types. In LCCS the value is very low, *i.e.* 4 percent, whereas in 3Q it is set at 25 percent. This notable difference may be due to the objectives with which the classes were defined as well as the concept of a vegetated area. Vegetation changes with the seasons and only the permanent life forms, *i.e.* trees and bushes, remain. Furthermore, if only 4 percent of an area is vegetated it is assumed that the rest of the area is empty, *i.e.* there are no other structures or occupied surfaces. If this was not so one would have to speak of a mixed class in which the vegetated area is subordinate to other land cover classes (*e.g.*, bare surfaces). The definition adopted by 3Q will either encourage creation of mixed classes or disregard extremely sparse vegetation.

6.4.2 Occurrence of land-use terminology

The occurrence of land-use terminology in some classes as well as the importance of the legends for monitoring of environmental change (*e.g.*, development of land-use patterns) calls for compromises in the translation. The two Norwegian legends, 3Q and DMK in particular, have a land-use oriented focus. 3Q is a legend developed to monitor agricultural land-use patterns, biodiversity and cultural heritage whereas DMK focuses on the land (*e.g.*, soil) as a resource for agriculture and forestry. LCCS is designed for the description of land cover although in some places land cover related (management) practices can be accommodated. This is especially true for artificially covered areas such as cultivated and built-up areas. Grasslands that are managed belong to the cultivated areas category of LCCS; grasslands that are abandoned and invaded by natural vegetation belong to the (semi-) natural vegetation category. In the first case some land cover related cultural practises could be described, in the latter case they cannot. The user could make user-defined attributes to cover these land-use related aspects but these attributes are not standardised and are consequently not considered in the Translator Module.

Classes that gave rise to considerable discussion during translation were “Clear felled areas” and “Burned areas” where the class names refer to a land-use practise or an environmental event. The resulting land cover type can be manifold, depending on the species invading the terrain after the event and the time that has passed after tree felling or fire. The land cover class(es) created in LCCS are neutral with respect to any applied interpretation of the land cover, including for example its ecological meaning. Therefore, these phenomena, and also damage due to hail storms or wind (*e.g.*, the use of the “vi” code in 3Q), cannot be accommodated by any other means than adding user-defined attributes.

The SMD legend is a general-purpose land cover legend albeit some land-use criteria are present. Especially the classes concerning burned and clear felled areas were difficult to translate and the solution adopted was to define a closed woody vegetation type with an added user-defined attribute explaining that it considers a clear felled or burned area.

Another SMD class related to a future cover, “Construction sites”, was difficult to translate because the type of construction and the time before the construction will become visible determine the description of the actual land cover with LCCS classifiers. As a result a mix was chosen between built-up areas, unconsolidated and consolidated materials but this choice is arbitrary. One cannot expect to find a perfect match between an actual and a potential land cover.

6.4.3 Occurrence of mixed classes

In a number of cases the correspondence to the classes and the available options in LCCS was imperfect and this was especially true when in the definition a range was included (*e.g.*, from open to closed). This occurred in the vegetation types, “Forest”, “Moors and heath land”, “Grass heath” and “Meadow” (SMD legend). The forest of DMK can be either closed or open forest in LCCS. To directly translate “Forest”, it should be possible to define a forest category that combines closed and open forest but in LCCS one is forced to create a mixed class to accommodate that the cover is from open to closed. However, a mixed class may be explained in various ways. How should a user of LCCS translated classes know if the original forest is either closed or open or if there is a range from open to closed?

In other class names two clearly distinct types of objects co-occur, such as “Fruit trees and berry plantations” in the SMD legend and various classes of the AIS-LCM legend. In this case various options are possible:

- A mixed class of fruit tree plantations with berry plantations is created because due to the mapping scale and/or the arrangement of fields these two types of fields cannot be distinguished individually at a spatial level.
- A single class is created containing the dominant crop fruit trees with the berries as a second crop because they occur in the same field. In this case it is a single class containing a multiple crop (N.B. it may also be possible that a single class exist in which the berries are dominant over the trees).
- A mixed class could be created combining the two above-mentioned options.

The best practise in such cases depends on how the two components are arranged spatially but this information was not available for the above-mentioned class (see Annex 6.A). It may also happen that all options occur in practise but that this is not reflected in the original legend or in the accompanying database.

The occurrence of lichen-dominated areas with trees cannot be accommodated in LCCS by creation of a mixed class. The concept adopted in LCCS for lichens is very limited and it is impossible to link this life form with any occurring stratification. The same would happen if the user would start with the definition of open trees, the lichens cannot be added. This is a real limitation for the correct translation of lichen-dominated vegetation types in the Nordic countries. Lichens also occur in mires but the combination of a waterlogged area with lichens is not considered in LCCS.

Mires are a very important feature in Nordic landscapes and they are usually not well represented in classifications. Nowadays it is important to report on mires especially in the context of the UN Wetland Convention. In the EELC legend the 4rd level is used for description of wetlands because the 3rd level, which follows Corine LC, has not the possibility to describe these classes well. LCCS provides enough options to describe the classes with the exception when lichens are present.

Sparsely vegetated areas in the SMD legend (SMD class 333) were translated as a mixed class containing unconsolidated materials and herbaceous open vegetation. The definition of “sparsely” as used in the SMD legend is lacking and depending on it, it could be argued that sparse herbaceous vegetation should have been selected for the translation. The translated class gives the impression that there are two elements present: (1) bare areas/bare soils with (2) open vegetation. But the concept of sparse vegetation in LCCS is not the same as a mixed class of bare soil with vegetation.

6.5 Results

6.5.1 Overview of use of classifiers by the legends

One of the things to examine in a translation is whether the classifiers present in LCCS are those that represent the commonly used criteria in any land cover (related) legend. If this is so, it is interesting to evaluate how the different classifiers have been used. If classifiers are not used the explanation may simply be that the legend contained only very limited land cover criteria that could be translated and that the other criteria used belong to the non-inherent land cover criteria. It may also be related to the scale at

which the original legend is applied: a small-scale mapping legend will not use as many classifiers as a large-scale mapping legend.

The two major LCCS land cover categories of interest for terrestrial landscape level monitoring are cultivated and (semi-) natural vegetated areas. The relevant classes of the five legends for those two categories and their use of classifiers are represented in Tables 6.4 and 6.5. Table 6.4 shows the use of terrestrial cultivated area classifiers and two relevant attributes. It is immediately evident that the AIS-LCM and 3Q legends use a range of available LCCS classifiers, whereas DMK and SMD only use the classifier Life Form, which is perhaps the most important classifier and hence the first available in LCCS. The DMK legend could only be translated in part because it is based upon a totally different concept, for which no classifiers exist in LCCS (see Annex 6.A). Furthermore, one can remark that certain classifiers or attributes have not been used at all or with only very limited use by these five legends (*e.g.* Field Size and Crop Type). The interpretation of this could be that the classifier is difficult to apply, not clearly defined and/or explained or is not considered to be of (any) importance. The latter would justify moving such a classifier further down the LCCS hierarchy or ascertain that a “skip” option is available as is indeed the case for Field Size.

Table 6.4. Overview of the use of classifiers and two specific attributes in the major land cover category “Cultivated Terrestrial Areas” (A11) by the different legends.*

Legend	Class code	Land cover classifiers						Attributes	
		A. Life form	B. Field size	B. Distribution	C. Crop combination	D. Water supply	D. Cultivation time factor	S. Crop cover	W. Crop type
AIS-LCM* (Denmark)	18	x	-	x	-	x	x	-	-
	07	x	-	x	-	x	x	-	-
3Q (Norway)	A1pl (etc.)	x	-	x	x	x	x	x	x
	A2fr	x	-	x	x	x	x	-	x
	A2bu	x	-	x	x	x	x	-	-
	A1ko	x	-	x	-	x	x	x	-
	A1br	x	-	x	x	x	x	-	-
	A3be	x	-	x	x	x	x	x	-
	A1en	x	-	x	x	x	x	x	-
	A1be	x	-	x	x	x	x	x	-
	A1in	x	-	x	x	x	x	x	-
	A1na	x	-	x	x	x	x	-	x
	A2jo	x	-	x	x	x	x	-	-
	A3sb	x	-	x	x	x	x	x	-
	A3kr	x	-	x	x	x	x	x	-
	A1gr	x	-	x	x	x	x	x	-
DMK** (Norway)	1	x	-	-	-	-	-	-	-
	2	x	-	-	-	-	-	-	-
	3	x	-	-	-	-	-	-	-
	4	x	-	-	-	-	-	-	-
SMD (Sweden)	211	x	-	-	-	-	-	-	-
	231	x	-	-	-	-	-	-	-
	222	x	-	-	-	-	-	-	-

* The EELC legend is not represented as it contains no relevant (i.e. A11) classes

** Class codes AIS-LCM legend: 18-Sæsonbestemt arealdække, 07-Afgræsset eller slået græs.

** Class codes DMK legend: 1. Jordbruksareal (Agricultural area), 2. Fulldyrka jord (Arable land), 3. Overflatedyrka jord (Surface cultivated area), 4. Innmarksbeite (Fertilized pasture).

Table 6.5 shows the use of classifiers and specific technical attributes for the two LCCS categories of (Semi-) Natural Vegetation, *i.e.* terrestrial and aquatic or regularly flooded environments (the “≠” means that the classifier is not applicable for one or other of these two LCCS categories). The classifiers Life Form and Cover are obligatory for any class definition. Height is almost always used because the range of values contained in the classifier does not result in any obstacles. The classifier Spatial Distribution is used much less; apparently not much emphasis is placed on the horizontal patterns of vegetation. The classifiers Leaf Type and Leaf Phenology are occasionally used. One of the problems, which occurred in the translation, was that one cannot skip Leaf Type to define Leaf Phenology only. As a result, if Leaf Type could not be defined, consequently one could not add Leaf Phenology. Remarkable is the almost complete absence of the use of the classifier Stratification: Are the applications for which the legends were created not interested in the vertical arrangement, *i.e.* layering, of the groups of life forms? Or is there, due to the climate not much layering present in the described vegetation types? Or is the use of the Stratification classifier in LCCS not seen as straightforward and therefore passed-over? The answer is probably a mixture of these three. In many forests undergrowth is systematically removed by either wild animals or management practises, or many of the described vegetation types are low in height and consequently no or not much layering can be distinguished or at most two layers can be distinguished but this is not reflected in the translated classes. Part of the answer may be that these legends are used in remote sensing applications in which any layering underneath the highest canopy cover cannot be identified on the image or photo.

Table 6.5. Overview of the use of classifiers and two specific attributes in the major land cover categories (Semi-) Natural Vegetation (A12 and A24) by the different legends.

Legend	Class code	Land cover classifiers										Attribute
		A. Life form	A. Cover	B. Height	C. Spatial Distribution (A12)	C. Water seasonality (A24)	D. Leaf type	D. Leaf phenology	F/G. Stratification 2nd layer	F/G. Stratification 3rd layer	T. Floristic aspect	
EELC*(Estonia)	6	X	X	X	≠	X	-	-	-	≠	X	
	19	X	X	X	≠	X	-	-	-	≠	X	
	20	X	X	X	≠	X	-	-	-	≠	X	
	21	X	X	X	≠	X	-	-	-	≠	X	
	10	X	X	X	≠	X	-	-	-	≠	X	
	13	X	X	X	≠	X	-	-	-	≠	X	
	18	X	X	X	≠	X	-	-	-	≠	X	
	17	X	X	X	≠	X	-	-	-	≠	X	
	12	X	X	X	≠	X	-	-	-	≠	X	
	9	X	X	X	≠	X	-	-	-	≠	X	
	8	X	X	X	≠	X	-	-	-	≠	X	
	11	X	X	X	≠	X	-	-	-	≠	X	
	14	X	X	X	≠	X	-	-	-	≠	X	
	16	X	X	X	≠	X	-	-	-	≠	X	
AIS-LCM**(Denmark)	14	X	X	X	X	≠	-	-	-	-	-	
	11	X	X	X	X	≠	-	-	-	-	-	
	05	X	X	X	-	≠	-	-	-	-	-	
	10	X	X	X	-	≠	-	-	-	-	-	
	15	X	X	X	-	≠	X	X	-	-	-	
	16	X	X	X	-	≠	X	X	-	-	-	
	08	X	X	X	≠	X	-	-	-	≠	-	

* Class codes EELC legend: 6. Coastal and shore reed bed, 19. Minerotrophic swamp forest, 20. Transitional bog forest, 21. Bog forest, 10. Treed fen, 13. Treed transitional bog, 18. Treed bog, 17. Dwarf shrub bog, 12. Shrub transitional bog, 9. Shrub fen, 8. Open fen, 11. Open transitional bog, 14. Bog lagg, 16. Complex bog, 15. Open bog.

(table 6.5. continued.)

Legend	Class code	Land cover classifiers										Attribute
		A. Life form	A. Cover	B. Height	C. Spatial Distribution (A12)	C. Water seasonality (A24)	D. Leaf type	D. Leaf phenology	F/G. Stratification 2nd layer	F/G. Stratification 3rd layer	T. Floristic aspect	
3Q (Norway)	S1la	X	X	X	X	≠	X	X	-	-	-	-
	S2bl	X	X	X	X	≠	X	X	-	-	-	-
	S3ba	X	X	X	X	≠	X	X	-	-	-	-
	S2bl	X	X	X	X	≠	X	X	-	-	-	-
	F1kr	X	X	X	-	≠	-	-	X	-	-	-
	F1vi	X	X	X	-	≠	-	-	-	-	-	-
	F1sb	X	X	X	X	≠	-	-	X	-	-	-
	F1sb	X	X	X	X	≠	-	-	X	X	-	-
	F2ri	X	X	X	≠	-	-	-	-	≠	-	-
	F2sk	X	X	X	≠	-	-	-	-	≠	-	-
	M2bu	X	X	X	≠	X	X	X	-	≠	-	-
	M1gr	X	X	X	≠	-	-	-	-	≠	-	-
	F3st/F3dr	X	X	X	≠	X	-	-	-	≠	-	-
DMK*** (Norway)	5	X	X	X	-	≠	X	X	-	≠	-	-
	6	X	X	X	-	≠	X	X	-	≠	-	-
	7	X	X	X	-	≠	X	X	-	≠	-	-
	8	X	X	-	≠	-	-	-	-	≠	-	-
SMD**** (Sweden)	3242	X	X	-	-	≠	-	-	-	-	-	-
	224	X	X	-	-	≠	-	-	-	-	-	-
	3243	X	X	X	-	≠	-	-	-	-	-	-
	3241	X	X	-	-	≠	-	-	-	-	-	-
	322	X	X	X	-	≠	-	-	-	-	-	-
	3212	X	X	-	-	≠	-	-	-	-	-	-
	3211	X	X	-	-	≠	-	-	-	-	-	-
	3111	X	X	X	-	≠	X	X	-	-	-	-
	3112	X	X	X	-	≠	X	X	-	-	-	-
	3113	X	X	X	-	≠	X	X	-	-	-	-
	31211	X	X	X	-	≠	X	X	-	-	-	-
	312122	X	X	X	-	≠	X	X	-	-	-	-
	312121	X	X	X	-	≠	X	X	-	-	-	-
	3122	X	X	X	-	≠	X	X	-	-	-	-
	3123	X	X	X	-	≠	X	X	-	-	-	-
	3131	X	X	X	-	≠	X	X	-	-	-	-
	5122	X	X	-	≠	-	-	-	-	≠	-	-
	411	X	X	X	≠	X	-	-	-	≠	-	-
	421	X	X	X	≠	-	-	-	-	≠	-	-
	5232	X	X	-	≠	-	-	-	-	≠	-	-
	4121	X	X	X	≠	X	-	-	-	≠	-	-
	4122	X	X	X	≠	X	-	-	-	≠	-	-

** Class codes AIS-LCM legend: 14-Busk- og skovområde, 4. 11-Buskbevokset hedeområde, 5. 05-Græsbevokset hedeområde, 6. 10-Busk- og græsbevokset hedeområde, 7. 15-Løvskov, 8. 16-Nålskov, 9. 08-Engområde.

*** Class codes DMK legend: 5 Barskog (Needle leaved forest), 6. Blandingsskov (Mixed forest), 7. Lauvskog (Broadleaved forest), 8. Myr (Mire)

**** Class codes SMD legend: 3242 Cleared-felled areas (before woody vegetation), 334 Burned areas (before woody vegetation), 3243 Younger forest, 3241 Thickets, 322 Moors and heathland, 3212 Meadow, 3211 Grass heath, 3111 Broadleaved forest not on mires or bare rock, 3112 Broadleaved forest on mires, 3113 Broadleaved forest on bare rock, 31211 Coniferous forest on lichen dominated areas, 312122 Coniferous forest >15m, 312121 Coniferous forest 5-15m, 3122 Coniferous forest on mires, 3123 Coniferous forest on bare rock, 3131 Mixed forest not on mires or bare rock, 5122 Water bodies, vegetation covered water area, 411 Inland marches, 421 Salt marshes, 5232 Sea and ocean, vegetation covered water area, 4121 Wet mires, 4122 Other mires.

6.5.2 Similarity assessment

Once legend classes have been translated into LCCS classifiers and imported to the Translator Module, the system can act as a reference base for legend comparison. Individual classes from different legends can be compared at the level of their classifiers and attributes, although only those which are provided by the system; user-defined attributes will not be considered. The similarity between classes can be quantified using the option *Similarity assessment* in the Translator Module's main menu. In the screen display the user has to select the reference class with which the other classes will be compared. A number of threshold settings are provided. If the classifiers can be compared and the options are identical the similarity is 100 percent (or 1), if not 0 percent (or 0). These values are stored in a table of correspondence in which the following assumptions have been made (Di Gregorio and Jansen, 2000):

- The classifier *Trees* is the same whether coming from (Semi-) Natural Vegetation (A12 and A24) or from Cultivated Areas (A11 and A23).
- The classifier *Herbaceous* comprises *Graminoids* and *Forbs*, or *Non-Graminoids*, therefore the threshold has been set at 50 percent (or 0.5) when comparing *Herbaceous* to either *Graminoids* or *Forbs*. The same applies to *Woody* which comprises *Trees* and *Shrubs*.

To make a *Similarity assessment* of two classes the procedure to be followed is (Di Gregorio and Jansen, 2000):

1. Select the *Classification Name* of the legend that should provide the Reference Class.
2. Select the appropriate class under *Classes*.
3. Click the Reference Class set of arrows to get the selected class in the Reference Class box.
4. Click the *Compare* button. (The Similarity of External Single Classes window appears.)
5. Click on the *Reference Class* button and the class selected will be shown on the left side, together with its classifiers and the options used.
6. Select *Empty Report* and press *OK* twice.
7. Select the legend to be compared by highlighting the name.
8. Set the threshold values to determine which classes are assessed. Two groups are distinguished: (1) to set if only classes with the first classifier the same should be assessed (otherwise, all classes); (2) to set the threshold value of the similarity.
9. Click *Process* and the assessment will start. A pop-up message will be displayed when the assessment is completed.
10. Select *Preview Report* and a report will be shown showing the Reference Class, the legend or classification selected for similarity assessment and the results, namely the classes and the similarity value.
11. Select *Close* to return to the Main Menu of the Translator Module.

5.5.3 Legend intracomparisons

The AIS-LCM and EELC legends have been selected for legend intracomparison. It should be noted that only the first 21 classes of the EELC legend have been translated into LCCS terminology. The aim of legend intracomparison is to quantify the similarity of classes belonging to the same legend, and thereby assess their distinctiveness. The similarity values will give an indication of how similar the physiognomic-structural descriptions of the classes in a legend are. The more similar the classes, the more difficult their correct distinction.

Table 6.6 shows the results for the intracomparison of the AIS-LCM legend. No threshold values were set. In the computation, only one element of a mixed class can be selected as the reference class that is automatically compared to the first element of any mixed class to be compared. This means that when selecting the reference class one can set which element of the mixed class will be the reference class (*e.g.*, see division of mixed classes 6, 7, 10 and 11 where the figures 1 and 2 refer to the first or second element of the mixed class). No reference class can be compared to the second element of a mixed class to be compared.

Along the diagonal axis one finds in general the highest values, especially in the group of classes belonging to the same major LCCS land cover category as indicated by the boxes in the table. However, there are also values showing high similarity further from the diagonal axis. Most of these values are linked to the aquatic (semi-) natural vegetation type of class "08-Engområde". This class can be regrouped with the terrestrial vegetation classes under the category of (Semi-) Natural Vegetation independent of the environment (*e.g.*, aquatic or terrestrial) in which the vegetation type occurs (dotted line in Table 6.6). The other, lower (but non-zero) off-diagonal similarity values are caused by the occurrence of similar life forms between classes.

Table 6.6. Intracomparison AIS-LCM legend (Denmark). (see the text for explanation of the boxes)

LCCS order Class codes	1 18	2 07	3 14	4 11	5 05	6 10	7 15	8 16	9 08	10 03	11 01
1	100	100	0	0	25	0	0	0	25	0	0
2	100	100	0	0	25	0	0	0	25	0	0
3	0	0	100	40	0	0	60	60	0	0	0
4	0	0	40	100	0	60	20	20	0	0	0
5	25	25	0	0	100	25	0	0	75	0	0
6.1	0	0	0	75	25	100	0	0	25	0	0
6.2	25	25	0	0	100	25	0	0	75	0	0
7.1	0	0	60	20	0	0	100	60	0	0	0
7.2	0	0	40	0	20	20	80	40	20	0	0
8	0	0	60	20	0	0	60	100	0	0	0
9	25	25	0	0	75	25	0	0	100	0	0
10.1	0	0	0	0	0	0	0	0	0	100	0
10.2	0	0	0	0	0	0	0	0	0	0	0
11.1	0	0	0	0	0	0	0	0	0	0	100
11.2	0	0	0	0	0	0	0	0	0	0	100

Class codes: 1. 18-Sæsonbestemt arealdække, 2. 07-Afgræsset eller slået græs, 3. 14-Busk- og skovområde, 4. 11-Buskbevokset hedeområde, 5. 05-Græsbevokset hedeområde, 6. 10-Busk- og græsbevokset hedeområde, 7. 15-Løvskov, 8. 16-Nålskov, 9. 08-Engområde, 10. 03-Ubevokset overflade, 11. 01-Åbent vand.

The intracomparison of the EELC legend follows the same class-wise *Similarity assessment* procedure where each class in turn as *Reference class* is compared against the same legend. The intracomparison shows a more “classic” example of the similarity values (Table 6.7): high values along the diagonal axis with the highest values inside the LCCS land cover category. Each land cover category is clearly distinct from other occurring land covers as there are no similarities to be found outside the land cover categories. This means that the high similarity between classes belonging to the same land cover category (e.g. (Semi-) Natural Aquatic Vegetation, Bare Areas, and Natural Waterbodies, Snow and Ice) makes the correct distinction and separation of classes difficult. This is especially true for the vegetation classes where differences might be based on the difference of a single classifier option or a class having one additional classifier. Separation of such classes needs to be supported by a thorough validation and verification effort.

Comparison of Tables 6.6 and 6.7 thus illustrates that the need for additional information for the correct assignment of class names in the EELC legend is much higher than for the AIS-LCM legend. They also show that the variation within a land cover category is very much dependent on the occurrence and definition of the classes present in the legend. It could be helpful in future to intracompare the classes of a preliminary legend before application in practise.

6.5.4 Comparison of legends

The comparison of two legends of neighbouring countries gives an indication of how similar land cover classes occur in these legends. For this reason the 3Q and SMD legends were selected for comparison. The results are presented in Table 6.8. The methodology is the same as described above in section 6.5.2. In the table the similarities from 50 to 75 percent and more than 75 percent are presented in lighter and darker levels of grey shading respectively. These values correspond with the thresholds that can be set in the Translator Module. However, for the comparison no threshold values were set. The boxes in the table present the major LCCS land cover categories in order to facilitate the interpretation of the similarity computation. A dotted line indicates the two land cover categories (Semi-) Natural Terrestrial and Aquatic or Regularly Flooded Vegetation (A12 and A24). In both categories the same classifiers occur with the same set of options, hence the high similarity as discussed above (section 6.5.3).

In the 3Q legend several cultivated area classes are distinguished whereas the SMD is geared towards description of general-purpose land cover hence the limited number of cultivated area classes. The majority of high values in Table 8 are found within the boxes indicating the land cover categories. However, several high values are found outside these boxes, for instance 3211 and 3212 of the SMD legend show similarity with cultivated area classes of 3Q, and class U4tr of the 3Q legend shows similarity with the

Table 6.7. Intracomparison EELC legend (Estonia); see the text for explanation of the boxes.

LCCS order Class codes	1 6	2 19	3 20	4 21	5 10	6 13	7 18	8 17	9 12	10 9	11 8	12 11	13 14	14 16	15 15	16 5	17 4	18 7	19 1	20 3	21 2
1	100	40	40	40	20	20	20	40	40	40	60	60	60	60	20	0	0	0	0	0	0
2	40	100	100	80	80	80	60	40	40	40	40	20	20	20	20	0	0	0	0	0	0
3	40	100	100	80	80	80	60	40	40	40	40	20	20	20	20	0	0	0	0	0	0
4	40	80	80	100	60	60	80	40	40	40	40	20	20	20	20	0	0	0	0	0	0
5	17	67	67	50	100	83	67	17	17	17	17	33	33	33	0	0	0	0	0	0	0
6	17	67	67	50	83	100	83	17	17	17	17	50	50	50	0	0	0	0	0	0	0
7	17	50	50	67	67	83	100	17	17	17	17	50	50	50	0	0	0	0	0	0	0
8	40	40	40	40	20	20	20	100	100	80	40	20	20	20	20	0	0	0	0	0	0
9	40	40	40	40	20	20	20	100	100	80	40	20	20	20	20	0	0	0	0	0	0
10	40	40	40	40	20	20	20	80	80	100	40	20	20	20	20	0	0	0	0	0	0
11	50	33	33	33	17	17	17	33	33	33	100	50	50	33	17	0	0	0	0	0	0
12	50	17	17	17	33	50	50	17	17	17	50	100	100	83	0	0	0	0	0	0	0
13	50	17	17	17	33	50	50	17	17	17	50	100	100	83	0	0	0	0	0	0	0
14	50	17	17	17	33	50	50	17	17	17	33	83	83	100	0	0	0	0	0	0	0
15	50	50	50	50	0	0	0	50	50	50	50	0	0	0	100	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	50	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	50	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	100	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	100	100
																			75	100	100

Original class codes: 1. Deep sea, 2. Shallow offshore water with sandy or stony sea floor, 3. Lake, 4. Sandy coast, 5. Shingle and gravel coast, 6. Coastal and shore reed bed, 7. Till and stony coast (limestone cliff), 8. Open fen, 9. Shrub fen, 10. Treed fen, 11. Open transitional bog, 12. Shrub transitional bog, 13. Treed transitional bog, 14. Bog lagg, 15. Open bog, 16. Complex shrub bog, 17. Dwarf shrub bog, 18. Treed bog, 19. Minerotrophic swamp forest, 20. Transitional bog forest, 21. Bog forest.

(Semi-) Natural Terrestrial Vegetation classes of SMD due to the co-occurrence of classifiers. Table 9 and 10 show some classes in more detail to help understand how these similarity values are computed and what causes the unforeseen occurrence of these values. Similarity between cultivated area classes and (semi-) natural vegetation classes is due to the occurrence of a limited number of joint classifiers since both land cover categories are dominated by plants and their vertical and horizontal arrangements. As a consequence, a similarity can be found between for instance graminoid crops with a herbaceous or graminoid type of (semi-) natural vegetation.

Table 9 and 10 show how the similarity is calculated and illustrate at the same time that the reference class determines the type and number of classifiers in the computation. When there are few classifiers (Table 9) the resulting similarity values are high, whereas with more classifiers in the reference class (Table 10) the resulting similarities are much lower. These two tables illustrate the bias in the algorithm implemented in LCCS: the fewer the classifiers in the reference class the higher the similarity. It has been suggested (Jansen *et al.* 2002) that the current algorithm be changed to one that also takes into account the number of classifiers used.

6.6 Conclusions

The thematic harmonisation of five Nordic data sets using the LCCS Translator Module reveals that the problems in finding the correspondence between the original criteria and the LCCS classifiers are related to differences in the definition of threshold values, use of land-use terminology that cannot be translated in LCCS classifiers and use of mixed classes when the original classes contain a range of values that do not correspond with the options available in LCCS. In particular, the occurrence of lichen-dominated areas with trees cannot be accommodated in LCCS by creation of a mixed class. The concept adopted in LCCS for lichens is very limited and it is impossible to link this life form with any occurring stratification. Some of the solutions adopted in the translation of classes may require discussion and would, more importantly, require consensus between translators of different countries.

The five translated legends make different use of the LCCS classifiers available. Specific-purpose legends such as 3Q and to a lesser degree AIS-LCM use almost the full range of classifiers to describe the Cultivated Area classes, whereas (Semi-) Natural Vegetation classes show more variation in the use of classifiers: the use of the classifier Spatial Distribution is limited and Stratification is not used probably because the used legends are used in remote sensing applications in which the layering cannot, or to a very limited extent, be detected. However, the reasons are not evident.

The intracomparisons of the AIS-LCM and EELC legends show that the variation within a land cover category is very much dependent on the occurrence and definition of the classes present in the legend. It could be helpful in future to intracompare the classes of a preliminary legend before application in practise in order to analyse how similar classes are and consequently how difficult may be their separation.

The legend comparison between the 3Q and SMD legends shows that the highest similarity values are found within a single land cover category but lower values occur especially between the Cultivated Areas and (Semi-) Natural Vegetation categories because they share a number of classifiers. It is important to note that the reference class determines the type and number of classifiers in the similarity computation. When there are few classifiers the resulting similarity values are high, whereas with more classifiers in the reference class the resulting similarities are much lower. The fewer the classifiers in the reference class the higher the similarity, this bias in the algorithm implemented in LCCS needs revision in order to better reflect the number of classifiers used in the computation.

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Table 6.8. Comparison between 3Q (Norway) (row) and SMD (Sweden) (column) legends. (see the text for explanation of the boxes and shading)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	Codes	211	231	141	222	3242	334	3243	3241	322	3212	3211	3111	3112	3113	31211	312122	312121	3122	3123	3131	3132	3133	5122	411	421	5232	4121	4122
1	A1pl*	0	0	0	14	7	7	14	0	0	0	0	14	14	14	43	43	43	43	43	14	14	14	0	0	0	0	0	0
2	A2fr	0	0	0	20	10	10	20	0	0	0	0	20	20	20	20	20	20	20	20	20	20	20	0	0	0	0	0	0
3	A2bu	0	0	0	0	10	10	0	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	A1ko	0	0	0	0	0	0	0	0	0	13	25	0	0	0	0	0	0	0	0	0	0	0	0	13	13	0	13	13
5	A1br	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	10	10
6	A3be	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	10	10
7	A1en	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	10	10
8	A1be	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	10	10
9	A1in	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	10	10
10	A1na	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	10	10
11	A2jo	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	20	10	10	20	10	10
12	A3sb	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	10	10
13	A3kr	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	10	10
14	A1gr	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	20	10	10	20	10	10
16	U4tr	0	0	50	0	25	25	25	0	0	0	0	25	25	25	25	25	25	25	25	25	25	25	0	0	0	0	0	0
17	U4	0	0	50	0	0	0	0	0	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	U4ha	0	0	50	0	0	0	0	0	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	U4go	0	0	50	0	0	0	0	0	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	U4ca	0	0	50	0	0	0	0	0	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	U4id	0	0	50	0	0	0	0	0	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	S1la	0	0	0	17	17	17	50	17	17	17	17	83	83	83	50	50	50	50	50	67	67	67	17	17	17	17	17	17
23	S2bl	0	0	0	14	14	14	43	14	14	14	14	71	71	71	43	43	43	43	43	57	57	57	14	14	14	14	14	14
24	S3ba	0	0	0	17	17	17	50	17	17	17	17	50	50	50	83	83	83	83	83	33	33	33	17	17	17	17	17	17
25	S2bl	0	0	0	14	14	14	43	14	14	14	14	43	43	43	71	71	71	71	71	29	29	29	14	14	14	14	14	14
26	F1kr	0	0	0	0	0	0	13	25	0	0	0	0	0	0	0	0	0	0	0	13	13	13	0	0	0	0	0	0
27	F1vi	25	25	0	0	25	25	25	25	25	50	25	25	25	25	25	25	25	25	25	0	0	0	25	75	75	25	75	75
28	F1sb	6	6	0	0	11	11	11	11	11	11	22	11	11	11	11	11	11	11	11	0	0	0	11	33	33	11	33	33
29	F1sb	3	3	0	0	7	7	7	7	7	7	13	7	7	7	7	7	7	7	7	0	0	0	7	20	20	7	20	20
30	F2ri	0	0	0	0	25	25	25	50	100	25	25	25	25	25	25	25	25	25	25	0	0	0	25	25	25	25	25	25
31	F2sk	0	0	0	0	25	25	25	50	75	25	25	25	25	25	25	25	25	25	25	0	0	0	25	25	25	25	25	25
32	M2bu	0	0	0	0	13	13	13	25	38	13	13	38	38	38	13	13	13	13	13	25	25	25	13	25	13	13	25	25
33	M1gr	13	13	0	0	25	25	25	25	25	50	25	25	25	25	25	25	25	25	25	0	0	0	25	75	50	25	75	75
34	F3st/F3dr	20	20	0	0	0	0	0	0	20	20	0	0	0	0	0	0	0	0	0	20	20	20	0	40	40	0	40	40
35	U1mo/U1bi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	U1gr/U1tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	U1je	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	U5ro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	U2fo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	U2fg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	U2bo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	U2bg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	U1fl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	U5kl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	U4id	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	U2ve	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	U3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	U5br**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	B1fj	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	B1bl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	B1gr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	B2jo/B2to	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	B2dy/B2fi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	V1ka	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	V1el	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	V1tj	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	V3sa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0												

Class codes SMD: 211 Arable land, 231 Pastures, 141 Green urban areas, 222 Fruit trees and berry plantations, 3242 Cleared-felled areas (before woody vegetation), 334 Burned areas (before woody vegetation), 3243 Younger forest, 3241 Thickets, 322 Moors and heathland, 3212 Meadow, 3211 Grass heath, 3111 Broadleaved forest not on mires or bare rock, 3112 Broadleaved forest on mires, 3113 Broadleaved forest on bare rock, 31211 Coniferous forest on lichen dominated areas, 312122 Coniferous forest >15m, 312121 Coniferous forest 5-15m, 3122 Coniferous forest on mires, 3123 Coniferous forest on bare rock, 3131 Mixed forest not on mires or bare rock, 3132 Mixed forest on mires, 3133 Mixed forest on bare rock, 5122 Water bodies, vegetation covered water area, 411 Inland marches, 421 Salt marshes, 5232 Sea and ocean, vegetation covered water area, 4121 Wet mires, 4122 Other mires. * 1=A1pl,A3pl,A4pl,F1pl,F2pl,M1pl and ** 48=U5br/U5gr/U5le/U5to.

(table 6.8 continued)

		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
	Codes	111	11211	11212	121	121	124	1421	1422	1423	1424	1425	1425	1426	1122	1123	132	1312	1311	112	332	4123	331	333	511	5121	335	5231
1	A1pl*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	A2fr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	A2bu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	A1ko	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	A1br	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	A3be	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	A1en	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	A1be	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	A1in	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	A1na	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	A2jo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	A3sb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	A3kr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	A1gr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	U4tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	U4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	U4ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	U4go	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	U4ca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	U4id	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	S1la	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	S2bl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	S3ba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	S2bl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	F1kr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	F1vi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	F1sb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	F1sb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	F2ri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	F2sk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	M2bu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	M1gr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	F3st/F3dr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	U1mo/U1bi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	U1gr/U1tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	U1je	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	U5ro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	U2fo	33	67	33	67	67	67	67	67	67	67	67	67	67	33	33	0	0	0	0	0	0	0	0	0	0	0	0
40	U2fg	33	33	67	67	67	67	67	67	67	67	67	67	67	33	33	0	0	0	0	0	0	0	0	0	0	0	0
41	U2bo	67	100	67	33	33	33	33	33	33	33	33	33	33	67	67	0	0	0	0	0	0	0	0	0	0	0	0
42	U2bg	67	67	100	33	33	33	33	33	33	33	33	33	33	67	67	0	0	0	0	0	0	0	0	0	0	0	0
43	U1fl	67	67	100	33	33	33	33	33	33	33	33	33	33	67	67	0	0	0	0	0	0	0	0	0	0	0	0
44	U5kl	50	50	50	100	100	100	100	100	100	100	100	100	100	50	50	0	0	0	0	0	0	0	0	0	0	0	0
45	U4id	50	50	50	100	100	100	100	100	100	100	100	100	100	50	50	0	0	0	0	0	0	0	0	0	0	0	0
46	U2ve	50	50	50	100	100	100	100	100	100	100	100	100	100	50	50	0	0	0	0	0	0	0	0	0	0	0	0
47	U3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	50	50	0	0	0	0	0	0	0	0	0
48	U5br**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	100	100	0	0	0	0	0	0	0	0	0
49	B1fj	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0
50	B1bl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0
51	B1gr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0
52	B2jo/B2to	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
53	B2dy/B2fi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
54	V1ka	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	67	33	67
55	V1el	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	67	33	67
56	V1tj	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	100	33	100
57	V3sa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	100	33	100

Class codes SMD: 111 Continuous urban fabric, 11211 Discontinuous urban fabric with more than 200 inhabitants with minor areas of gardens and greenery, 11212 Discontinuous urban fabric with more than 200 inhabitants with major areas of gardens and greenery, 121 Industrial or commercial units, 121 Industrial or commercial units, 124 Airports, 1421 Sport grounds, shooting ranges, motor, horse and dog racing tracks, 1422 Airfields (grass), 1423 Ski slopes, 1424 Golf courses, 1425 Non-urban parks, 1425 Non-urban parks, 1426 Camping sites and holiday cottage sites, 1122 Discontinuous urban fabric with less than 200 inhabitants, 1123 Rural fabric with open plots, 132 Dump site, 1312 Other mineral extraction sites, 1311 Sand and gravel pits, 112 Road and rail networks and associated land, 332 Bare rock, 4123 Peat extraction sites, 331 Beaches, dunes and sand plains, 333 Sparsely vegetated areas, 511 Water courses, 5121 Water bodies, open water area, 335 Glaciers and perpetual snow, 5231 Sea and ocean, open water areas.

Table 6.9. Similarity between two Cultivated Area classes of the 3Q legend with two classes of the SMD legend.

3Q (Norway)		SMD (Sweden)	Similarity
<i>4. A1ko</i>		<i>3211. Grass heath</i>	
A. Life Form:	Graminoid crops	A. Life Form: Graminoids	1
		A. Cover: Closed	-
B. Spatial Distribution:	Continuous		0
D. Water Supply:	Rainfed cultivation		0
D. Cult. Time factor:	Permanent cropped		0
			25 %
<i>4. A1ko</i>		<i>3212. Meadow</i>	
A. Life Form:	Graminoid crops	A. Life Form: A2 Herbaceous	0.5
		A. Cover: A10 Closed	-
B. Spatial Distribution:	Continuous		0
D. Water Supply:	Rainfed cultivation		0
D. Cult. Time factor:	Permanent cropped		0
			13%
<i>12. A3sb</i>		<i>3211. Grass heath</i>	
A. Life Form:	Graminoid crops	A. Life Form: Graminoids	1
		A. Cover: Closed	-
B. Spatial Distribution:	Continuous		0
C. Crop Combination:	Single crop		0
D. Water Supply:	Rainfed cultivation		0
D. Cult. Time factor:	Permanent cropped		0
			20%
<i>12. A3sb</i>		<i>3212. Meadow</i>	
A. Life Form:	Graminoid crops	A. Life Form: A2 Herbaceous	0.5
		A. Cover: A10 Closed	-
B. Spatial Distribution:	Continuous		0
C. Crop Combination:	Single crop		0
D. Water Supply:	Rainfed cultivation		0
D. Cult. Time factor:	Permanent cropped		0
			10%

Table 6.10. Similarity of 3Q class F2ri (A24) with (Semi-) Natural Terrestrial Vegetation (A12) classes of SMD.

3Q (Norway)		SMD (Sweden)	Similarity
<i>30. F2ri</i>		<i>3241. Thickets</i>	
A. Life Form:	Shrubs	A. Life Form: Shrubs	1
A. Cover:	Closed	A. Cover: Closed	1
B. Height:	5-0.3m		0
	<0.5m		0
			50%
<i>32. M2bu</i>		<i>322. Moors and Heathland</i>	
A. Life Form:	Shrubs	A. Life Form: Shrubs1	
A. Cover:	Closed	A. Cover: Closed1	
B. Height:	5-0.3m	B. Height: 5-0.3m	1
	3-0.5m	<0.5m	0
C. Water Seasonality:	Waterlogged soil		0
D. Leaf Type:	Broadleaved		0
E. Leaf Phenology:	Deciduous		0
F. Stratification:	single layer		0
			38%

References

- Di Gregorio, A. & Jansen, L.J.M. 1998. A new concept for a land cover classification system. *The Land* 2.1:55-65.
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Annex 6.A – Description of used legends

6.A.1 AIS-LCM – Danish Area Information System Land Cover Map (Geoff Groom)

18-Sæsonbestemt arealdække = 10228(1)[Z11] *Permanently Cropped Area With Herbaceous Crop(s)*

Areas, that change markedly between being vegetation-covered and non-vegetated states, including cultivated areas.

- mainly includes areas with annual cropping, such as of grains, root crops.
- also includes areas newly sown to grass.
- also includes areas newly cleared of vegetation, such as clear felled forest or land for building.

07-Afgræsset eller slået græs = 10228(1)[Z12] *Permanently Cropped Area With Herbaceous Crop(s)*

Grass areas with little accumulation of dead vegetative material - however the biomass present can be either high or low. Includes grazed fields and hay fields.

14-Busk- og skovområde = 20007-13233 *Continuous Closed Medium High Forest*

Dry or wet area dominated by bush cover.

- includes bush and small tree cover, max. height, 5 - 6 m.
- includes scrub (thicket of typically *Salix* spp.).
- includes dwarf forest.
- includes young forest.

11-Buskbevokset hedeområde = 20019-12050 *Continuous Closed Dwarf Shrubland (Thicket)*

Mainly dry, semi-natural area dominated by woody shrubs, such as *Calluna* spp., *Erica* spp., *Vaccinium* spp., *Empetrum* spp. - max. height, about 0.5 m.

10-Busk- og græsbevokset hedeområde = 20022-12050 / 20038-12293 *Open Dwarf Shrubs (Shrubland) / Open Short Herbaceous Vegetation*

Dry, semi-natural area dominated by a complex mosaic of grasses and woody shrubs, such as *Calluna* spp., *Erica* spp., *Vaccinium* spp., *Empetrum* spp. - max. height, about 0.3 m high

This use of a Mixed description reflects upon mainly spatial rather than semantic aspects of the class, i.e. the 2 components can and frequently do co-occur in a single mapping unit.

05-Græsbevokset hedeområde = 20038-12293 *Open Short Herbaceous Vegetation*

Dry, semi-natural areas dominated by grasses, without major removal of dead vegetative material.

- may also have some forbs present.
- Typically on sandier, dryer soils on higher ground.

15-Løvskov = 20090 / 20132 *Broadleaved Deciduous Forest / Broadleaved Deciduous Woodland*

Forest dominated by deciduous trees.

- includes forest with broadleaf and/or needleleaf tree species
- includes forest with cover <65%

This use of a Mixed description reflects upon both spatial and semantic aspects of the class, i.e.:

- a) the 2 components can and frequently do co-occur in a single mapping unit.
- b) the mixture is used to capture a range of values (Cover) that do not correspond with a single LCCS classifier.

16-Nålskov = 20092 / 20134 *Needleleaved Evergreen Forest / Needleleaved Evergreen Woodland*

Forest dominated by evergreen trees.

- includes forest with broadleaf and/or needleleaf tree species
- includes forest with cover <65%

This use of a Mixed description reflects upon both spatial and semantic aspects of the class, i.e.:

- a) the 2 components can and frequently do co-occur in a single mapping unit.
- b) the mixture is used to capture a range of values (Cover) that do not correspond with a single LCCS classifier.

08-Engområde = 40064 *Open Herbaceous Vegetation On Permanently Flooded Land*

Annually wet, semi-natural area dominated by grasses, either with or without major removal of dead vegetative material.

- includes marshland, reed swamps.
- may have some forbs present.

03-Ubevokset overflade = 5001 / 5004 / 6004 *Built Up Area(s) / Non Built Up Area(s) / Unconsolidated Material(s)*

Bare surfaces.

- includes natural uncovered surfaces (such as beaches), unvegetated agricultural fields and artificial bare surfaces (such as extraction areas).
- also includes Consolidated bare surfaces (such as rock outcrops and built-upon land).

This use of a Mixed description reflects upon both spatial and semantic aspects of the class, i.e.:

- a) the 2 components can and frequently do co-occur in a single mapping unit.
- b) the mixture is used to capture a range of values that do not correspond with a single LCCS classifier.

01-Åbent vand = 8001 / 7001 *Natural Waterbodies / Artificial Waterbodies*

Areas with permanent open water.

- includes standing and running water

Also includes Artificial water bodies.

This use of a Mixed description reflects upon mainly semantic rather than spatial aspects of the class, i.e. the mixture is used to capture a range of values that do not correspond with a single LCCS classifier.

6.A.2 EELC - Estonian Land Cover Classification Scheme (Kiira Aaviksoo)

1. Deep sea = 8002-5-V2 *Perennial Natural Waterbodies (Standing)*, *Salinity: Slightly Saline*

Shelf area with water depth more than 1 m. Without vegetation.

2. Shallow offshore water with sandy or stony sea floor = 8014-5-V2U6 *Shallow Perennial Natural Waterbodies (Standing)*, *Salinity: Slightly Saline*, *Scattered Vegetation: Graminoids*

Water depth up to 1 m, often with reed (*Phragmites communis*) patches. Sea floor visible in image.

3. Lake = 8014-5-V1U6 *Shallow Perennial Natural Waterbodies (Standing)*, *Salinity: Fresh, < 1000 ppm of TDS*

Scattered Vegetation: Graminoids

Natural or artificial water bodies with variable water depth. Graminoids (*Phragmites communis*, *Schoenoplectus lacustris*) form patches or even quacking mats (*Drepanocladus* spp.).

Reed beds often in coastal zone.

4. Sandy coast = 6009-M213M410 *Shifting Sands / Dune(s)*, *Lithology: Unconsolidated clastic sedimentary rock - Sand*, *Age: Quaternary - Holocene*

Beaches, dunes and expanses of sand along seashore. Vegetation cover patchy (*Phragmites* spp., *Honckenya peploides*) or in strips (*Laemus arenarius*, *Schoenoplectus tabernaemontanii*).

Open area with sand.

5. Shingle and gravel coast = 6005-6-M214M410 *Stony Bare Soil And/Or Other Unconsolidated Material(s)*, *Lithology: Unconsolidated clastic sedimentary rock - Gravel*, *Age: Quaternary - Holocene*

Open area with shingle and gravel along seashore. Graminoids cover (*Crambe maritima*, *Atriplex* spp., *Galium verum*, *Geranium robertianum*) sparse.

Open area with shingle and gravel.

6. Coastal and shore reed bed = 40063-4723-N3N6Zt1 *Closed Tall Grassland On Waterlogged Soil*, *Soils: Loose and Shifting Sands with Dunes*, *Floristic Aspect: Phragmites communis*

Reed beds with abundant vegetation in coastal zone of sea (*Phragmites communis*) or lakes (*Schoenoplectus lacustris*).

7. Till and stony coast (limestone cliff) = 6005-7 / 6002-2-U5 *Very Stony Bare Soil And/Or Other Unconsolidated Material(s) / Gravels, Stones And/Or Boulders*, *Scattered Vegetation: Forbs*

Sparsely vegetated coast with stones of different size. Vegetation cover sparse, composed dominantly of ferns (*Gymnocarpium robertianum*, *Asplenium* spp.).

Sparsely vegetated coast with stones of different size.

Fens as one type of wetlands are occurring on nutrient-rich (minerotrophic) peat in low-lying land, inland through-flow basins, on river flood valleys, areas of springs, margin zones of transitional bogs. Fens have peaty ground with peat layer more than 30 cm thick. Areas identified by using the GIS-layer named fen mask. Physiognomic features: pattern in satellite image is homogeneous, colour in TM453 as RGB bluish-green. Blue colour refers to great extent of moisture in surface and plant tissues (waterlogged).

8. Open fen = 40060-3009-Zt2 / 40029-859 *Closed Medium Tall Rooted Forbs On Waterlogged Soil*, *Floristic Aspect: Carex spp., Filipendula ulmaria / Scattered Shrubs*

Vegetation composed of different sedges (*Carex* spp.), which often form tussocks – *Carex elata*, *C. caespitosa* - and forbs (*Filipendula ulmaria*, *Dryopteris thelypteris*, *Athyrium filix-femina*) in grass layer. Sedges are the dominant (physiognomic) species of this type of LC. (Brown) mosses are hidden. In shrub layer scarce willows (*Salix* spp.) are mostly common, some scattered trees - swamp birch, black alder and spruce can also occur.

Grass layer with sedges and shrub layer with willows.

9. Shrub fen = 40051-4786-Zt3 / 40028-903 *Closed Medium High Shrubs On Waterlogged Soil*, *Floristic Aspect: Salix spp. / Scattered Medium High Trees*

Vegetation composed dominantly of willows (*Salix* spp.) and alder buckhorn (*Frangula alnus*). In grass layer sedges (*Carex* spp.) are present, scattered trees (*Betula pubescens*, *Alnus glutinosa*) can also occur.

Shrub layer with willows and scattered trees (*Betula pubescens*, *Alnus glutinosa*).

10. Treed fen = 40048-331-Zt4 / 40060-3009-Zt2 *Medium High Woodland On Waterlogged Soil*, *Floristic Aspect: Betula pubescens, Alnus glutinosa / Closed Medium Tall Rooted Forbs On Waterlogged Soil*, *Floristic Aspect: Carex spp., Filipendula ulmaria*

Vegetation composed dominantly of trees – swamp birch (*Betula pubescens*), black alder (*Alnus glutinosa*) and less spruce (*Picea abies*). Tree crowns not interlocking (less than 70%). Shrub and grass layer (cf. units ## 8, 9) visible partly between trees.

Plant canopy not closed (less than 70%).

Transitional bogs as one type of wetlands are occurring on nutrient-poor (mixotrophic) transitional bog peat (peat deposit more than 30 cm thick), where brown mosses of fens are intersected with sphagnum mosses of bogs. Ordinary transitional bogs succeed fens in development and one can find them as transitional areas

between fens and (raised) bogs. Areas identified by using the GIS-layer named transitional bog mask. Physiognomic features: pattern in satellite image slightly heterogeneous, colour in TM453 as RGB bluish-green with greyish-brown (pine) or orange (birch) dots. Blue as indicator of water content (surface, plants).

11. Open transitional bog = 40072-20-Zt5 / 40993-1-Zt6 Open ((70-60) - 40%) Medium Tall Grassland On Waterlogged Soil, Floristic Aspect: *Carex* spp / Open ((70-60) - 40%) Mosses, Floristic Aspect: *Sphagnum* spp.

Vegetation composed of a mixture of eutrophic and oligotrophic species. Fen species are occupying lower patches between hummocks, which are presented by more oligotrophic (bog) vegetation. Plant communities represent different species of sedges (*Carex* spp.) and mosses (brown mosses and mesotrophic sphagnum ones). Representatives of shrub and tree layers are few.

Mixotrophic communities of sedges and sphagnum mosses.

12. Shrub transitional bog = 40051-4714-Zt7 / 40028-4759 Closed Dwarf Shrubs On Waterlogged Soil, Floristic Aspect: *Oxycoccus* spp. / Sparse Medium High Trees

Vegetation composed dominantly of willows (different species) and dwarf shrubs (*Oxycoccus* spp. especially). In grass layer sedges (*Carex* spp.) are presented, scattered deciduous and coniferous trees can occur.

Cranberry transitional bog.

13. Treed transitional bog = 40048-45-Zt8 / 40024-20-Zt5 / 40993-1-Zt6 Medium High Woodland On Waterlogged Soil, Floristic Aspect: *Betula pubescens*, *Pinus sylvestris* / Open ((70-60) - 40%) Medium Tall Grassland, Floristic Aspect: *Carex* spp / Open ((70-60) - 40%) Mosses, Floristic Aspect: *Sphagnum* spp.

Vegetation composed dominantly of birch (*Betula pubescens*) and pine (*Pinus sylvestris*) trees. Tree crowns not interlocking. Shrub and grass layer (cf. units ## 11, 12) visible partly between trees. Plant canopy not closed (less than 70%).

Bogs as one type of wetlands are occurring on nutrient-absent (ombrotrophic) poorly decomposed Sphagnum peat moss. Organogenic forms of thick peat deposits (more than 30 cm thick) can occur on the places of ancient concave landforms, which are during development filled by undecomposed remains of vegetation – peat. Surface of bogs is often convex, zones of different patterns are situated regularly (concentric or eccentric) around the bog centre(s). Areas identified by using the GIS-layer named bog mask. Physiognomic features: pattern in satellite image is heterogeneous, except lagg area, colour in TM453 as RGB bluish-green with black (pools) or greyish-brown (pine) dots. Blue as indicator of water content (surface, plants).

14. Bog lagg = 40072-20-Zt9 / 40993-1-Zt6 Open ((70-60) - 40%) Medium Tall Grassland On Waterlogged Soil, Floristic Aspect: mixotrophic sedges / Open ((70-60) - 40%) Mosses, Floristic Aspect: *Sphagnum* spp.

Depressions around bog massifs and bog islets, which are characterised by better water supply and growing conditions for plants. Vegetation of these very wet places composed of continuous mesotrophic sphagnum ground cover. Different species of sedges (*Carex lasiocarpa*, *C. limosa* and *C. rostrata*) are common.

Depressions around bog massifs and bog islets.

15. Open bog = 40981-Zt6 / 40081-574-Zt10 / 40036-601-Zt11 Closed Mosses, Floristic Aspect: *Sphagnum* spp. / Sparse ((20-10) - 4%) Dwarf Shrubs On Waterlogged Soil, Floristic Aspect: *Calluna vulgaris* / Sparse ((20-10) - 4%) Short Grassland, Floristic Aspect: *Eriophorum* spp

Vegetation composed of sphagnum mosses and cotton grasses. Low hummocks. Cotton grass bog and open hollow-ridge bog (often without orientation) sites are mainly presented. Plant communities represent different species of sphagnum (*Sphagnum* spp.) and cotton grass (*Eriophorum vaginatum*, *Trichophorum* spp.). Dwarf shrub (*Calluna vulgaris*, *Chamaedaphne calyculata*) cover is less than 50%. Scarce stunted pines (*Pinus sylvestris*).

Open bog with sphagnum mosses, sedges and dwarf shrubs.

16. Complex bog = 40072-29-Zt12 / 40993-1 / 40076-699 Open ((70-60) - 40%) Short Grassland On Waterlogged Soil, Floristic Aspect: *Rhynchospora* spp. / Open ((70-60) - 40%) Mosses / Sparse ((20-10) - 4%) Medium High Trees On Permanently Flooded Land (Persistent)

Vegetation composed mainly of sphagnum mosses, which form hummocks, arranged to concentric or eccentric hollow - (treed) ridge - pool communities. Alteration of ridges, hollows and pools gives this bog type irregular pattern. Species same, excl. trees and beak sedge (*Rhynchospora alba*), as in the unit # 15.

Complex of hollow-treed ridge-pool communities.

17. Dwarf shrub bog = 40051-4714-Zt10 / 40028-912-Zt13 Closed Dwarf Shrubs On Waterlogged Soil, Floristic Aspect: *Calluna vulgaris* / Scattered Low Trees, Floristic Aspect: *Pinus sylvestris*

Vegetation composed of different shrubs (*Calluna vulgaris*, *Oxycoccus* spp, *Empetrum nigrum*, *Andromeda polifolia*, *Chamaedaphne calyculata*) is abundant and covers more than half of the continuous sphagnum cover. Stunted trees (*Pinus sylvestris*) cover only some per cent.

In addition to *Calluna*, *Oxycoccus* spp, *Empetrum nigrum*, *Andromeda polifolia*, *Chamaedaphne calyculata* are common.

18. Treed bog = 40048-54-Zt13 / 40012-288-Zt14 / 40993-1 Low Woodland On Waterlogged Soil, Floristic Aspect: *Pinus sylvestris* / Open (40 - (20-10)%) Dwarf Shrubs, Floristic Aspect: *Ledum palustre*, *Calluna vulgaris* / Open ((70-60) - 40%) Mosses

Vegetation composed dominantly of pine trees (*Pinus sylvestris*). Tree crowns not interlocking. Shrub and grass layer (cf. units ## 15, 17) visible partly between trees.

Tree canopy not closed (less than 70%).

19. Minerotrophic swamp forest = 40042-4759-Zt4 / 40022-1165-Zt2 / 40993-287-Zt15 Medium High Forest On Waterlogged Soil, Floristic Aspect: *Betula pubescens*, *Alnus glutinosa* / Open ((70-60) - 40%) Medium Tall Rooted Forbs, Floristic

Aspect: *Carex* spp., *Filipendula ulmaria* / Open (40 - (20-10)%) Mosses, Floristic Aspect: *Bryales* spp.

Birches (*Betula pubescens*), black alders (*Alnus glutinosa*) and spruces (*Picea abies*) compose medium-high forest, where crowns are interlocking. Under layers, presented by abundant forbs (*Filipendula ulmaria*) and sedges (*Carex* spp., *Calamagrostis canescens*) on brown mosses, visible only in few places. Tree cover closure more than 70%.

20. Transitional bog forest = 40042-4759-Zt8 / 40024-20-Zt9 / 40993-1-Zt6 Medium High Forest On Waterlogged Soil, Floristic Aspect: *Betula pubescens*, *Pinus sylvestris* / Open ((70-60) - 40%) Medium Tall Grassland, Floristic Aspect: mixotrophic sedges / Open ((70-60) - 40%) Mosses, Floristic Aspect: *Sphagnum* spp.

Birches (*Betula pubescens*) and pines (*Pinus sylvestris*) compose medium-high forest, where crowns are interlocking. Under layers, presented by abundant sedges (*Carex* spp.) on sphagnum cover, visible only in few places. Sphagnum species influence tone (lighter than previous) of pattern of this class.

Tree cover closure more than 70%.

21. Bog forest = 40042-4768-Zt13 / 40012-2-Zt14 / 40993-1-Zt6 Low Forest On Waterlogged Soil, Floristic Aspect: *Pinus sylvestris* / Open ((70-60) - 40%) Dwarf Shrubs, Floristic Aspect: *Ledum palustre*, *Calluna vulgaris* / Open ((70-60) - 40%) Mosses, Floristic Aspect: *Sphagnum* spp.

Pines (*Pinus sylvestris*) compose of low forest. Crowns interlocking. Sphagnum cover above which dwarf shrubs (*Ledum palustre* and other species named under unit # 17) are common, presents under layers, which are visible only in few places. Due to prevailing sphagnum mosses tone of this LC type is bright.

Tree cover closure more than 70%.

6.A.3 3Q – Norwegian Tilstandsovervåkning og resultatkontroll i jordbrukets kulturlandskap (Wendy Fjellstad)

“Semi-natural grazed areas” consist of:

- A1 grazing on cultivated meadows; a planted fodder crop that could be harvested mechanically
- A3 - grazing on land that cannot be harvested mechanically - the ‘crop’ is not planted, but formed through many generations of grazing pressure.
- A4 this category includes meadow areas that may or may not be in agricultural use, pasture with low grazing intensity and wild-looking hay meadows that are not cut at the time the aerial photograph was taken. This may be abandoned pasture and hay meadows where succession has not yet lead to incursion by bushes and scrub, but where it is impossible to ascertain whether management of the land has ceased or not.
- F1 non-agricultural semi-natural grassland: grass and herb dominated dry-land vegetation that is considerably influenced by human activities, but which is not clearly grazed or cut. Usually directly associated with agricultural land and buildings.

For each of categories A3, A4 and F1 there are two classes of scrub encroachment:

- sb 5 - 25 % cover of bushes or bushes and trees.
- kr more than 25% cover of bushes or bushes and trees.

If there are no bushes - only trees - the ‘pure’ category is used (A3be, A4be or F1vi) with recording of the trees as points. This enables us to distinguish between wooded pasture that is in use and pasture undergoing forest regrowth.

For each category sb and kr there could be several different LCCS categories with varying degrees of cover and heights and either one or two vertical layers. All these possible classes are not represented in the translation.

For the distinction between A3 and F1 use has been made of the agricultural fodder grasses category for A3 (in mixed classes with natural bushes and trees) and using the semi-natural/natural grassland category for F1 (again with mixed classes for bushes and trees). It may not have been entirely correct to use the fodder grasses option since this is not a planted crop in A3. However, this division between agriculture and semi-natural fitted best with the 3Q concept of agriculture. The category A4 was not translated because there is no technical attribute in LCCS available for grazing pressure. Without this attribute the results would have been the same as the F1 classes.

Clear-felled and burned areas are in the category F4. This category was not translated because without use-attributes it would be the same as the F1 category. Forest areas that are clear-felled, wind-felt or burned, but where forest re-growth is not yet tall enough to be classified as forest (i.e. average height < 3m). Exposed rock and rocky knolls within cleared forest are classed as B1fj and F2ra respectively. The remaining area is classed as cleared forest, irrespective of vegetation density, vegetation type and bush cover. The following distinctions are made:

- ho forest areas that have been clear-felled for forestry production.
- ga linear areas of forest that have been cleared to give access to tractors, ski-tracks, transmission lines, boundary demarcation lines etc. Areas under transmission lines and along boundary demarcation lines are

to be recorded as F4ga even if tree regrowth is greater than 3m high, unless the forest in these areas is indistinguishable from surrounding forest, in which case it should be mapped as forest.

- vi area where trees have been blown over by strong wind.
- br area where trees have been burned down or killed due to fire.

The translated classes from the 3Q legend are:

A1pl,A3pl,A4pl,F1pl,F2pl,M1pl = 10494-5671-S10W7 *Permanently Cropped Area With Rainfed Needleleaved Evergreen Tree Crop(s)*, Crop type: Wood & Timber

New plantation for forestry or Christmas tree production. COMMENT: In 3Q there are various categories of plantation depending on the apparent use of the land prior to planting (arable, grazed, semi-natural grassland, mire etc.). Perhaps this reflects an impatience to be able to record land use change from one category to another - to know what land type disappeared to make way for the plantation. Obviously, over time this will become unnecessary as comparisons of old and new maps will give this information. It should be added that 3Q-plantations fall under the definition of forest as soon as the average tree height is 3m and tree cover >25%. (Again, comparison of old and new maps will in time also allow us to identify present forest that was planted).

A2fr = 10494-W8 *Permanently Cropped Area With Rainfed Tree Crop(s)*, Crop Cover:(Orchard(s))

Perennial horticultural plants with over-wintering trunks, such as fruit trees, garden trees in nurseries etc. COMMENT: although A2fr in practice will generally be orchards, the category can include e.g. garden trees grown for sale

A2bu = 10566 *Permanently Cropped Area With Rainfed Shrub Crop(s)*

Perennial horticultural plants with over-wintering woody stalks, such as blackcurrant, raspberry, garden bushes in nurseries, etc. COMMENT: 3Q distinguishes horticultural crop type on the basis of life form only and thus includes food and non-food (garden) plants in the same category.

A1ko = 10318-S3 *Permanently Cropped Area With Graminoid Crop(s)*, Crop type: Cereals

Cereals, oil plants etc.: Fully cultivated or surface cultivated land covered by plants of which the seeds are used by people or animals. COMMENT: Before choosing cereals I have to state that this is a 'food crop'. My category includes other seed crops such as oilseed rape - which could be used for food or non-food purposes. Here in the LCCS it would seem that use comes before cover type for this technical attribute? Maybe a mixed class including industrial crops would better cover all examples of A1ko?

A1br = 10820 *Graminoid Crop(s) With Fallow System*

Fallow land: agricultural area lying fallow; high proportion of annual weeds/ visible plough lines or areas of bare soil. Fallow land with < 25 % vegetation is classified as A1na - bare earth.

A3be = 10822-L2S7 *Permanently Cropped Area Graminoid Crop(s)*, Major Landclass: Sloping Land, Crop type: Fodder

Area clearly characterised by grazing and that is not suitable for mechanised cultivation. Uneven surface can have up to 5 % bush cover. COMMENT: I used 'Landform' to distinguish between cultivated meadow (can be harvested mechanically) and the A3 category pasture. "Sloping land" doesn't quite capture this - you'd be surprised at the slopes they harvest mechanically in Norway! And there may be other reasons that an area can't be harvested mechanically, just as spatial configuration, bogginess, stoniness, small-scale unevenness etc. Of course, the fodder cover is also rather different on grazed land than ungrazed, both physically and its distribution (at a fine scale) interspersed with animal paths and trampled ground. The actual "crop" is also different in terms of species.

A1en = 10822-S7 *Permanently Cropped Area Graminoid Crop(s)*, Crop type: Fodder

Cultivated meadow: grass-dominated agricultural area on fully cultivated or surface cultivated land that can be mechanically harvested. Seed production of meadow plants such as *Trifolium* species, *Phleum pratense* etc. is included in this category. (Cultivated meadow that is grazed is recorded as A1be).

A1be = 10822-S7(2) *Permanently Cropped Area Graminoid Crop(s)*, Crop type: Fodder

Grass-dominated agricultural area on fully cultivated or surface cultivated land that can be mechanically harvested, but that - at the time the aerial photograph was taken - is being used for grazing of domestic animals. COMMENT: A clone of A1en

A1in = 10822-S7(2)(2) *Permanently Cropped Area Graminoid Crop(s)*, Crop type: Fodder

Enclosure: permanently fenced enclosure, usually small in area and closely associated with a farm. The area is usually characterised by trampled ground when in use by domestic animals, and dominated by weedy vegetation when not in use or in low intensity use. COMMENT: A clone of A1en.

A1na = 10822-W6 *Permanently Cropped Area Graminoid Crop(s)*, Crop Cover: Low (30-15) %

Bare earth: agricultural area with at least 75 % bare soil. COMMENT: The percentage thresholds are different for the 3Q category and LCCS, and for A1na it is not necessarily the crop cover that is low, but can for example be a low occurrence of weeds before the crop has been sown. A1na includes the short fallow period between annual crops - probably this category is only suitable for mapping at detailed spatial and temporal scales, and therefore not included in LCCS.

A2jo = 11002 *Permanently Cropped Area Non-Graminoid Crop(s)*

Perennial horticultural plants that lack over-wintering woody stalks or trunks, such as strawberry plants, garden plants in nurseries etc. COMMENT: 3Q distinguishes horticultural crop type on the basis of life form only and thus

includes food and non-food (garden) plants in the same category.

A3sb = 10822—S7 / 20499-6022 *Permanently Cropped Area Graminoid Crop(s), Crop type: Fodder / Sparse ((20-10) - 4%) Woody Vegetation, Single Layer*

Pasture with 5 - 25 % cover of bushes or both bushes and trees. Tree covered point objects are not recorded on this land type, but rather are included in the assessment of the total cover of bushes and trees. Pasture with no bushes but with scattered trees is to be interpreted as A3be, where the trees are recorded either as tree covered point objects or patches of forest (depending on extent). COMMENT: I chose to mix agricultural land and semi natural land. The bush/tree cover thresholds are different in 3Q and LCCS, as is tree height (a 3Q tree is over 3m tall - further info is not collected).

A3kr = 10822-L2S7 / 20298 *Permanently Cropped Area Graminoid Crop(s), Major Landclass: Sloping Land, Crop type: Fodder / Open Woody Vegetation, Single Layer*

Pasture with at least 25 % cover of bushes or both bushes and trees, where the land between the bushes and thickets is clearly characterised by grazing. Tree covered point objects are not recorded on this land type, but rather are included in the assessment of the total cover of bushes and trees. COMMENT: % thresholds and height in 3Q don't match LCCS categories. Also, the 3Q category can be either a single layer of bushes or two layers (bushes and trees).

A1gr = 1002-S4 / 11002-S5 *Permanently Cropped Area Non-Graminoid Crop(s), Crop type: Roots & Tubers / Permanently Cropped Area Non-Graminoid Crop(s), Crop type: Pulses & Vegetables*

Leafy and root vegetables: Fully cultivated or surface cultivated land covered by plants of which the leaves, flowers, tubers, stalks or roots are used by people or animals. COMMENT: As for A1ko, my class includes 2 of the technical attribute crop types. This time I made a mixed class - seems a good option? (By the way, why does 'continuous fields' appear in the LCC label for graminoid crops but not for the same choices under non-graminoid crops?).

A2al = 11149 / 11149 *Scattered Clustered Permanently Cropped Area With Small Sized Field(s) Of Non-Graminoid Crop(s) / Scattered Clustered Permanently Cropped Area With Small Sized Field(s) Of Non-Graminoid Crop(s)*

Three or more horticultural products cultivated in so small an area or in such a spatial configuration that their separation would not be expedient. COMMENT: This class is very difficult to translate because there are many possible combinations for the specific content of any particular A2al polygon.

U4tr = 11177 *Vegetated Urban Area(s)/Park(s)*

Parks and gardens with at least 25 % tree cover.

U4 = 11179 *Vegetated Urban Area(s)/Lawn(s)*

Urban greenways, sport and recreation areas.

U4ha = 11179(1)[Z1] *Vegetated Urban Area(s)/Lawn(s)*

Parks and gardens with less than 25 % tree cover.

U4go = 11179(1)[Z2] *Vegetated Urban Area(s)/Lawn(s)*

Golf course.

U4ca = 11179(1)[Z3] *Vegetated Urban Area(s)/Lawn(s)*

Campsite: area prepared for camping, including camping huts and caravans.

U4id = 11179(1)[Z4] *Vegetated Urban Area(s)/Lawn(s)*

Sport and leisure facilities, including riding centres and motor sports areas. COMMENT: In 3Q, lawns at sports grounds are not distinguished from hard surface grounds or associated buildings (a clear example of 'use' being given priority over 'cover'!).

S1la = 20097 *Broadleaved Deciduous Forest*

Forest comprising at least 75 % broadleaved trees (of unspecified type).

S2bl = 20097-15045 *Mixed Forest*

Forest comprising a mixture of broadleaved and coniferous tree species. At least 25 % broadleaved trees in coniferous forest, or at least 25 % conifers in broadleaved forest.

S3ba = 20099 *Needleleaved Evergreen Forest*

Forest comprising at least 75 % coniferous trees (of unspecified type).

S2bl = 20099-15045 *Mixed Forest*

COMMENT: There seem to be 2 possible codes for mixed forest in LCCS, depending on whether one chooses broadleaved trees first or coniferous?

F1kr = 20377-13476 *Medium High Shrubland With Herbaceous*

Semi-natural meadows and weedy areas, that are not used for agricultural purposes but that are influenced by human activities, and that have at least 25 % cover of bushes or both bushes and trees. Tree covered point objects are not recorded on this land type, but rather are included in the assessment of the total cover of bushes and trees. Areas where trees alone comprise at least 25% cover are recorded as forest.

F1vi = 20409 *Closed Herbaceous Vegetation, Single Layer*

Semi-natural meadows and weedy areas with less than 25 % bush-cover, that are not used for agricultural purposes but that are influenced by human activities. (Solitary trees or clusters of trees are to be recorded as tree covered point objects).

F1sb = 20445-12763 *Medium To Tall Grassland With Trees*

Semi-natural meadows and weedy areas, which are not used for agricultural purposes but that are influenced by human activities, and that have 5 - 25 % cover of bushes or both bushes and trees.

F1sb = 20447-105533 *Medium To Tall Grassland With Medium High Trees And Medium High Shrubs*

Semi-natural meadows and weedy areas, which are not used for agricultural purposes but that are influenced by human activities, and that have 5 - 25 % cover of bushes or both bushes and trees.

F2ri = 40010-4714 Closed Dwarf Shrubs

Heath vegetation dominated by heather and brushwood.

F2sk = 40010-4786 Closed Medium High Shrubs

Mountain birch woodland and other woodlands with average tree height less than 3 m, in areas with conditions marginal for tree growth. Low growing trees and bushes comprise at least 50 % of the vegetation.

M2bu = 40723-4786-R2 *Broadleaved Deciduous Closed Medium High Shrubs On Waterlogged Soil, Water Quality: Brackish*
Beach swamps that are at least 50 % covered by bushes that are over 1 m.

M1gr = 40063 Closed Grassland On Waterlogged Soil

Mire with at least 50 % graminoid cover. Generally seepage/flush mires. Includes ericaceous and willow dominated grassy mires where the bush-layer is less than 1 m tall.

F3st/F3dr = Open Herbaceous Vegetation On Temporarily Flooded Land, Water Quality: Brackish

F3st: meadows that are periodically inundated by seawater/brackish water; F3dr: vegetation on heaps of seaweed, driftwood etc. and on beachy knolls that are strongly influenced by sea spray. At least 25 % of the area comprises bare rock, pebbles, gravel or sand. COMMENT: The 3Q classes combine saline and brackish, whereas LCCS requires that I choose one of these. Also, I have to choose regularly flooded- meaning inundated for at least 2 months of the year. I would have preferred to use influence of saltwater as a technical attribute for dry-land vegetation.

U1mo/U1bi = 5002-4 *Paved Road(s)*

U1mo: main road with separate carriageways and limited access, specially constructed and controlled for fast motor traffic; U1bi: other surfaced roads used for motor traffic. COMMENT: we are interested in road type due to different roles for access & recreation.

U1gr/U1tr = 5002-5 *Unpaved Road(s)*

U1gr: gravel roads; U1tr: roads that for the entire year or parts of the year are not suitable for normal cars, but that are passable by tractor.

U1je = 5002-6 *Railway(s)*

Access routes with rails and sleepers that are only intended for railway vehicles.

U5ro = 5002-7 *Communication Line(s)/Pipeline(s)*

Pipeline corridors.

U2fo = 5003-11-A26 *Medium Density Industrial And/Or Other Area(s), Built-up object: Cultural, Entertainment and Recreation Area*

Built-up area that is neither residential nor industrial, such as schools, play-schools, sports halls, town halls, churches etc. and that has less than 50% green area.

U2fg = 5003-12-A26 *Low Density Industrial And/Or Other Area(s), Built-up object: Cultural, Entertainment and Recreation Area*

Built-up area that is neither residential nor industrial, such as schools, play-schools, sports halls, town halls, churches etc. and that has at least 50% green area.

U2bo = 5003-14 *Medium Density Urban Area(s)*

Residential areas with less than 50 % green area.

U2bg = 5003-15 *Low Density Urban Area(s)*

Residential areas with at least 50 % green area.

U1fl = 5003-8—A21 *Industrial And/Or Other Area(s), Built-up object: Airport*

Airport runways: surfaced area used for the take-off and landing of aeroplanes.

U5kl = 5003-8—A37 *Industrial And/Or Other Area(s), Built-up object: Sewage Treatment Plant*

Sewage treatment plant.

U4id = 5003-8—A38 *Industrial And/Or Other Area(s), Built-up object: Sports and Leisure Facilities*

Sport and leisure facilities, including riding centres and motor sports areas. COMMENT: In 3Q, lawns at sports grounds are not distinguished from hard surface grounds or associated buildings (a clear example of 'use' being given priority over 'cover'!).

U2ve = 5003-8—A44 *Industrial And/Or Other Area(s), Built-up object: Other - glasshouses*

Plastic greenhouses or glasshouses principally used for cultivating plants in a regulated climate.

U3 = 5004-1 *Waste Dump(s)/Deposit(s)*

Storage areas, dumps and rubbish tips.

U5br/U5gr/U5le/U5to = 5004-2 *Extraction Site(s)*

Quarries/gravel and sand extraction/clay extraction/peat extraction.

B1fj = 6002-1 *Bare Rock(s)*

Exposed rock and rock fragments from the local bedrock.

B1bl = 6002-10 *Bare Rock And/Or Coarse Fragments - Boulders*

Accumulated coarse stones in sloping terrain, mounds or ridges.

B1gr = 6002-8 *Bare Rock And/Or Coarse Fragments - Gravels*

Water-worn coarse stones (> 6 cm in diameter) on river shores and beaches, including on dry riverbeds and empty reservoirs.

B2jo/B2to = 6005 *Bare Soil And/Or Other Unconsolidated Material(s)*

B2jo: bare ground with soil, clay, sand or gravel; B2to: mire areas lacking vegetation.

B2dy/B2fi = 6006 Loose And Shifting Sands

B2dy: wind transported/wind deposited sand; B2fi: water-treated sand, soil and gravel (< 6 cm in diameter) in rivers and beach zones (freshwater), includes former riverbeds and empty reservoirs.

V1ka = 7002-1-V1 Artificial Perennial Waterbodies (Flowing), Salinity: Fresh, < 1000 ppm of TDS

Canals and other artificial waterways: running water with artificial water course (also regulated parts of rivers and streams).

V1el = 8002-1-V1 Perennial Natural Waterbodies (Flowing), Salinity: Fresh, < 1000 ppm of TDS

Rivers and streams: running water with natural water course.

V1tj = 8002-5-V1 Perennial Natural Waterbodies (Standing), Salinity: Fresh, < 1000 ppm of TDS

Tarns, ponds and lakes: still-standing freshwater.

V3sa = 8002-5-V4 Perennial Natural Waterbodies (Standing), Salinity: Very Saline

Saltwater and brackish water.

6.A.4 DMK – Norwegian Digitalt Markslagkart (Arnt Kristian Gjertsen)

Digitalt markslagkart (DMK) is an important map database covering about 55% of the land area of Norway. The area above the forest limit is not covered. DMK is a classification of land type where focus is on land productivity for agriculture and forestry. The classification consists of several independent criteria and was tailored for fieldwork when it was developed in the 1950s and 1960s. The maps are made at scale 1:5000. The main classes are:

- Agricultural land (Jordbruksareal)
 - Fully cultivated land (Fulldyrka jord)
 - Surface cultivated land (Overflatedyrka jord)
 - Fertilized pasture (Innmarksbeite)
- Forest (Skogareal)
 - Needle leaved forest (Barskog)
 - Mixed forest (Blandingsskog)
 - Broadleaved forest (Lauvskog)
- Other areas (Anna areal)
 - Mire/wetland (Myr)
 - Other soil covered upland areas (Anna jorddekt fastmark)
 - Area with shallow soil (Grunnlendt mark)
 - Bare rock (Fjell i dagen)

In the DMK legend agricultural land is mainly classified according to the degree of cultivation, i.e. whether or not it is cultivated onto ploughing depth or less than this depth. The main focus is related to land-use rather than land cover. The classes that are distinguished show in their definition this focus:

- Fully cultivated land (Fulldyrka jord): the area is cultivated to plough depth and is regularly ploughed. The classification does not differentiate crops; thus, the area can be covered with herbaceous crops, berry shrubs, or fruit trees.
- Surface cultivated land (Overflatedyrka jord): the area is cultivated only on the surface that is cleaned and made level to allow mechanized harvesting. The classification does not differentiate crops, but grasses are the most typical crop. However, growing of other crops is also practised.
- Fertilized pasture (Innmarksbeite): the area is regularly fertilized and grasses cover more than 50 percent of the area. Shrubs and trees are often present. If the area qualifies as forest (minimum 6 trees per 0.1 ha that are or can be 5 m tall) it will still be classed as pasture as long as it is used as pasture.

The same accounts for cultivated land that is further classified into:

- Easily managed land (Lettbrukt areal): area where size, layout, and topography (slope < 1:5) allows for use of 4-wheel tractors.
- Less easily managed land (Mindre lettbrukt areal): area where size, layout, and topography (slope < 1:3) allows for use of small tractors.
- Not easily managed land (Tungbrukt areal): area that does not meet the requirements of the two former criteria.

Land that can be cultivated at least to qualify to “Less easily managed land” is classified as cultivated land.

An area qualifies as forest if there are 6 or more trees per 0.1 ha that are or can be more than 5 m tall. Clear felled areas are included in the class. The classification has unusual breakpoints for mixed forest with 20 percent cover as lower limit and 50 percent cover as higher limit for needleleaved trees, thus a forest area with 40 percent broadleaved

trees is classified as needleleaved forest. The forest of DMK can be either closed or open forest in LCCS. To directly translate "Forest", it should be possible to define a forest category that combines closed and open forest, i.e. in LCCS one is forced to create a mixed class to explain that the cover is from open to closed. However, a mixed class may be explained in various ways. The problem with clear felled areas continues to exist.

- Needleleaved forest (Barskog): more than 50% of the trees are needleleaved.
- Mixed forest (Blandingskog): between 20–50% of the trees is needleleaved.
- Broadleaved forest (Lauvskog): less than 20% of the trees are needleleaved.

Forest is further classified into site index:

- High site class index (Høy bonitet)
- Medium high site class index (Middels bonitet)
- Low site class index (Lav bonitet)
- Non-productive forest (Impediment)

In DMK an area is forest also when it is for the moment without trees. And if an area is covered with needleleaved trees under a canopy of broadleaves, it is classified as needleleaved. Because needleleaved is presumably what the forester wants an that has largest economic value (so it was in the 1960s and 1970s, and maybe today also).

"Myr" or Mire is defined as peat land with peat thicker than 30 cm. No description of vegetation cover in the class, but if the mire is densely stocked, it would appear as forest and not as mire. Mire and wetland is classified according to three criteria:

- Vegetation: distinguishes between non-demanding and demanding vegetation.
- Degree of decomposition
- Depth of organic soil

The translated classes from the DMK legend are:

Jordbruksareal (Agricultural area) = 0003(1)[Z17] *Cultivated and Managed Terrestrial Area(s)*

Area that is cultivated and used for agricultural production. Includes arable land, surface cultivated area, and fertilized pasture.

Fulldyrka jord (Arable land) = 10025 *Herbaceous Crop(s)*

Fully cultivated area. The area is arable and ploughed regularly. The crop can be any kind of agricultural crop, i.e. fruit trees, berry shrubs, leafy and root vegetables, cereals. Practise depends on the region: in north and west grasses are dominating, in south-east cereals and vegetables are dominating.

Overflatedyrka jord (Surface cultivated area) = 10037 *Graminoid Crop(s)*

Surface cultivated area. The area is cleared and level on the surface, such that mechanized harvesting is possible. Grass production is typical but growing of vegetables is also practised.

Innmarksbeite (Fertilized pasture) = 10037(2)[Z1] *Graminoid Crop(s)*

Fertilized pasture. The area is fertilized and more than 50% of the area is covered with grasses. Shrubs and trees can be present. If the area fulfils the requirement of forest, it is still classified as pasture (not forest) as long as it is used as pasture.

Lauvskog (Broadleaved forest) = 20090 *Broadleaved Deciduous Forest*

Area with more than 6 trees/0.1ha that are or can be more than 5 m tall. More than 80% is broadleaved trees.

Barskog (Needle leaved forest) = 20092 *Needleleaved Evergreen Forest*

Area with more than 6 trees/0.1ha that are or can be more than 5 m tall. More than 50% is needleleaved trees.

Blandingskog (Mixed forest) = 20092-15045 *Mixed Forest*

Area with more than 6 trees/0.1ha that are or can be more than 5 m tall. Between 20-50% is needleleaved trees.

Myr (Mire) = 40013 *Closed Herbaceous Vegetation*

Wet area where peat has been formed and that are at least 30 cm thick.

6.A.5 SMD – Swedish Land Cover Data (Eva Ahlcrona)

211 Arable land = 10025(1)[Z11] *Herbaceous Crop(s)*

231 Pastures = 10025(1)[Z12] *Herbaceous Crop(s)*

141 Green urban areas = 11176 *Vegetated Urban Area(s)*

222 Fruit trees and berry plantations = 10001 / 10013 *Tree Crop(s) / Shrub Crop(s)*

3242 Cleared-felled areas (before woody vegetation) = 20001(1)[Z13] *Closed Woody Vegetation*

An alternative may be to mix classes as open bare soil, herb, woody vegetation, etc.

334 Burned areas (before woody vegetation) = 20001(1)[Z14] *Closed Woody Vegetation*

An alternative can be to mix classes such as bare soil, herbs, woody vegetation, etc.

3243 Younger forest = 20006-13314 / 20014-1267 *Closed Shrubland (Thicket) / Open ((70-60) - 40%) Shrubs (Shrubland)*

3241 Thickets = 20017 / 20021-1 *Closed Shrubland (Thicket) / Open ((70-60) - 40%) Shrubs (Shrubland)*

322 Moors and heathland = 20018-12050 / 20022-12050 / 20037 *Closed Dwarf Shrubland (Thicket) / Open Dwarf Shrubs (Shrubland) / Herbaceous Open Vegetation*

3212 Meadow = 20025 / 20037-1 *Herbaceous Closed Vegetation / Herbaceous Open ((70-60) - 40%) Vegetation*

3211 Grass heath = 20033 / 20045 *Closed Grassland / Open Grassland*

3111 Broadleaved forest not on mires or bare rock = 20090 / 20132-1 *Broadleaved Deciduous Forest / Broadleaved Deciduous ((70-60) - 40%) Woodland*

3112 Broadleaved forest on mires = 20090-M251 / 20132-1-M251 *Broadleaved Deciduous Forest, Lithology: Organic rock - Peat / Broadleaved Deciduous ((70-60) - 40%) Woodland, Lithology: Organic rock - Peat*

3113 Broadleaved forest on bare rock = 20090-N1 / 20132-1-N1 *Broadleaved Deciduous Forest Soils: Bare Rock / Broadleaved Deciduous ((70-60) - 40%) Woodland, Soils: Bare Rock*

31211 Coniferous forest on lichen dominated areas = 20092 / 20134-1 / 21439 *Needleleaved Evergreen Forest / Needleleaved Evergreen ((70-60) - 40%) Woodland / Open Lichens*

312122 Coniferous forest >15m = 20092-13152 / 20134-1105 *Needleleaved Evergreen High Forest / Needleleaved Evergreen ((70-60) - 40%) Woodland*

312121 Coniferous forest 5-15m = 20092-13233 / 20134-1186 *Needleleaved Evergreen Medium High Forest / Needleleaved Evergreen ((70-60) - 40%) Woodland*

3122 Coniferous forest on mires = 20092-M251 / 20134-1-M251 *Needleleaved Evergreen Forest, Lithology: Organic rock - Peat / Needleleaved Evergreen ((70-60) - 40%) Woodland, Lithology: Organic rock - Peat*

3123 Coniferous forest on bare rock = 20092-N1 / 20134-1-N1 *Needleleaved Evergreen Forest, Soils: Bare Rock / Needleleaved Evergreen ((70-60) - 40%) Woodland, Soils: Bare Rock*

3131 Mixed forest not on mires or bare rock = 20132 / 20134 *Broadleaved Deciduous Woodland / Needleleaved Evergreen Woodland*

3132 Mixed forest on mires = 20132-M251 / 20134-M251 *Broadleaved Deciduous Woodland, Lithology: Organic rock - Peat / Needleleaved Evergreen Woodland, Lithology: Organic rock - Peat*

3133 Mixed forest on bare rock = 0132-N1 / 20134-N1 *Broadleaved Deciduous Woodland, Soils: Bare Rock / Needleleaved Evergreen Woodland*

5122 Water bodies, vegetation covered water area = 40015-3274-R1 *Closed Free Floating Forbs, Water Quality: Fresh*

411 Inland marshes = 40057-R1 *Closed Herbaceous Vegetation On Waterlogged Soil, Water Quality: Fresh*

421 Salt marshes = 40014-R2 / 40014-R3 *Closed Herbaceous Vegetation, Water Quality: Brackish / Closed Herbaceous Vegetation, Water Quality: Saline*

5232 Sea and ocean, vegetation covered water area = 40015-3274-R2 / 40015-3274-R3 *Closed Free Floating Forbs Water Quality: Brackish / Closed Free Floating Forbs, Water Quality: Saline*

4121 Wet mires = 40057-R1(1)[Z15]/40973-R1/8... *Closed Herbaceous Vegetation On Waterlogged Soil, Water Quality: Fresh / Closed Lichens/Mosses, Water Quality: Fresh / COMBINATION DOES NOT EXIST OR HAS NOT YET BEEN ENTERED IN DATABASE*

4122 Other mires = 40057-R1(1)[Z16]/40973-R1/8... *Closed Herbaceous Vegetation On Waterlogged Soil, Water Quality: Fresh / Closed Lichens/Mosses, Water Quality: Fresh / COMBINATION DOES NOT EXIST OR HAS NOT YET BEEN ENTERED IN DATABASE*

133 Construction sites = 5001 / 6004 / 6001 *Built Up Area(s) / Unconsolidated Material(s) / Consolidated Material(s)*

112 Road and rail networks and associated land = 5002-4 / 5002-6 / 5003-8 *Paved Road(s) / Railway(s) / Industrial And/ Or Other Area(s)*

111 Continuous urban fabric = 5003-13 *High Density Urban Area(s)*
SMD: >80% consists of impervious surfaces.

11211 Discontinuous urban fabric with more than 200 inhabitants with minor areas of gardens and greenery = 5003-14 *Medium Density Urban Area(s)*
SMD: 50-80% consists of impervious surfaces.

11212 Discontinuous urban fabric with more than 200 inhabitants with major areas of gardens and greenery = 5003-15 *Low Density Urban Area(s)*
SMD: 30-50% consists of impervious surfaces.

121 Industrial or commercial units = 5003-8 *Industrial And/Or Other Area(s)*

124 Airports = 5003-8—A21 *Industrial And/Or Other Area(s), Built-up object: Airport*

123 Port area = 5003-8—A32 *Industrial And/Or Other Area(s), Built-up object: Port Area (including Docks, Shipyards, Locks)*

1421 Sport grounds, shooting ranges, motor, horse and dog racing tracks = 5003-8—A38(1)[Z1] *Industrial And/Or Other Area(s), Built-up object: Sports and Leisure Facilities*

1422 Airfields (grass) = 5003-8—A38(1)[Z2] *Industrial And/Or Other Area(s), Built-up object: Sports and Leisure Facilities*

1423 Ski slopes = 5003-8—A38(1)[Z3] *Industrial And/Or Other Area(s), Built-up object: Sports and Leisure Facilities*

1424 Golf courses = 5003-8—A38(1)[Z4] *Industrial And/Or Other Area(s), Built-up object: Sports and Leisure Facilities*

1425 Non-urban parks = 5003-8—A38(1)[Z5] *Industrial And/Or Other Area(s), Built-up object: Sports and Leisure Facilities*

1426 Camping sites and holiday cottage sites = 5003-8—A38(1)[Z6] *Industrial And/Or Other Area(s), Built-up object: Sports and Leisure Facilities*

1122 Discontinuous urban fabric with less than 200 inhabitants = 5003-9(1)[Z7] *Urban Area(s)*
SMD: 30-80% consists of impervious surfaces.

1123 Rural fabric with open plots = 5003-9(1)[Z8] *Urban Area(s)*

SMD: 30-80% consists of impervious surfaces. Compared to 1122 the class 1123 is not defined as a populations centre and the buildings are therefore more scattered.

132 Dumpsite = 5004-1 *Waste Dump(s)/Deposit(s)*

1312 Other mineral extraction sites = 5004-2(1)[Z10] *Extraction Site(s)*

1311 Sand and gravel pits = 5004-2(1)[Z9] *Extraction Site(s)*

332 Bare rock = 6002 *Bare Rock And/Or Coarse Fragments*

4123 Peat extraction sites = 6005-M251 *Bare Soil And/Or Other Unconsolidated Material(s), Lithology: Organic rock - Peat*

331 Beaches, dunes and sand plains = 6006 *Loose And Shifting Sands*

333 Sparsely vegetated areas = 6004 / 20037 *Unconsolidated Material(s) / Herbaceous Open Vegetation*

511 Watercourses = 8002-1-V1 *Perennial Natural Waterbodies (Flowing), Salinity: Fresh, < 1000 ppm of TDS*

5121 Water bodies, open water area = 8002-5-V1 *Perennial Natural Waterbodies (Standing), Salinity: Fresh, < 1000 ppm of TDS*

335 Glaciers and perpetual snow = 8009 *Perennial Ice*

5231 Sea and ocean, open water areas = 8002-5-V2 / 8002-5-V3 *Perennial Natural Waterbodies (Standing) Salinity: Slightly Saline / Perennial Natural Waterbodies (Standing)*

7. Integration of partial coverage and full coverage landscape monitoring information

Workshop report, 23 – 24 October 2000, Tune, Denmark.

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Summary

As an activity under topic-2 of the NordLaM project, a workshop was held in October 2000 to examine the characteristics and integration of partial coverage (*i.e.* 'sample') information with full coverage (*i.e.* 'census') information in relation to landscape level monitoring. The use of image data in this is relevant, as a means that is often used for obtaining census information, and also a means that is widely used in sample based survey. Invited presentations examined the typology of sample – census integration methods, national landscape monitorings that operate and integrate between sample and census levels and key issues that are faced in making and presenting results from such activities. The general issues involved were summarised in round-table discussions.

Keywords: census; sample; monitoring; integration

7.1 Introduction

The use of image data in landscape level monitoring typically comprises means for obtaining relatively low detail information for large areas. This contrasts with the typical use of ground based survey, for collection of more detailed information for smaller areas that are seen as representative of some larger area. Certain forms of image data such as aerial photos are also used in the latter monitoring activity. In many of the programmes for providing the landscape level monitoring information now needed for sustainable environment and biodiversity management it is generally important and useful to recognise these two levels of information gathering. It is necessary to understand the particular characteristics of full and partial coverage monitoring including the contribution of images to each, and develop and adopt appropriate strategies for integration of the resulting full and partial coverage data. Integration of full and partial coverage monitoring data is, as recognised in the NordLaM project, one issue within a set of systemic issues for enhancement and development of the roles and use of image data in Nordic landscape level monitoring. The workshop that is reported here was held by the NordLaM project in October 2000 to explore this topic (see Annex 7.A for list of the workshop participants).

7.2 Background and aims of the workshop

The workshop was convened as one of a series of activities under the umbrella of the NordLaM project (1999-2003). The objective of NordLaM is to develop the use of Earth observation (EO) image data in strategic (*i.e.* national and regional) programmes of landscape level monitoring (LLM) for the Nordic countries. NordLaM deliverables, to the Nordic Council of Ministers, include presentations on the state-of-the-art in the Nordic countries and elsewhere, reports of meetings and demonstrations focused on specific LLM issues and recommendations for LLM methods, standards and protocols for future use across the Nordic countries. Seven LLM issues, relating to the use of EO have been identified for NordLaM project focus during the period 2000-2003 (Groom 2001).

In LLM activities within the Nordic countries, as elsewhere, some landscape monitoring is based upon sample data whilst other uses data of the full extent of an area. The information contents of the types of resulting data typically differ considerably. Partial coverage (sample based) landscape level monitoring typically provides very detailed, precise and accurate information for the sample areas, whilst full coverage ('census') data is typically thematically far poorer and also possibly less precise and accurate. However, in many cases programmes for providing the types of LLM information now needed for sustainable environment and biodiversity management need to integrate partial and full coverage LLM

data. Indeed, it can be expected that such integration results in new capabilities for LLM that are ‘greater than the sum of the parts’.

The aim of this workshop was to examine the possibilities for combining partial and full coverage LLM data, in terms of both the needs and objectives for such integration and the technical requirements and methods for achieving such integration.

In the strategic design of LLM programmes, integration has also been more fully modelled in terms of three-levels (e.g. Inghe, 2001), namely those of field survey, aerial reconnaissance and satellite survey. The two-level situation, of partial and full coverage data that is explored here can also be seen as an extract from that three-level approach, without representing any contradiction to it.

7.3 A typology for full and partial coverage data integration

From the experience of European forest monitoring, for timber production, non-wood goods and services and landscape attributes, a typology of the integration of full and partial coverage monitoring data can be identified and elaborated. This theme was developed in the presentation made to the workshop by Michael Köhl.

Official statistics on landscape attributes, such as national estimates of forest coverage can be misleading. For example the statistics of national forest cover, as have been reported to Eurostat and UNECE show Sweden and Spain as having similar extents of forest covered land; likewise, Austria and Portugal. Inspection of even basic information from images, such as a map of greenness for Europe indicates that this is not the case. However, statistics, like maps, are highly desirable outputs. In simple terms, satellite images provide a basis for maps, while sample surveys provide a basis for statistics (red arrows in Figure 1). But, sample surveys can also be used to make maps and images used to provide statistics (Figure 1, blue arrows), and both can be combined to provide either maps or statistics (Figure 1, yellow arrows).

The need for more sophisticated methods of generating maps and statistics from images and sample surveys was illustrated by the situation faced by the Swiss NFI between the mid-1980s and mid-1990s. This period saw an increase from 400 to 600 in the number of attributes to monitor but a 25% decrease in the funding for the work. Understanding the characteristics of monitoring attributes is essential. This includes understanding methods of assessment and scale (nominal, ordinal, interval or ratio). Attributes, such as in forest monitoring relate to aspects of non-wood goods and services and landscape, as well as timber production.

With these points in mind, the typology of methods for integration of partial and full coverage monitoring information, in terms of the use of sample surveys and images to produce statistics and maps, can be elaborated:

1. Basic single phase operations (Figure 7.1, red arrows)

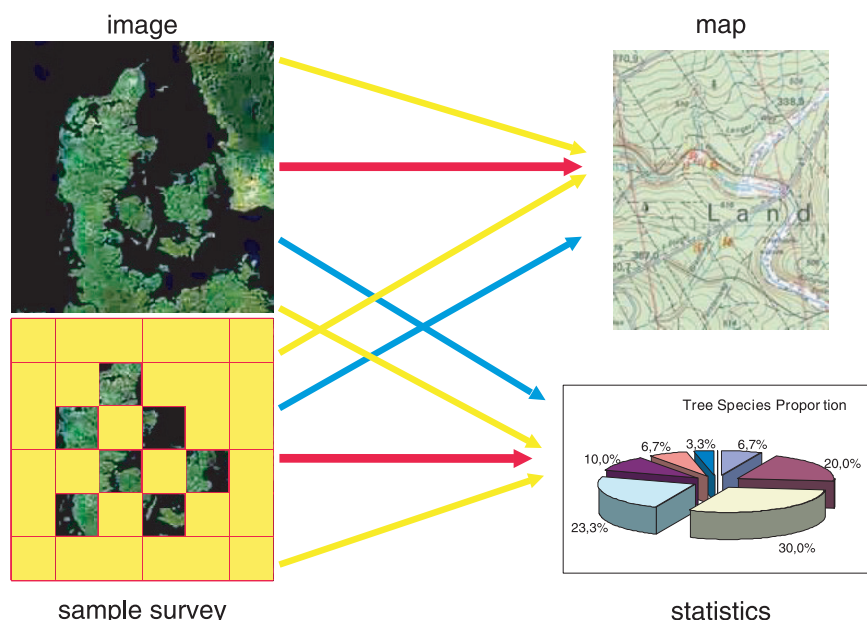
- 1a) satellite image $\Rightarrow$ map

- 1b) sample survey $\Rightarrow$ statistics

Both the simple derivations of maps from images and of statistics from sample surveys represent single-phase operations, with the former being the most straightforward. Thus, in an ideal world monitoring could be completed directly by mapping, either manual or automated, from images. The last 30 years in remote sensing can be seen as a progression in terms of mapping from images from a period of just ‘visual interpretation’, through a period of ‘empirical models’ to a period of ‘physical models’. However, it is necessary to also be aware that in spite of research and developments in the derivation of attributes directly from image data, this goal is still largely unattained. Image data are not measurements of the desired attributes, but instead are measurements of indirect attributes such as albedo, temperature and backscatter. Invertible models, for direct conversion of image data to data of the desired attributes, have been successfully developed for very few environmental or ecological attributes (Danson *et al.* 1995). Instead, maps of desired attributes are still often derived directly from image data on the basis of manual mapping and automated empirical or semi-empirical classification.

The derivation of statistics from sample surveys is also a basic single-phase operation. However, an important aspect of this operation is that an inference about the reality is made from the results of sample data assessment and analysis. Thus, the result is only ‘grey’, rather than ‘true colour’.

Figure 7.1.
A typology of methods for
integration of partial and
full coverage monitoring
information. (see text for
further explanation)



2. Combined sample and census operations (Figure 7.1, yellow arrows)
 - 2a) stratified sampling and population estimation (Figure 7.2)
 - 2b) multi-phase sampling (Figure 7.2)
 - 2c) sample + image $\Rightarrow$ map

Combined operations such as stratified sampling, represent more complex methods for deriving an estimate for a population. For example, this type of operation includes use of a satellite image as a basis for a class map of homogeneous strata. Independently derived statistics from sample plots may then be combined with the class map to make statistical estimates of attributes for the population. This represents the most basic form of sample-census data integration, which is frequently applied in LLM. However, as was noted in discussion, it is important to consider whether the map involved in type of integration is appropriate to the task; in some cases, such as in relation to habitat types, there are fundamental problems associated with expressing natural attributes as maps.

Important extra knowledge on the error components in the population estimates can be added by multi-phase sampling. This involves integration of a dense grid of samples with basic attribute information with a less dense grid of more detailed attribute information. However this comes at the cost of greater effort.

The combined population estimation operations described above use image data that has been thematically classified such as into land cover or vegetation classes. A map estimating the values of a sampled attribute over a full area can also be derived from combination of sample data and unclassified (*i.e.* 'raw') image data. One general method for combination of sample attribute data and supplementary census data is K-Nearest-Neighbour (K-nn) (Tomppo 2001). This procedure utilises a distance measure that is defined in the feature space of the supplementary data, such as the spectral data space of the image. In the computation of the attribute estimate for a mapping cell field plots (*i.e.* sample data) are weighted according to their spectral 'closeness' to the cell. 'K' refers to the number of plots that are considered as 'close', *e.g.* $K = 2$ means that only the 2 plots that are spectrally closest to the mapping unit are non-zero weighted in the computation. Masking is often used in order to exclude certain parts of the image data set from the process. The basic K-nn requires attributes expressed as means but it can also be applied to attributes that are on a categorical scale. K-nn is often also known as 'multi-source inventory', referring to its combination of census image and ground sample data. This method has been adopted for the Finnish national forest inventory in which typically 100 to 400 inventoried variables can be simultaneously estimated for extensive areas (Tomppo 2001) and is also applied in the Swedish forest inventory (Reese *et al.*, 2000), Norway and several other countries. K-nn is a flexible, statistically orientated and highly cost-effective method for mapping of population attribute estimates, particularly for forest inventory. However, beyond its basic application, such as for the estimation of associated error terms, considerable complexity can be introduced, and developing an operational statistical error assessment technique is a highly challenging task (Tomppo 2001). Typically, K-nn is associated with lower errors for larger areal units than for individual pixels (*e.g.* Reese *et al.* 2000).

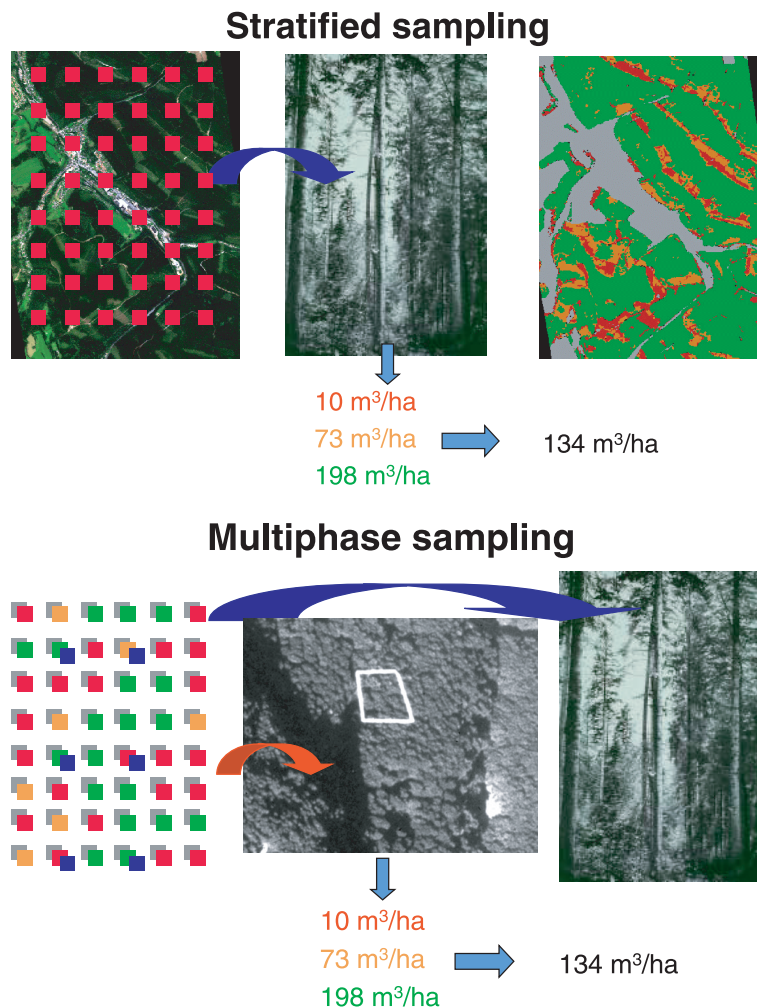


Figure 7.2. Examples of combined sample and census operations.

3. Sample data $\Rightarrow$ Map operations (Figure 7.1, blue arrow)

Traditional statistics involves estimation of population parameters from a set of sample statistics. However, even if the set of samples has some spatial arrangement this aspect is not used in the statistical procedure. This is not the case in geostatistics. Thus, it is also possible to derive a map from sample data using geostatistical methods. Geostatistical methods include semivariance analysis for investigation and modelling of the geospatial properties of the sample data and the use of a variogram for interpolation, *i.e.* derivation of maps from sample data taking account of their geospatial properties. This latter operation is generally referred to as kriging. Kriging has been successfully used in the mapping of forest attributes (*e.g.* Köhl *et al.*, 2000).

4. Image $\Rightarrow$ Statistics operations (Figure 7.1, blue arrow)

As discussed above, in general it is not possible to directly estimate many landscape attributes from image data. An alternative and the remaining option in this basic typology is the derivation of local area statistics from image data alone. These statistics are often referred to as 'landscape indices', and can be calculated on the basis of computations within image kernels *ie.* 'moving windows'. However, such indices can be difficult to interpret and can operate non-linearly depending upon, for example, whether the local area comprises many edges or a matrix structure. Adaptive moving windows are a development of this procedure that indicates interesting possibilities for reducing such drawbacks.

With a range of possibilities for combining field survey sample and image census data information the choice can be difficult. These procedures also represent a range between tried-and-tested methods that provide basic map or statistical products and more experimental, less assured options that have however greater potential for providing more interesting results. Therefore, optimisation of any survey work requires striking a balance between the required level of precision and the acceptable level of accuracy.

Even though it may be true that “it is easy to lie with statistics – but it is even easier to lie without” (G.P.Patil), the statistical issues in integration of sample and census data should never be considered as trivial. As the workshop was reminded in discussion following Michael Köhl presentation, use of even the ‘simple’ integration methods demand consideration of the assessment errors and model errors that are involved. Ideally, a proper error budget study should be undertaken. In relation to this, it was noted that one other use that can be made of census data in the integration process is as an auxiliary information layer to reduce error terms in the estimations made.

7.4 Landscape level monitoring in Austria – examples of census and sample data integration

A number of projects in Austria that together develop integration of image data with sample field data illustrate well how this can provide a basis for national landscape ecological monitoring, addressing cultural, socio-economic and biological aspects. This work was presented to the meeting by Thomas Wrba. Three specific projects are involved:

- SINUS (1996-2000) that has developed LLM in terms of landscape structure
- BINKL (1998-2001) that addresses LLM in terms of bio-indicators
- LANDLEBEN (2000-2002) that examines LLM with respect to biodiversity assessment and farming practices.

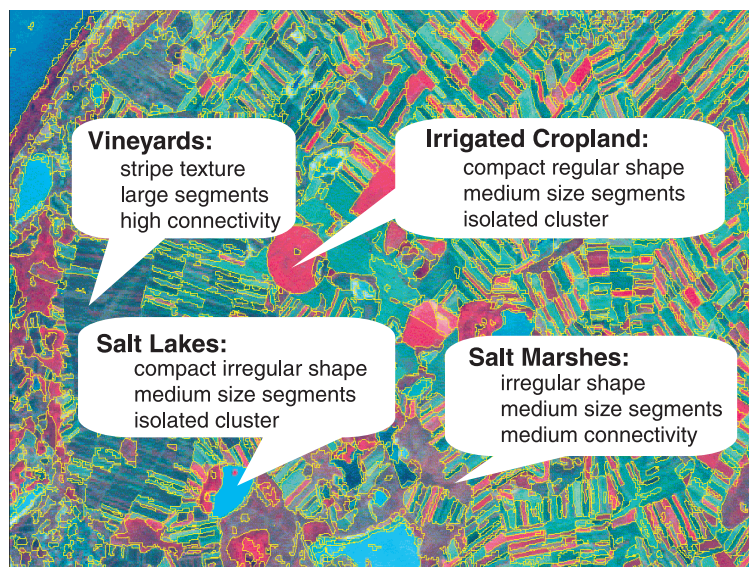
A driving theme through these projects has been data integration for elaboration of indicators of sustainable land use in agricultural landscapes. Underlying these projects are the Forman and Godron (1986) principles of a landscape as ‘a repeated spatial pattern of landscape elements’, e.g. ‘scattered patch landscape’, ‘corridor dominated landscape’, ‘chequerboard pattern landscape’, ‘network pattern landscape’.

Satellite image data have been used within the SINUS work for two elements of the integrated set of landscape monitoring data:

- a national land cover classification, produced by automated image segmentation and supervised classification of Landsat TM image data, with the resulting spectrally homogenous image objects grouped into 15 predefined classes
- a national map (scale, 1:200,000) of cultural landscape types produced by rule-based visual interpretation of Landsat TM image data; approximately 16,000 polygons are grouped into 37 predefined Cultural Landscape Type classes (12 Types, 37 Subtypes (Figure 7.3) that are ecologically meaningful land units with homogenous pattern and processes (i.e. landscape structure).

These SINUS products therefore represent two regional level census components. As well as this analysis of landscape structure on a regional scale using satellite images, there has been integrated development within SINUS for monitoring of landscape structure on a local scale using 200 sample sites. Stratified random sampling was seen as particularly appropriate for LLM in Austria due to the high landscape diversity. The national map of Cultural Landscape Types was intersected with national maps

Figure 7.3. Extract from the Austrian SINUS image-derived Cultural Landscape Type mapping.



of elevation and geology and isocustering was used to produce stratification with eight classes. The distribution of 1:10,000 scale 5 x 5 km topographic map sheets and aerial photos provided a sampling frame for random selection of ten 5 x 5 km sample areas from each stratum; a further 20 5 x 5 km sample areas in this frame were selected subjectively. Within each of these 100 sample areas two paired 1x1 km test sites were selected for the actual field survey. The 200 1 x 1 km test sites were surveyed in terms of land use, patch origins, a matrix/patch/corridor model, hemerobiotic state and species richness. Altogether, the resulting field sample database comprises over 100,000 landscape elements (polygons) that are described by up to 20 field-recorded attributes. This database has been used for analysis of functional landscape types ('Funlands'), integrating the different surveyed attributes. The SINUS field sampling work has addressed the primarily agricultural landscape of Austria; forested areas, high mountains and urban areas have been outside of its scope. Typically five person-days were spent surveying each of the 200 sites. The intention is to make repeated survey of the same 200 1 x 1 km test sites, as part of a monitoring programme for the Austrian agricultural landscapes.

The BINKL project has explored possibilities for bioindication of sustainable agriculture by means of human impact sensitive species (vascular plants, birds and bryophytes), based upon 40 of the 200 SINUS test sites. These areas have been examined in terms of their Funlands characterisation. The aim has been to find indicator species for specific landscape types.

LANDLEBEN incorporates socio-economic data into the framework of SINUS and BINKL. Owing to the nature of much socio-economic data the sample areas for LANDLEBEN, although lying coincident with those of SINUS, are far larger. Methods include interviews with farmers, elaboration of farm styles and identification of driving forces for landscape change, enabling integration of biotic data and socio-economic data at the farm level.

Important statistical information for national and regional policy makers on the state and sustainability of the Austrian agricultural landscape and its biodiversity is facilitated by the integration between the census and sample levels of this monitoring work. Beyond merely reporting the proportions of different landscapes, the field data enables elaboration in terms of the landscape elements and structures, and ultimately the patterns of change, associated with each landscape type, and therefore each part of Austria. Furthermore, the linkage of both the field survey data and the national mapping of cultural landscape types with the local and national mapping of land cover provides the basis for more realistic inventory and mapping of landscape attributes. Thus, this Austrian work represents application and development of the combination of full and partial coverage layers through stratified sampling (2a) that was outlined in the typology of integration operations. The additional analysis of functional landscapes in these Austrian projects, based on the integrated data structures, enables generation of numerous other thematic products. Maps of regional and local indicators of sustainable land use, such as the degrees of fragmentation and urbanisation of Austrian cultural landscapes are one example of this. National issues can therefore be rigorously and critically investigated by monitoring at the local level.

7.5 Monitoring the 'unobservable' – Reflections upon combination of the synoptic view and field based survey data in the GB Countryside Surveys

A fundamental issue in LLM is 'how can we combine the synoptic view of land cover derived from remotely sensed imagery with field-based survey data to model conditions in the wider countryside?' This theme was explored in the presentation made by Roy Haines-Young with respect to the experiences of the Countryside Survey (CS) of Great Britain in 1990 and 2000 (<http://www.cs2000.org.uk>). The CSs have implemented various methods to solve this issue. Underlying key aspects of the CS are (a) maintenance of continuity of the data series and (b) environmental stratification of 'unchanging' environmental parameters. As in Austria, the CS structure of stratified random samples provides a basis for statistical estimates over large areas. However, the CSs and SINUS also fundamentally differ in that the CS does not make use of image data analysis as part of the stratification process.

Field survey of a stratified sample of over 500 1 x 1 km areas is one arm of the CS. This provides the basis for weighted estimates of cover types over larger areas, and through repeated survey of the same sample areas, estimates of changes. Alongside this field survey both CS1990 and CS2000 have also involved production of a census land cover map (LCM) from satellite images. For CS2000 this was produced as a 'per-parcel' rather than a 25 m 'per-pixel' map as was made for CS1990. The per-parcel

approach was seen as providing a more believable, object-based representation of landscape objects. The LCM, either per-pixel or per-parcel, provides the potential, through integration, for a higher spatial resolution view of landscape attributes in the wider countryside than the field survey side of CS can provide by itself.

From both CS1990 and CS2000 integration of the sample field survey results and the census LCM has been provided to policy makers in the form of the Countryside Information System (CIS) desktop-PC package of 1 x 1 km summary CS data. Thus, integration of the CS field sample and census land cover data is seen as being feasible and cost-effective. However, the CIS provides a structure for integrating sample and census data rather than a fully integrated system. Some fundamental issues remain unresolved:

- How should the two independent estimates of stock be calibrated, as is required in order to link the CS2000 Field Survey and LCM2000 data for the UK BAP 'Broad Habitats'? For example, at what spatial scale (*i.e.* level of data aggregation) should calibration functions be derived – 1 x 1 km.sq.? county?
- How should attribute data for the field survey polygons be handled in the integration? – Should integration be by classical accounting model methods or by use of simultaneous equations?
- How should error terms be calculated and presented?
- How should the linear features and their attributes recorded by the field survey be handled in the integration?
- Is it also possible to work the integration the other way, *i.e.* to assign attribute data derived from the images to the field survey objects? – Stepping beyond the typology elaborated earlier in this paper, such an operation might involve a 3-phase, rather than merely 2-phase, integration process.

Key questions for this type of integration work are:

- At what scale is calibration / linkage appropriate?
- Can the integration process be reversed?
- How are uncertainties handled?
- To what extent can the CS data users drive the integration process within a system such as the CIS?

Major sticking points for development of the CS integration are:

- Linkage of the CS sample and census layers has been viewed as a case of 'taking two independent estimates of objects in the countryside and deriving a third'.
- Satellite image derived LC maps tend to be 'cartoons of the landscape'.
- Making map based estimates of objects at the local level is a major hurdle.
- Calibration of two independent image derived estimates of stock, such as for change assessment, is problematic.
- Three types of audience are being addressed by the CS monitoring work : the scientific communities, the policy making communities, and the public awareness and campaigning communities.

One solution to the issues faced by attempts to integrate synoptic and field survey aspects of LLM, such as those discussed here, might be to ensure that the integration process starts-out with a clear goal-orientated focus.

7.6 Discussions

Follow-up discussions elaborated and extended the issues and ideas raised in the three presentations. Table 7.1 presents a summary of the follow-up discussions, arranged in terms of:

- i) The applied framework for undertaking partial and full coverage information integration as part of LLM
- ii) Methodological issues of how integration should be undertaken
- iii) The characteristics and application of partial coverage information for integration with full coverage information
- iv) The characteristics and application of full coverage information for integration with partial coverage information.

Two clear issues with respect to the wider framework of integration are:

- The need to develop full and partial coverage information integration ideas in order to fill in gaps in current LLM activities or to more fully exploit current LLM structures
- The need to develop and implement integration in step with developments in the needs of various user communities for the types of outputs it might generate and the translation of outputs into envi-

Table 7.1. Summary of the workshop discussion of Partial-Full-Information-Integration (PFII).

(i) Applied Framework	(ii) Methodological Issues
a) the ability to make estimates at the local level – this is for example particularly important for the Danish NFI b) the opportunities presented by PFII for broad env./ecol. issues such as Nature Quality are important. c) PFII is part of the primary need for information in order to answer the What, Where & Why of landscape and environment and for prediction via modelling. d) the framework for formulating PFII must include review of user needs for landscape level monitoring (LLM) information, including European -vs- National needs and the needs of scientific, policy-making and public communities. e) the development of PFII should be combined with developments in the use of indicators as a cost effective approach for LLM.	a) optimisation of the use of data as a whole is crucial – this includes issues of survey design and the reliability of results b) issues of natural variability and scales are crucial in developing PFII methods c) importance of a clear typology of integration methods, with clear links to the required outputs of LLM activities, such as either maps or estimates. d) there should be focus upon development of integration methods that can be used operationally, in particular with respect to field surveys e) goal-orientated integration solutions should be emphasised f) there should be clear statistically worked through demonstrations of the PFII methods g) PFII should be built into related work with a functional and process domain focus, such as grossing-up from local processes to regional processes h) PFII should be undertaken within a context of using the results as indicators
(iii) Sample Information Form & Use	(iv) Census Information Form & Use
a) the object basis for PFII needs to be examined – are our field survey (FS) and remote sensing (RS) derived objects really comparable ? b) tools are needed for integration of the nomenclatures of partial and full coverage information. c) the strategic locating of samples needs to be examined, particularly if this is based upon images d) goal-orientated sampling should be investigated further e) the statistical procedures relating to sample data should be reviewed	a) the object basis for PFII needs to be examined – are our FS and RS derived objects really comparable ? b) tools are needed for integration of the nomenclatures of partial and full coverage information c) supplementary full coverage information layers, such as agricultural statistics data, should be investigated d) there should be focus on the spatial distribution / context setting of agreements & disagreements between sample and census layers and other data e) domain-based thinking, such as with respect to spectral -vs- functional domains should be investigated

ronmental and ecological indicators.

With respect to the methodological framework for integration three areas for further research and development work are:

- Finding a clear typology of integration methods, including their relationships to different types of outputs, operational use and statistical aspects.
- Examination of underlying assumptions of integration methods regarding scaling issues and natural phenomena.
- Development of methodologies for integration in the context of the applied framework, such as in terms of goal-orientated solutions and the use of outputs from LLM information integration as indicators.

Several issues that had been noted previously, such as a goal-orientated approach and the need for review of statistical procedures, are also relevant in consideration of demands upon the partial coverage information for integration with full coverage information.

With respect to the characteristics and application of full coverage information in integration it was clear that there are still several largely unexplored possibilities; however, each of these three, (a), (b) and (c) in Table 1(iv) represents a considerable developmental and experimental task.

Two major issues that are common to the demands asked of both the synoptic and the field level information are:

- the need to ask if the census and sample data relate to comparable objects
- the need to develop nomenclatures for their integration.

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Annex 7.A - Workshop participants (and affiliation at time of workshop)

Anna Bodil Hald	National Environmental Research Institute, Kalø, Denmark
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Göran Ståhl	Swedish University of Agricultural Sciences, Umeå
Marion Potschin	University of Balse, Switzerland
Mats Dalsgaard	National Forest and Landscape Research Institute, Denmark
Michael Köhl	Dresden University of Technology, Germany
Minna Kallio	Finnish Environment Institute, Helsinki
Per Löfgren	Swedish University of Agricultural Sciences, Umeå
Pia Frederiksen	National Environmental Research Institute, Roskilde, Denmark
Roy Haines-Young	Centre for Ecology and Hydrology & University of Nottingham, UK
Thomas Wrbska	University of Vienna, Austria
Wendy Fjellstad	Norwegian Institute of Land Inventor, Ås

8. Very high spatial resolution airborne and Space-based remote sensing for landscape level monitoring

Workshop report, 3 - 5 November 2001, Turku, Finland

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Summary

During 3-5 November 2001 the NordLaM Project held a workshop entitled "High spatial resolution airborne and space-based remote sensing for landscape level terrestrial monitoring." The workshop was hosted by the Department of Geography, University of Turku, Finland at the Tammivalkama Hotel and Conference Centre, Turku, Finland. Twenty participants attended, representing Norway, Denmark, Sweden, Finland and Estonia. The workshop programme was roughly divided between communications from: (1) university and institutional researchers; (2) national monitoring programme representatives; and (3) industry sector data and service providers. High spatial resolution (HSR) in the workshop context was defined as 5 – 30 m ground pixel size, while very high spatial resolution (VHSR) was used to describe recent < 5 m pixel size space-based imagery and advanced aerial (digital-) photo mosaics. The workshop participants' respective positions on the use of HSR/VHSR image data for landscape monitoring can be summarized by the following: (1) University and institutional researchers are actively developing theory and methods that extend the utility of VHSR data for landscape level monitoring (LLM). In particular, these researchers are striving to understand and encapsulate in proven methodologies the relationships between remotely sensed data, landscape pattern (& processes), and landscape indices, at the VHSR monitoring resolution. Work with VHSR datasets (aside from aerial photographs) has been limited mainly due to the costs of these new data sets. Research into VHSR also requires intensive new ground-referencing programmes. Work with both HSR and VHSR datasets to date have shown that landscapes contain processes operating over a range of scales: one survey resolution (*i.e.* 30 m ETM) will thus be appropriate for only a narrow range of monitoring goals. The response to this realization has been research into the use of scales *within* an image; and a move within research work beyond 'pixel-based' techniques to 'object-based' theory and methodologies is occurring. (2) National programme representatives have successfully developed methods for LLM using HSR. They have found, however, that HSR-based monitoring is not applicable to every monitoring task: it is well suited to regional and national reporting, but is less accurate for local estimates. The use of VHSR in the form of traditional aerial photo interpretation is still common, especially where broad area coverage is not required (*e.g.* the Swedish landscape monitoring programme, NILS). Space-borne VHSR as an expensive and as yet un-proven tool, but currently being examined by several groups. (3) Industry providers have interesting new VHSR data, including digital ortho-photo mosaics with accompanying digital height models (derived from airborne digital camera & scanning LIDAR combinations). New software tools are also now available which should improve the speed and accuracy of the traditional aerial photograph interpretation method, an important tool for landscape monitoring at the local level.

Keywords: remote sensing; landscape monitoring; spatial resolution, orthophotos

8.1 Introduction

High and very high spatial resolution remote sensing is an issue in landscape level monitoring (LLM) that was identified by the NordLaM project in 2000 as one of seven topics for focus (Groom 2001). This NordLaM topic is a response to (a) the recording of individual landscape objects that form part of many Nordic LLM activities and (b) the increasing availability and sophistication of HSR and VHSR image data and tools for their analysis. High spatial resolution (HSR) in the workshop context was defined as 5 – 30 m ground pixel size, while very high spatial resolution (VHSR) was used to describe recent < 5 m pixel size space-based imagery and advanced aerial (digital-) photo mosaics.

The main aim of this workshop was to promote an exchange of information concerning the state of the art in high spatial resolution earth observation data use for landscape monitoring within the Nordic community's interdisciplinary group of landscape monitoring researchers, practitioners and commercial data providers. For the participants, the workshop aim was to increase co-ordination of Nordic use of images in landscape level monitoring by involvement of remote sensing specialists and non-specialists

in an examination of relevant remote sensing issues. For the Nordic Council of Ministers, the workshop aim was to strengthen trans-Nordic aspects of environmental monitoring and to provide input towards future policy and science programmes.

8.2 Remote sensing for LLM: some background

Before delving into a summary of the presentations and discussions, it will be useful to briefly examine the notion of partitioning and introduce scale space: i.e. the relationship between the scale of the RS measurements and the scale of the patterns and processes to be monitored. Further, we provide insight into two over-arching trends that constrain remote sensing utility for LLM. These trends are 1) changes in LLM tasks and 2) developments in RS data and processing methods.

8.2.1 Partitioning & Measurement Space

Landscapes are at a base level the structured flow of information, energy and matter in a region of interest. Areas of locally high gradients of this information, energy or matter provide the structure, or perceived heterogeneity, within the continuums of process. This structure, rather than the continuum, is what is readily interpreted by humans and thus the basis for our partitioning landscape into 'objects'. We do this with our visual system when we examine a landscape from a vantage point. An important point is that when we move from continuums to objects (via partitioning), we are doing so within restricted spatial and temporal conditions. Change the parameters, for example by increasing the spatial grain or temporal extent of the survey data, and we invariably change the returned partitions. Taking a large enough set of partitions, covering a wide range of possible parameters, and one defines or creates a measurement space.

Now, since a partitioning is a derivative of the continuums of process, conditional on the parameters, our challenge becomes to find appropriate levels within the measurement space where we can make a partition that is highly correlated to a process in which we are interested. This brings us to the issue of pixel-based analysis of remotely sensed image data. What are pixels? Pixels can be thought of as an intermediate stage within the partitioning process. By measuring reflected radiation (in the case of passive sensors) in a regularized and continuous grid, we are capturing a subset of the continuum structure described above. From this information, we extract a partition by grouping areas of homogeneity. Traditionally, this has been done through supervised or unsupervised classification, on the basis of pixels similarity to others as defined in the spectral feature space. The hypothesis underlying RS-based monitoring using a per-pixel approach is that there exists a robust relationship between the measured values, captured at one level of the measurement space, and some processes of interest. When this hypothesis fails, we must turn to more information about our landscapes, whether at a different scale, or dimension (spectral, temporal, angular, polarity).

Measurement space can be examined in terms of a measurement / landscape object dialectic (Figure 8.1). The diagram shows the relationship between landscape objects and the resolution of sensors. Note

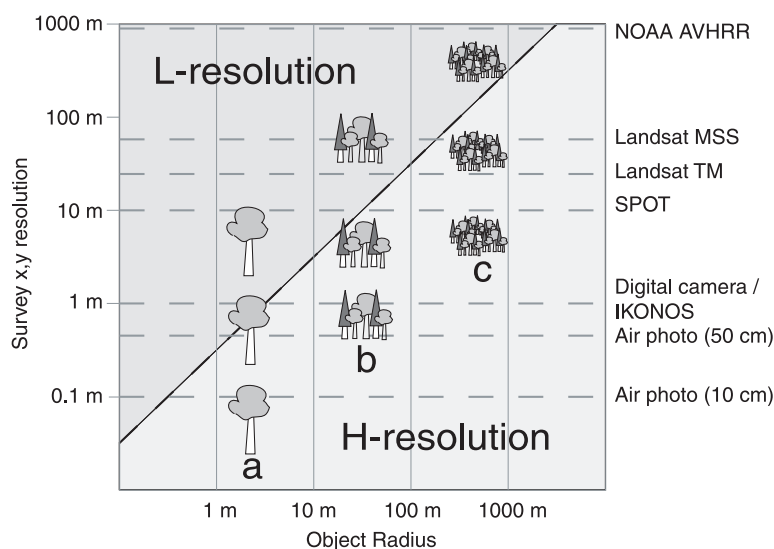


Figure 8.1. Resolution expressed as a relationship or ratio between the landscape object under investigation and the sensor 'footprint'. Strahler et al. (1986) divides this continuum into two phases, L and H. H-resolution situations are those wherein the RS imagery is finer than the object size. The L-resolution case is the corollary based on their definition.

that a small stand of trees (Figure 8.1 ‘b’), with a radius of approximately 50 m, can be monitored in H-resolution mode, with aerial photography or IKONOS imagery; in L-resolution mode with 30 m TM imagery, or in the threshold region, with SPOT imagery. The point is that LLM relies on remote sensing in the pre-partitioning stage, and thus that the remotely sensed data restrict LLM to the domain of patterns that the data’s scale parameters capture.

It has recently come to light that other methods exist which extract more from remotely sensed data. Methods which are more creative in the partitioning method, for example by moving away from a simple pixel classification towards object-based image assessment, are beginning to be tested. Later in this report some of these methods are discussed.

8.2.2 Changes in LLM tasks

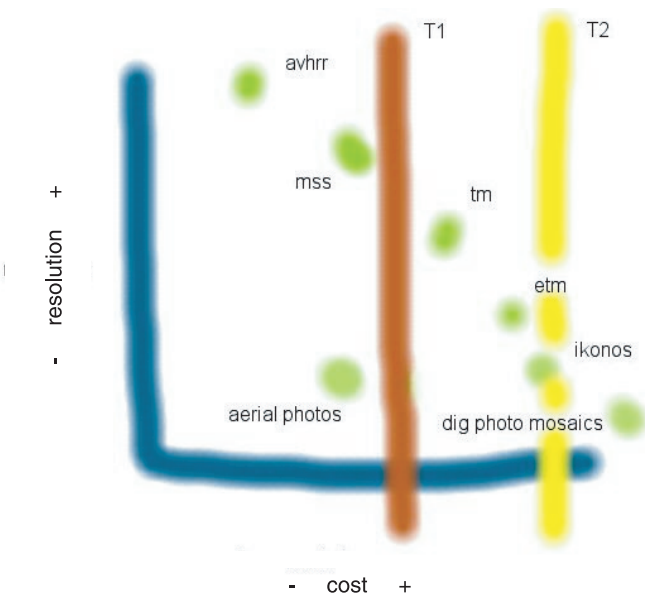
The needs of the monitoring community (managers, researchers, *etc.*) changes as understanding of the landscapes develops and as management circumstances change (Table 8.1).

Table 8.1. List of landscape level monitoring goals that change through time.	
Early LLM	
Global/regional scale:	ocean monitoring, global forest monitoring, disaster monitoring, NFI
Local scale:	operational forest management, urban planning
More recent LLM ‘goals’	
Global/regional scale:	biodiversity monitoring, landscape diversity monitoring, agricultural policy effects
Local scale:	biodiversity monitoring, agricultural subsidy policy enforcement

8.2.3 Developments in RS data and processing

The cost of images from ‘mature’ (relatively coarse resolution) sensors has decreased steadily with time; but imagery from the most current VHRS sensors is usually prohibitively expensive for most monitoring programmes (Figure 8.2). The factors driving down the cost of the data are manifold, and include a) advances in assembly methods and economies of scale in the manufacture of electronic and optical components, and b) the completion of cost recovery programmes of governmental (*e.g.* NASA) Earth observation missions, affecting the prices charged to customers.

Figure 8.2. The graph shows a simplified schematic of the relationship between cost of image data and image resolution. At time 1 (T1), operational requirements (“cost”) prohibit monitoring with any data to the right of the red line. At a later date, T2, more data sets are potentially available to a monitoring project.



Strategic monitoring programmes normally take many years to implement, and they are normally not in the position, neither financially nor methodologically, to work with the most recent data products. By 'methodologically', we refer to the fact that monitoring requires a sound understanding of goals and the steps required to relate remotely sensed data to Earth surface processes. This workshop was an attempt to determine the state of the current methodological foundation. VHSR data is certainly becoming financially feasible. A question is, is the level of RS and landscape ecology theory and methodology developed enough to incorporate this latest VHSR sensor data into monitoring programmes?

8.3 Summary of presentations

8.3.1 Research programmes

Several research themes were introduced and explored various workshop presentations. In the following sub-sections several of the main research themes are grouped and summarized.

Scale, patches and metrics: the relationships between RS data and landscape processes

The first researcher presentation was a combination of material on LLM background and project description, given by Niels Christian Nielsen. In the first part of the presentation, Niels provided a succinct introduction to the current research agenda, noting that LLM research was being conducted by researchers in many fields including biology, remote sensing and landscape ecology. The common element was a holistic approach and an interest in finding the relationship between the scale in the observed data and the scale or levels of process operating in the landscape. He provided a comparison of the similarities in research approaches between remote sensing and landscape ecology, including a holistic approach and a focus on heterogeneity.

In the second part of his presentation Niels described an experiment to test the sensitivity of structural metrics as quantifiers of forest fragmentation at an Italian study site. The data used for the study was a Landsat TM scene (~25 m ground pixel resolution) and a IRS-C WiFs scene (~200 m). The classified imagery was compared to 1:10,000 scale forest inventory maps. Using majority filtering, several other scale level images of the scene were created. The resulting classifications were compared to the forest inventory using a number of spatial metrics. Niels reported that with an increase in pixel size, the smaller classes disappeared: creating apparently diminishing landscape diversity. The issue of the appropriate scale for capturing process, and the best RS data as an intermediate stage, is still an open question.

Sandra Luque continued the exploration of scale, patch and metric issues in landscape monitoring. Sandra described a recently initiated project called TEMPOS (Temporal and Spatial Diversity of Boreal Forest and Peatland Vegetation). She quoted Levin (1992) when defining the project focus :

One must recognise that the description of the system will vary with the choice of scales; that each species, including the human species, will sample and experience the environment on a unique range of scales; and that, rather than trying to determine the correct scale, we must understand how the system description changes across scales.

In her presentation entitled "Monitoring ecological processes and quality of forest landscapes in Finland - Using keystone indicators and the Finnish Multi-source National Forest Inventory", she listed the goals of the project: the delineation of patches of 'suitable habitat' within the study area landscape; the identification of 'landscape level mechanisms' underlying the landscape complexity; and the gaining of a better understanding of the temporal aspect of the mechanisms and emergent pattern. This last goal will be assessed by examining three stages in the development of the Lammi study area landscape, with data from 1987, 1994 and 2000.

Once a suitable scale of observation has been identified, a diverse set of assessment tools, called metrics or indices, can be used to examine the patchiness of a landscape. Useful metrics and indices are measures of structure of the patterns in the survey data (e.g. RS images) which, after careful study, are shown to relate to some landscape process of interest. Metrics may relate to the internal condition of the patch or may act as a comparison to neighbouring patches. Additionally, metrics can be grouped according to the level of landscape hierarchy they correspond to: patch-level metrics are those defined for individual patches; class-level metrics are integrated over all the patches of a given type (class); regional metrics are aggregated over one or more classes within a specified subregion of a landscape; landscape-scale metrics are further integrated over all patch types or classes over the extent of the data.

Semantics: what is the meaning behind classifications, metrics and pixels?

A whole workshop can be organized around the topic of uncertainty in RS data for monitoring. One aspect of uncertainty that was explored at this workshop was that of semantic uncertainty. Semantic uncertainty describes the uncertainty between partitioning systems, such as landscape classifications. Wolter Arnberg provided insight into research conducted by his colleague Ola Ahlqvist. Further work on uncertainty will be examined in the Sustainable Landscapes project, within the MISTRA-supported (Strategic Research Foundation for the Environment) research programme Remote Sensing for the Environment. Sustainable Landscapes integrates ecologists, physical and human geographers. Semantic uncertainty is an important quality aspect for integration of data. It underlies the comparing of map units from different monitoring programmes, which may be separated by time, methodology, or by differences in inputs data (e.g. different scales of RS imagery, cf. the discussion of this in Section 1.1).

Wolter also presented work on the question of mapping 'pixels' to landscape units: how to bridge the gap. He also posed the question, is it true that the pixel is the minimum mapping unit? Can we do sub-pixel analysis? Or, must we recognise that the pixel is not an object as such and that RS imagery must be assessed in the context of homogeneous regions, or segments (see next section).

Objects: what exists beyond the pixel-based approach?

Anssi Pekkarinen presented work concerning the future of the Finnish Multi-source Forest Inventory, in which high spatial resolution sensors are seen as a key to better local-level monitoring. However, with these HSR data sets a pixel-by-pixel classification method does not apply. Spectral separability of features at these scale levels is very problematic. The problems of applying pixel-based procedures with finer spatial resolution data have resulted in a focus towards object orientated methods and image segmentation processes. Image segmentation has been viewed as a process of transforming images from gridded pixels into spatially continuous, disjoint and homogeneous areas. Segmentation methods using aspects of the image pixels themselves and the expression of edges and of regions in image data have been investigated. These methods involve initial image segmentation followed by region merging (Pekkarinen 2002). These techniques have been tested with respect to three major NFI application requirements: estimation of timber volume, change detection and for development and implementation of a forest management planning tool.

High RMSEs in the pixel-based (standard k -NN; Tomppo 1991, 2001) estimation of timber volume have been associated with error in the co-referencing of field plots and image data. Image segmentation has therefore been tested as a way of stabilising this problem. However, the results have been that at the plot level there is only a slight improvement in the timber estimation RMSE levels. The image segmentation was seen as working well, but the field data used in the estimation are seen as not representative for the segments. Training data on the segment level, rather than the stand or plot level is needed.

Pixel-based change detection procedures are very sensitive to mismatch between images, in particular with respect to data calibration. The alternative object based method that was tested produced more stable calibration and analysis, with 70 – 90 percent of clear cuts on mineral soils successfully detected. On peat soils variations in the soil moisture were associated with lower successful detection rates.

Two important tasks in a forest management planning tool are (a) semi-automated stand delineation and (b) allocation of field sample data to stands. Existing tools are problematic due to subjective and variable elements in the stand delineation and field data collection. An alternative two-phase sampling with stratification has been suggested as a solution. In this procedure an initial dense grid of points is assigned auxillary (old inventory, image) data values; this requires averaging of the auxillary data, which is problematic. Clustering of these data then provides a basis for a 2nd phase sample from which estimates are derived on the initial set of points. Segmentation could take this approach a step further, with initial image segmentation followed by clusterings of the segments, allocation of field sample data and generalised estimation of attributes for each segment. This could provide a solution to some of its problems. A further advantage of this over the basic two-phase operation is that more natural units are associated with the feature extraction, with more homogenous forest characteristics within the segment-based strata.

8.3.2 Nordic and Estonian Landscape Monitoring Programmes

Finnish MSFI

The Finnish National Forest Inventory (NFI) represents a major operational application of RS data to the management of a renewable resource. This multi-source forest inventory (MSFI) method and its development through the use of higher spatial resolution image data and image segmentation were presented to the workshop by Anssi Pekkarinen (see above for further discussion of Anssi's presentation). In the Finnish MSFI high spatial resolution image data (mainly Landsat TM) are used alongside NFI field data and digital map data in a k -nearest-neighbour (k -NN) estimator to produce both statistics and thematic maps. The k -NN method determines an estimate of an attribute, such as stand age, as a weighted average of k -spectrally nearest field plots (Tomppo 2001; Chapter 7 in this volume).

Although the k -NN-based MSFI method has shown good accuracy at the regional and national level, high RMSE have resulted when the method has been applied at the stand- and plot-levels. These results are partially a product of the small average size of the Finnish forest stands and the coarse spatial resolution of the survey and sample data. The small average size of forest stands is particularly a problem across southern Finland, where the average is just 1.5 ha. As described in Section 2.1, several methods are currently being tested to improve the estimation of forest parameters, including the use of higher spatial resolution image data, from both satellite and aircraft sensors.

Norway MSFI

Multi-source forest inventory with application of image segmentation methods is also being developed and tested in Norway, as the meeting heard from Tove Vaaje. An important applied issue in Norwegian forest inventory is the need for regional forest maps. There are four main data sources that can be used for this in Norway: digital land use maps (DMK), digital elevation data (DEM), the field data of the NFI and satellite images. The DMK data provide basic information about the land capability, such as for different types of forest. The DEM data are important for correcting image data for terrain effects and for stratifying the NFI plots into altitudinal zones. The NFI data are on a regular 3 km grid with sampling repeated every five years and permanent plots supplemented with temporary plots. The image data used are those of Landsat TM.

The principles to Norwegian MSFI are that there is a defined neighbourhood for each pixel, with an algorithm that finds all the training pixels that meet the neighbourhood definition in order to estimate attributes. A fundamental assumption is that spectral similarity implies similarity in the forest conditions. Test made at the level of a single municipality ('kommune') showed satisfactory results for top height, dominant tree species, total number of trees, number of conifers and the mean height of young forest. In this procedure satellite image data are used for the spectral analysis and also for deriving a cloud mask to remove NFI plots covered by clouds in the image data. The DMK data provide a forest mask and forest production potential input. Image segmentation has been used in this MSFI to make more informative and usable maps.

Swedish National Landscape Monitoring Programme (NILS)

A major national programme of landscape level monitoring for Sweden, NILS (formerly "SLÖ"), is due to begin in 2003. As reported to the workshop by Per Løfgren, this programme is currently developing and testing its techniques, including use of very high spatial resolution image data. The choice and application of VHSR image data in NILS is designed around the spatial sampling scheme of the programme. The main element of NILS will be a set of 500 5 × 5 km monitoring sites that will be re-visited for monitoring with a 5 – 10 year interval. These monitoring sites will be a stratified random sample. Stratification, based on digital maps, is used for obtaining homogeneous units to improve the precision in national estimates, for obtaining large enough sample sizes from certain key areas (agricultural areas, wetlands, etc.), and also in order to define regions for which separate estimates should be presented. The 5 × 5 km sampling units will be divided into two parts. In an inner sector, intensive mapping and inventory of habitat composition and structure, as well as species composition, will be carried out. In an outer sector the landscape, and landscape changes, will be described in a more general way, as an additional input to the understanding of changes in species composition that might occur in the inner sector.

To monitor changes in landscape composition, a combination of photo interpretation and field survey will be used. The reference unit of classification will be large field plots and interpretations made in aerial photos can thus be calibrated using the field assessments. Aerial photo interpretation will be an important part of the design; infrared images are planned to be acquired specifically for the purpose of the landscape monitoring programme. By photo interpretation, the different cover and land-use classes in the inner sector of the sampling units will be delineated, mapped, and described by a number of characteristics (*e.g.*, cover type, land-use, tree species composition, *etc.*). Field sample plots will be laid out in a (random) systematic pattern over the inner sector of the sampling units, as well as in a sample of the specifically identified wetland and grassland areas. The sample plots will be used for calibrating the assessments made in the aerial photos (*e.g.* cover type, land-use class, *etc.*). Line intersect sampling will be carried out along randomly distributed transects in the field, in order to obtain a basis for the calibration of aerial photo based estimates of the length and quality of linear features (roads, hedges, stone-walls, ditches, patches along roads and ditches, *etc.*). Strip surveying might be used in the field in addition to line intersect sampling. The purpose is to obtain better precision for important point elements, like large trees, small ponds, etc. Insect trapping will be carried out on specifically selected sites within the inner sector of the sampling units. HSR image data from satellite remote sensing might in the future also be part of the programme, used to obtain full (regional or national) coverage of important landscape features, observable in satellite images.

Use of HSR and VHRS image data in Estonian landscape monitoring

A programme of monitoring of the agricultural landscapes of Estonia uses aerial photography data from the 1950s, 1970s and 1990s to study the development of 21 2 x 2 km sites. As was described to the workshop by Kalev Sepp, methods for data gathering for landscape features from these images have been similar to that made in the Swedish LiM project of the 1990s (Ihse, this volume). Analyses of the scale of landscape features in these areas have been linked to field data on key species, in particular earthworms and soil micro-organisms. The goal was to explain the connection between landscape structure indicators and the characteristics of ecological status of agricultural landscapes. Thus land cover information from the aerial photography has been used to understand more about the ecology of bumble-bee populations in particular, with the biotic data based on line transect recordings. Kalev reported that several species of bumble bee were found to be excellent candidates as indicator species, concluding that bumble-bees can be used as bio-indicators for evaluation of the naturalness of agricultural landscapes. Further development of this monitoring programme, including its use of VHRS images is underway. This research furthers the goal of monitoring Estonian agricultural landscapes for changes due to increases or decreases in anthropogenic pressure, such as occurs with changes in agricultural policy.

A second Estonian Environmental Monitoring programme has focused on the use of satellite image data for landscape study and landscape level monitoring. This work was reported to the workshop by Andrus Meiner and Kiira Aaviksoo. The main image data used in this has been Landsat TM, *i.e.* high rather than very high spatial resolution data. A major task under this Estonian Ministry of Environment programme has been land cover mapping, of both present day (1990s/2000) conditions and past land cover (1980s). Six extensive monitoring areas have been used in this work, representing 4481 km² or 10% of Estonia. A hierarchical classification system has been created, with 58 classes at level-3, reflecting local land cover types. High levels of the hierarchy corresponded to internationally used categories. Analysis of the test areas in terms of core and buffer areas, landscape diversity, etc. has been made based on the land cover maps produced for them, combined with field data. In general the land cover mapping has operated successfully, but for some of the level-2 categories particular mapping problems were encountered: alvar grasslands, fallow lands, wooded meadows and shrublands. Retrospective mapping with images from the 1980s has enabled analysis of land cover and landscape features change matrices.

8.3.3 Industry Communications

Developments in Earth observation images

The pace of change in the supply of VHRS image data from airborne platforms in particular was demonstrated by presentations to the workshop by two Danish companies, Bio/consult (workshop presentation by Peter Hollebeek) and Kampsax A/S (Anders Bo Andersen) that develop and undertake operational

aerial image based mapping and monitoring. These presentations provided insight into the state-of-the-art in the sensing equipment now and soon-to-be available for routine imaging.

In some respects much aerial reconnaissance is still based around techniques that have been with us for several decades, *i.e.* 23 x 23 cm B/W or colour film cameras flown with 60% overlap between photos. Developments in the last 10 years in computerised systems for semi-automated ortho-rectification and film scanning have made routine transformation of these raw images to VHSR digital ortho-photo data. Thus, for example, national coverage 0.4 m pixel, RGB digital orthophoto data of Denmark are now a regularly updated (at least one every 2 years) and widely used product from Kampsax. The particularly rapid recent (last five years) advances in the production and use of digital orthophoto data such as these has also been facilitated by the developments in:

- Forward-motion compensation (FMC), inertial navigation systems (INS) and in-flight GPS; provided this equipment is installed and operated effectively ortho-rectification and co-registration of airborne images now causes little of the problems they represented even only five years ago. The experience of Bio/consult has been that whilst a relatively simple 2 Hz GPS is adequate for imaging over the sea, over land it is necessary to use an INS, interfacing the GPS to a gyro.
- Advanced image compression algorithms and software, such as ECW and Mr.Sid that have made it more practical for users to receive and work with VHSR colour image data; thus, a 5,000 x 5,000 24-bit (*i.e.* 75 MB) RGB image (*i.e.* a 0.4 m pixels image covering just 2 x 2 km) can be provided as a 5 MB file. The PC and WWW compatibility of these compressed file formats has been a very significant development in the increased use of digital orthophoto data.

Even higher spatial resolution digital image data are required by some users, for example municipalities that are predominantly urban. However standard sensing systems such as stereo film cameras, flown at lower altitudes are also used to produce high quality digital ortho-photo data that meet these requirements. Thus, 10 cm pixel digital orthophoto data are also routinely made. These ultra-high spatial resolution digital image data typically find application by municipalities for registration of road markings and 'street furniture'

However, more radical changes to this traditional arena of aerial survey are developing too, in terms of systems that record an image directly in digital form as an alternative to the use of film. Three different types of digital system are video cameras, single shot digital cameras and airborne line scanners. Video cameras represent a relatively simple and cheaper digital imaging option. A typical video camera installation, costing approximately 10,000 Euros comprises four co-aligned video cameras each fitted with lenses for red, green, blue and NIR, thereby providing a basis for multi-spectral image processing and analysis. Several types of single shot digital cameras have been used by Bio/consult mainly in connection with marine and coastal wildlife survey as an alternative to counting by observers. These systems generally comprise a CCD camera back that can be fitted to a conventional camera lens. The CCDs can be sensitive to light of up to 1000 microns, providing a basis for NIR imaging as well as RGB, using filters that can be either lens-mounted or are fitted to the camera-back. As an example of the data that can be obtained, the PhaseOne H20 camera back comprises a 4080 x 4080 array of 9 micron CCD elements. As with any CCD based system, there is a trade-off between the resulting image pixel size (determined by the flying height) and the signal to noise ratio that is associated with the intensity of light received by each CCD element. It is also important to be aware that the two principle manufacturers of professional-grade digital camera backs, Kodak and PhaseOne use different algorithms for interpolation of the dispersed "Bayer Pattern" of red, green, or blue filtered CCD elements, which can result in differences in the resulting image data.

In general digital cameras have good bit-depth, for operating in low reflectance imaging, such as of turbid water. Professional-grade single-shot digital cameras, such as the PhaseOne H20 or LightPhase are several times more expensive than video-camera systems. Line scanning, the technology generally used for imaging from space is the most advanced and expensive form of digital imaging from aircraft for VHSR. Whilst some organisations, mainly government research institutes have operated line scanning sensors for over 10 years, these systems are still relatively uncommon. However, they provide several advantages. As well as providing the possibility for VHSR and truly multi-spectral image data they provide more rapid imaging of large areas than is possible with analogue of digital cameras. Moreover, line scanning provides increased possibilities for finding objects for ortho-rectification; whereas with conventional stereo aerial photography flown for 60% overlap only 60% of all objects appear on all of any three adjacent photos, with triple coverage line-scanning all objects are imaged three times.

A second major recent development during the last five years in VHSR 'imaging' from aircraft for landscape level work has been the increasing availability and use of laser-scanning to derive height data. An across-track array distance measurements obtained by a laser operating at very high pulse rates (typically 90 - 150 MHz) provides a high density field of spot-heights, from which a height model can be produced. A laser-scanning system such as the TopoSys-II is routinely used by Kampsax to produce national 20 m grid elevation data of Denmark with a vertical precision of 1 – 2 meters. Higher spatial resolution (5 m and 1 m grid) and higher vertical precision (e.g. 15 cm) data can also be produced, such as are required by authorities and utilities in urban areas; these data products also have major potential for mapping of open landscape features. Factors limiting the use of laser-scanning for height modelling include aircraft positioning and attitude, variability in atmospheric humidity, and the complexity in extracting surface models from the spot heights. Advanced processing of the raw laser-scanning data, together with post-processing for up-standing objects enables production of both a digital terrain (*i.e.* ground) model (DTM) and a digital surface (eg. tree, building top) model (DSM), the difference between these being the digital elevation model (DEM). Overlay of height model data with RGB digital orthophoto image data can currently provide dramatic and revealing perspectives on landscapes and exciting 'fly-through' possibilities. Moreover, the upcoming generation of laser-scanning systems combines the collecting of height and RGB-NIR image data within a single instrument.

Developments in Earth observation analysis tools

Traditionally VHSR image data, such as acquired from aircraft have been used in applications by means of manual digitisation of features. This is still the case for much of the data capture made from digital orthophotos (such as the the Kampsax 40 cm and 10 cm coverages of Denmark; see, for example, Groom *et al*, in prep) for and by local authorities and utilities. Dedicated workstations and software for on-screen digitisation is now widely used, including systems such as those produced by Intergraph and ERDAS for on-screen 3D viewing of stereo-pair image data. The Intergraph system has been the workhorse of the Norwegian 3Q project for several years for its registration of landscape units and features and both systems have been tested by the Swedish NILS programme for its landscape level monitoring. Both these 3D viewing systems currently require the user to wear specialised glasses and experience in 'seeing' the landscape in 3D; some people find this easier than others.

Image data analysis and classification is also possible with VHSR image data, such as has been widely used with HSR image data from satellites for over 15 years, *e.g.* principal components analysis, supervised and unsupervised classification. However, in some cases due to the high data volume of VHSR image data, the use of compressed data formats prevents such processing. Moreover, for some compressed data formats it is not possible to decompress the data back to the original data values. However it is generally possible to 'split' a colour image into R-G-B components for pseudo-multispectral processing.

Advances in the last five years in image segmentation and object-orientated analytical methods and programming (Burnett & Blaschke 2003) are making important developments possible in the classification and analysis of image data, including VHSR images. At finer spatial resolutions larger numbers of landscape objects across a greater range of scales are discernible. But image segmentation is also relevant for more advanced mapping of traditional image objects such as fields and forest stands, as was discussed in the workshop presentation by Anssi Pekkarinen (Section 8.3.2). Vesa Leppänen demonstrated to the workshop an image segmentation set of software tools ("Arboreal") that is customised to forest inventory. This application is designed for work with VHSR digital aerial imagery. Initial segmentation of forest stands is followed by segmentation of individual tree crowns. Databasing within the software of the spatial parameters, such as crown size of the trees in each stand, together with some external training information on the tree types and age in at least some stands enables fast estimation of stand timber volume and species distribution over entire image scenes. There are also several other more general image segmentation and object-orientated image analysis and classification software applications on the market (*e.g.* eCognition*, Feature Analyst*) that are being increasingly worked with for landscape level mapping, in particular with VHSR image data.

* eCognition: <http://www.definiens-imaging.com/>

* Feature Analyst : <http://www.featureanalyst.com/index.html>

8.4 Workshop Conclusions

8.4.1 Research Programmes

- ❖ Gaps in ecological knowledge revealed:
 - As we start to expand monitoring from the regional level to the local and plot, we recognize that coarse landscape level processes are easier to monitor than higher intensity and frequency local elements
 - Spectral separability of landscape elements, already difficult at the regional level (*i.e.* with TM data) is exasperated at local scales
 - Spatial scale of analysis varies with objects of interest (processes), and guidelines are needed as to how to do multi-scale landscape monitoring
 - More funding for and emphasis on fieldwork-based EO research is required
- ❖ Change detection schemes need improving when working with objects instead of pixels (Nielsen, Arnberg, Luque)
- ❖ More (and less expensive) VHSR images are needed for methodology development and testing

8.4.2 National Monitoring Programmes

- ❖ 'Old' high resolution satellite data (Landsat TM images) has now found a place within operational monitoring programmes, as a good tool for regular searching and updating of landscape state information:
 - Landsat TM and ETM satellite data have the best quality/cost ratio for environmental monitoring (good spectral, temporal, spatial and radiometric resolution & just 0.30 less than 0.02 Euros per km²)
 - This is generally based on per-pixel methods, which give satisfactory results for regional and national statistics but which have been criticised for plot-level estimates
 - Satellite data is greatly dependent upon: clouds & water content in soil and vegetation
 - Operational use of satellite images often requires masking (*e.g.* MSFI in Finland and Norway), and large amounts of field plots for calibration of estimates
 - Satellite mapping does not replace geobotanic mapping
- ❖ Spectral and spatial resolution of Landsat TM is too rough for detail habitat mapping, thus high resolution data is being experimented with:
 - However, this requires a move away from per-pixel analysis methods
 - Per-patch/segment methods are being tested
 - New data being tested includes satellite-based data (IKONOS) and airborne (HIMAP, AISA, digital camera mosaics & LIDAR)
- ❖ The issue of the expense of new VHSR data from Space is significant
- ❖ The efforts required for mosaicing airborne images to cover large areas is also significant

8.4.3 Industry Representatives

- ❖ New data is here, including airborne digital camera and spectrometer mosaics
- ❖ New software tools are here that can accelerate the interpretation new imagery and updating of classifications for change detection

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9. Deriving Indicators from Earth Observation Data - Limitations and Potential for Landscape Monitoring

Workshop report, 22 - 23 October 2001, Drøbak, Norway

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Summary

On the 22nd-23rd October 2001, the Norwegian Institute of Land Inventory (NIJOS) hosted a NordLaM project workshop in Drøbak, near Oslo. The aim of the workshop was to examine limitations and potentials for using Earth observation data to derive indicators in connection with landscape level monitoring. This report provides a summary of the workshop, drawing freely between the material in the invited oral presentations and the associated open discussions. The presentations provided a mixture of examination of general indicator principles, ideas and issues, description of the use of indicators in Nordic monitoring programmes, and examination of the broader European landscape typology and indicator context.

Keywords: Indicators, environmental reporting, landscape classification, remote sensing

9.1 Introduction: Workshop purpose and aims

There is currently great interest in the development of indicators to monitor trends of change in the landscape. For national and international purposes Earth observation (*i.e.* satellite images and aerial photos) is seen as an economically feasible source of data from which to derive such indicators. Earth observation images form the basis of several monitoring programmes in the Nordic countries, such as the 3Q-programme and Thousand Places Inventory in Norway, and National Inventory of Landscapes in Sweden (NILS, formerly known as SLÖ). Wider afield there are similar programmes underway or planned for several European countries, and indeed Europe as a whole.

Although image data provide a good overview of the landscape, there are also limitations on the type and quality of monitoring data that can be extracted from these sources. In order to provide robust indicators, it is important to be aware of both the benefits and drawbacks of this type of data.

'Image data and indicators' is one of a set of themes within the NordLaM project. This theme examines the ways in which information that can be derived from image data contributes to and interacts with the requirements for outputs of landscape level monitoring (LLM) expressed in terms of environmental and ecological indicators.

Indicators are increasingly important in many international protocols and processes for the sustainable management of environments. Numerous Nordic and European monitoring programmes have addressed the need for output of their results in terms of indicators. Indicators are seen as tools to facilitate standardisation and comparisons. They should therefore also be considered in connection with bridging differences in classification systems and monitoring methodologies between countries. Work is needed, however, to address the calculation of indicators and interpretation of indicators at national and international levels.

The Nordic countries are in the early stages of LLM. There is a general need to increase the degree of coordination and harmonisation of Nordic monitoring efforts, providing a basis for comparability between countries. It is also important that the Nordic countries make use of the experience gained by other European countries and ensure compatibility with more wide-reaching international efforts to produce environmental indicators. The workshop aimed to achieve a common understanding of indicator issues and, more specifically, to identify and explore the limitations and potential for using Earth observation data to derive landscape level indicators.

At the start of the workshop, a number of questions were presented as a stimulus to discussion:

- What interests and values in the landscape do we want to monitor?
- What are the demands from decision-makers?
- What are the criteria for successful indicators?

- How do actual indicators fulfil these criteria?
- What are the limitations to producing indicators from image data?
- How should we express indicator results to different users?

9.2 The policy context of landscape indicators

Landscape issues have gained increasing recognition in policies, both at the national and international level, culminating in the Council of Europe's European Landscape Convention (ELC) adopted in 2000. Prior to this, landscape was mainly seen as a background for preserving species and habitats, and cultural heritage.

Through international initiatives such as the Pan-European Biological and Landscape Diversity Strategy (PEBLDS) (Sofia, 25 October 1995), and through increasing inclusion in important reports such as "Europe's Environment - The Dobbris Assessment" (Stanners & Bourdeau, 1995), "landscape" is now explicitly recognised as an important environmental concern in its own right. In addition to its role as an arena for the preservation of biological diversity and cultural heritage, landscape is seen to be important for cultural identity, for its aesthetic qualities, for contributing to people's physical and psychological well-being, and as a vital framework for the sustainable development of rural areas.

Where earlier emphasis has been to identify landscapes of outstanding universal value, the European Landscape Convention has a broader scope, considering all landscapes:

"Acknowledging that the landscape is an important part of the quality of life for people everywhere: in urban areas and in the countryside, in degraded areas as well as in areas of high quality, in areas recognised as being of outstanding beauty as well as everyday areas".

The European Landscape Convention aims "to promote landscape protection, management and planning, and to organise European co-operation on landscape issues". Each country adopting the Landscape Convention is, amongst other things, obliged:

- "i) to identify its own landscapes throughout its territory;
- ii) to analyse their characteristics and the forces and pressures transforming them;
- iii) to take note of changes".

The first of these points is likely to require some kind of landscape typology, or guidelines for landscape mapping. Using indicators as tools will facilitate the second and third points.

9.3 Conceptual frameworks for indicators

An indicator is an objective measure that provides information about an issue of interest. A successful indicator should be calculated in a way that is repeatable and transparent. It should quantify and simplify information and thus facilitate communication. An indicator must also be sensitive to change, so problems can be detected before they become acute.

Various frameworks have been suggested to structure and organise indicators. During the process of establishing environmental indicators for agriculture, the Organisation for Economic Co-operation and Development (OECD) established a framework of Pressure – State – Response (PSR) (OECD, 1994). This was later modified to Driving forces – State – Response (DSR) (OECD, 1997), since 'pressure' was seen to be a negative term, suggesting only forces leading to undesirable change. 'Driving forces' was considered a more neutral term that could incorporate both drivers of negative change and positive forces leading to beneficial and desirable change. The framework was designed to illuminate the linkages between causes, effects and actions.

The DSR framework has since been further elaborated by the European Environment Agency (EEA, 1998), evolving into the 'DPSIR-framework', whereby indicators are defined in terms of Driving forces – Pressures – States – Impacts – Responses. In this framework, 'driving forces' are seen as the socio-economic factors that trigger pressures (both negative pressures and positive pressures).

So, for example, increased economic subsidies to encourage extensive grazing in mountainous regions would be considered a driving force that would lead to an increased grazing pressure on rangelands. A pressure indicator in this situation might be taken as the number of farmers taking-up the subsidies. State indicators in such a cycle might be the area of rangelands or the animal density, whilst the impact indicator should indicate the change in a valued variable, such as the biodiversity. The response indicator is intended to reflect the actions taken by society, governments, farmers, *etc.* to the changes occurring. In

this rangeland example, this might be regulation of the subsidies according to their impact.

Some have argued that indicators are by definition normative, distinguished from environmental statistics that are collections of quantitative data. Viewed in this way, indicators should always be part of a normative framework of environmental information, and defined to be directional or comparable with reference values. In this interpretation, the impact category expresses the valued change or “distance to target”. Again taking the rangeland example, the impact category should contain the change in biodiversity or other values that was initially attached to the demand for higher grazing pressure. This highlights the requirements of understanding and expressing the values that society attaches to landscapes.

The EEA's DPSIR-framework deliberately sought to distinguish between static features (stocks) and dynamic changes (flows) (Wascher, 2000a). Yet this means that an indicator of state may appear as an indicator of impact once expressed as a change in state. Taking the rangeland example above, the state may be the area of rangeland and the impact of the increased subsidies may be an increase in the area of rangeland since the introduction of the subsidies. From discussions, this distinction between stocks and changes may be more confusing than helpful. Generally, most monitoring programmes that are using an indicator approach are concerned with relative changes over time rather than the actual state at a given time, and the reason for measuring a state is usually the belief that a change in the state will have an impact.

Although the DSR and DPSIR frameworks are useful as conceptual frameworks for thinking about the relationships between causes, effects and actions, they have proved somewhat difficult to use in structuring indicators. Thus, it is not always clear which of the DPSIR components an indicator is addressing. This applies even to the simpler DSR framework, because relationships between causes, effects and responses are complex. The effects of one change in the landscape may be the cause of other changes, and what is a response to one situation may become a driving force in another situation.

Examples of indicators, to some extent structured according to the DPSIR-model, can be found in the report from the EU Concerted Action Project “Environmental Indicators for Sustainable Agriculture” (ELISA) (Wascher 2000a). This project aimed to provide the European Commission, the European Environment Agency (EEA) and other institutions with tools to monitor the effects of agriculture on the environment and to determine the potential of sustainable agriculture in the European Union. The project was co-ordinated by the European Centre for Nature Conservation (ECNC) and provided input, amongst other things, to the development of Agri-Environmental Indicators (AEI) by the OECD. Input to the OECD was particularly influential for the theme of landscape indicators – the least developed of the OECD AEI themes¹.

Within a context of ‘landscape’ there is a notable focus within indicator work, as seen in the OECD-AEI and ELISA projects, on primarily agriculture landscapes, *i.e.* the ‘cultural’ landscapes that are predominant across much of Europe. Comparable international processes have been undertaken in relation to forestry, such as demonstrated by the Improved Pan-European Indicators for Sustainable Forest Management (that has since been adopted by the October 2002 Expert Level Meeting of the Ministerial Level Conference on the Protection of Forests in Europe (MCPFE 2002)). However, as noted at the workshop,

¹ In the OECD agro-environmental indicator work the landscape is seen in terms of three central components: landscape structures or appearance, including environmental features (e.g. habitats), land use types (e.g. crops), and man-made objects or cultural features (e.g. hedges); landscape functions, such as a place to live, work, visit, and provide various environmental services; and landscape values, concerning the costs to farmers of maintaining landscapes and the value society places on agricultural landscape, such as recreational and cultural values. - It is interesting to note that in a meeting of the OECD in Zurich, 5th to 8th November 2001, on the theme of agro-environmental indicators for biodiversity and habitats, the OECD secretariat proposed a move away from the DSR-framework to a “sustainability framework”. The new framework structures indicators according to the three dimensions of sustainability: environmental, social and economic. The DSR-model is still seen as useful for thinking about linkages between causes, effects and actions, but it is hoped that the sustainability framework will provide a simpler method for structuring indicators and will make the functional links between the different dimensions of sustainability more explicit. In this framework, the key to a more sustainable agriculture is seen to be better management of stocks and flows of capital, including natural capital (e.g. soil, water, air, biodiversity), man-made or physical capital (e.g. farm machinery, chemical inputs) and human capital (e.g. farmer education, knowledge and management skills). - While this framework may immediately be easier for the structuring of indicators, it does not, however, solve the questions of how those functional relationships manifest themselves, which “capital elements” may substitute for others or how relative indicator movements may contribute to overall sustainability. Moreover, there is the question: at which spatial scale should the sustainability be evaluated? (See also Annex 9.C for more recent OECD indicator developments.)

there has been much less effort expended towards development of indicators for other aspects of the landscape, in particular for predominantly grassy areas and for areas where edges form significant landscape components. For these aspects of the landscape there remain methodological problems to solve.

In our frameworks and typologies of indicators there is a need for recognition of both the retrospective use of indicators and the forward use of indicators. As was expounded at the workshop by Wenche Dramstad much of the development work with landscape indicators is based around what has happened in the past, without consideration of what might happen in the future. Thus, many proposed and used indicators relate only to past patterns with the implicit assumption that these will be the main events of the future too. Without in-built flexibility indicators may fail because they do not respond to novel types of land use (*e.g.* countryside that is used to store recently manufactured cars), novel fiscal or legal instruments or new ways of acquiring environmental or ecological information.

9.4 Landscape classification and indicators

The use of indicators in landscape monitoring and understanding is also significantly situated within a broader landscape context, of the classification and mapping of landscape types. Initiatives towards landscape classification and mapping have been undertaken at both European and national scales for a variety of purposes. The most prominent aims for land/landscape classifications are:

- to form a sampling base for statistical calculation of selected environmental variables/indicators - often including biodiversity aspects
- to form a spatial base for environmental monitoring and reporting and for regional planning - particularly planning for sustainable development

The first purpose is exemplified in the British “Countryside Survey” land classes approach, where a large number of variables including climatic data, topographic data, human artefacts and geological data were analysed and classified to produce 32 land classes, which formed a basis for stratified random sampling of ecological parameters. The land classes are “arbitrary” in the sense that they do not express a specific landscape typology, but a basis for production of statistical information. The same approach has been used in several other studies, see *e.g.* for Germany (Hoffmann-Kroll *et al.* 2000). These approaches accommodate the needs for assessing components of the landscape.

The second purpose lies behind a range of landscape and ecological classifications. They may be derived from predominantly biogeological variables for classification of landscape potential with subsequent evaluation of landscape suitability or other planning purposes (*e.g.* Bastian 2000) or from ecological parameters for large-scale environmental reporting, like the Canadian hierarchical classification for Broad Ecosystem Inventory (Marshall *et al.* 1996).

In the Nordic countries, a foundation for landscape regionalisation was created by a Nordic Council of Ministers Project that started in 1974 and was completed 10 years later. This project resulted, amongst other things, in the division of countries into physical-geographical regions, with a classification of vegetation zones and landforms, and a survey of representative natural habitats within each of the described regions. This project was followed up by a second Nordic Council of Ministers Project from the 1980's (NMR 1987) that aimed to modify the existing model to a form more useful for rural landscape planning. Specifically this meant a much greater focus on the man-made elements of the landscape, historical and present land use, and an assessment of the totality or overall impression of the landscape “including space characteristics, scale, and scenic qualities”. The methodology was tested on study areas in Norway, Sweden, Denmark, Finland and Iceland and the first three of these countries also made suggested outlines of a regional division at the national level. Finland already had a regional division made by the Finish Landscape Commission in 1980, whilst Iceland used the natural geographical division without modifications.

In Norway, this work was continued, with funding from the Department of Trade. The main motivation was to create a regionalisation that would highlight the tourism potential in different regions in Norway and give the tourist industry a tool for planning. Continued methodological refinement led to the completion of the National Reference System for Landscape in 1996. The system has three geographical levels: landscape region, sub-region and landscape area. Of central importance are the three-dimensional contents of the landscape, and the interaction between the natural and cultural factors, which shape and comprise the visual impression of the landscape. At all three levels a systematic description is based on six factors: 1) major landform, 2) geological composition, 3) water and waterways, 4) vegetation patterns, 5) agricultural areas, 6) buildings and technical installations. The landscape character is a synthesis of these six factors. The reference system comprises 45 landscape regions and 444 sub-regions. The

landscape area level is the most detailed level and is not complete, being conducted only on commission from local or regional authorities. This level is suitable at the municipality level for practical land use planning and management.

Recently, the need has been voiced for a typology of European landscapes, which should provide a key comparative and reporting tool for pan-European environmental reports. The interest in landscape typologies as a tool for identification of important processes – such as intensification, land abandonment, *etc.* – derives from a change in the perception of landscapes, their changes and the values attached to them. While the protection of landscapes was formerly aimed at the “gems” – landscapes of high aesthetic or historical value, it is today recognised that landscapes in general are a fundamental element for people’s sense of identity, and that the broad landscape processes should also be a case for concern (Wascher 2000b; Wascher & Jongman, in press). Moreover it is argued that landscape as a horizontal concept is especially well-suited for planning for sustainable development.

The Action Plan on European Landscapes (as part of PEBLDS, see above), aimed to develop a European Landscape map as a basis for deriving landscape indicators. One map of European landscapes (Meeus 1995) was already developed for the Dobbris Assessment (Stanners & Bourdeau 1995). It identified 30 major landscape types, based on geology, climates, land form, soil, land use, hydrology, settlement pattern, dynamics and scenery. Due to lack of detail and accuracy, another mapping exercise is however proposed in the Action Plan, based on a hierarchical concept with four levels. Vegetation and geomorphology defines the first level, which is further divided into 10 major landscape zones. Differentiation continues related to a land-use relevant division in uplands and lowlands, and at the lowest level 250 variations of natural and cultural landscape types should be identified.

Landscape types or landscape regions are seen as advantageous as units for reporting indicator values, compared with more traditionally used administrative units such as counties. Administrative units can often contain quite different types of landscapes, with different characteristics and affected by different driving forces. When indicator values are aggregated for large, heterogeneous areas, such as a county, the average values obtained may describe an average landscape that in fact does not exist. Opposing trends of change in different types of landscape may be masked. By reporting values across fairly homogeneous landscape types, this problem is reduced.

Some problems persist however, in using landscape typologies as units for reporting indicator values. In particular, the fact that landscape classifications and typologies may not be stable over time, due to changes in driving forces – be it sectoral changes or global climate change. This may be a severe problem when classifications are used for sampling stratification, as the size of the basic units change or as sample sites may move from one class to another. It is also important to consider whether specific indicators are applicable across all landscape types or just some. Since funding is usually limited, locally or regionally relevant indicators may be prioritised over those seen as being less applicable in the specific landscape type or landscape region. Thus, it will be difficult to calibrate between landscape regions an indicator that has particular significance for just some of the landscape types, such as the prevalence of particular cultural features, *e.g.* stone walls. Failure to record a standard set of indicators may thus hinder comparisons, both within and between countries. Reporting indicators in terms of progress towards defined targets may be a solution to enable a higher order degree of comparability between countries without sacrificing regional relevance and the monitoring of unique or uncommon aspects of the specific landscapes.

In work with landscape regionalisation or typology a distinction should be made between those systems that use indicators to create the typology and those that use the typology as background units for reporting indicator values. The move towards expression of indicators in terms of a landscape typology, *i.e.* for defined spatial units, also carries with it a risk for strategic monitoring that these derived values will be the only data that are archived. It is generally essential for monitoring that the possibility for recourse to the monitoring data in its raw form remains.

Landscape classification is defined by scale, with the possibility for different typologies appropriate to different scales. Scale is also a core parameter of indicators, and the characteristics of indicators with respect to changes in scale (up- and down-scaling) needs particular investigation. This is especially necessary in view of increasing requirements within Europe for indicators that are relevant at local levels.

9.5 Reporting and evaluating indicator values

Generally, scientists would favour a wealth of different indicators that would capture different aspects of a complex reality (Dramstad *et al.* 1998; Dale & Beyeler 2001). Politicians on the other hand, are keen to keep the number of indicators to a minimum. Thus, there have been, generally unsuccessful, attempts to

derive 'magic numbers' that serve to integrate different individual indicators. One possible solution is to use many indicators to achieve understanding of development trends and driving forces, which can then be summarised as a smaller set of aggregated indicators for policy-makers. An example of such an aggregated indicator is the Natural Capital Index (NCI) (ten Brink 2001) which combines abundance data for many different species and presents a result in terms of progress towards a target. At the scientific level, the data would be analysed for each species to identify trends and underlying causes for changes in abundance, but the NCI provides a simplified summary that is better for communicating to policy-makers. It can also be useful to combine individual indicators to map hot-spots, etc. as long as the process used in this is transparent and reversible.

Indicator values, even for some of the most straightforward indicators, need to be interpreted and it is therefore the story around the indicator that is of most use to policy-makers rather than the numbers themselves. A foundation in basic ecological, cultural or aesthetic processes is frequently essential for indicator validation. Scientists need to be better at communicating with policy-makers – perhaps employing some kind of environmental journalist to help to translate scientific findings to a language that can be understood by policy-makers and the general public. Often scientists include explanations about the strengths and weaknesses of methods, warnings about statistical significance and ecological significance, and caveats about how the data can be used. This type of information, although important in the scientific interpretation of indicators, is not useful for policy-makers, who need clear messages on which to base policy development. The pitfalls of moving from data to expression of such data in the form of maps, such as the filtering that this represents, also needs to be clearly appreciated in the communication of landscape indicators.

One solution to the problems of communication between scientists and policy-makers is to establish a much closer co-operation between these groups, including the early stages of choosing indicators, defining how indicators should be presented and in specifying clear targets and how progress towards these should be assessed. A common experience for those involved in establishing a monitoring programme seems to be the feeling that specific goals have not been defined and that one should record everything that it is possible to record. Whilst scientists traditionally have distanced themselves somewhat from the setting of targets, viewing this as a political choice, it would appear to be necessary for those working with indicators to become more involved in this process.

9.6 Earth observation data and landscape indicators

From international attempts to define landscape indicators and from the experiences of ongoing monitoring projects it is clear that Earth observation data have an important role to play in providing land cover and land use data, particularly via the production of maps. A large number of spatial metrics believed to be of relevance for various topics of landscape interest can be derived from maps, and in the future may be derived directly from images.

Image data provide information for indicators in several forms. Some indicators work from raw image data. Other indicators, such as change indicators, become possible following basic image data processing, such as inter-image calibration. Many spatial metrics indicators have been developed for work with classified image data, in particular land cover and land use maps. Lastly, there are sophisticated landscape indicators that require integration of maps derived from image data with other spatial information. It is interesting to note that most indicator work with image data has actually been with secondary products, mainly maps, derived from images, rather than the image data themselves. With respect to the frameworks considered in Section 9.3, it is also the case that image data are most often used for input to indicators of landscape state, rather than being interpreted for indicators of driving forces, pressures, impacts or responses. This is evidenced by the fact that indicators are frequently derived from inventory type products from remote sensing, such as land cover maps and spatial databases of landscape features, as in the 3Q programme (Section 9.7.2). The relationship of image data to other sources of input to an indicator, such as biological data is interesting. Thus, it may be that an indicator is based primarily on biological data, e.g. that a group of species that depend on a particular habitat is being lost. Image data then provide qualification to this indicator in the form of a distribution map or an estimate of the rate of loss over an extended area.

A tendency when using Earth observation data is that technical issues may tend to take over. For example, much work is still to be done in developing methods and techniques to extract information from images. Techniques such as pattern recognition, used directly on image data, are extremely prom-

ising for the future production of indicators that can more closely capture reality. Similarly, there is a wealth of different spatial metrics that capture different aspects of landscape content and composition, and there is great potential for developing still new measures and indices. However, it is important also to focus on the quality of landscape habitats. It is thus necessary to also explore how far Earth observation data can contribute to this kind of information, and how and to what extent field observation is needed to complement the information from image data.

In the face of the potential for technological development that Earth observation data represent, it should be emphasised that there are also many social-economic issues that are an essential part of the indicator debate – especially linked to the aim of developing meaningful cause-effect links between drivers and impacts. A classic problem is the choice of sampling frameworks – should they build on ecological, economic or administrative units. The need for co-operation between disciplines is therefore great. For the agricultural landscape however, increasing spatial details in socio-economic information opens opportunities for aggregation to ecologically or administratively relevant spatial units, and thereby for improved linkages between pressure and state/impact indicators. In addition, it is important to realise that we cannot wait until the perfect indicator set has been developed – either from the technological or the social side - but must start using indicators now, to provide a baseline against which to monitor changes.

A particular advantage of image data is that, once captured, it will always be available for use in the future when technical or financial circumstances allow new analyses to be made on the historical data. Already, the value in this approach has become very apparent through the use of old aerial photographs, which provide a unique source of information on the changes that have happened in the landscape over the last decades. Predicting landscape change is not easy and, as noted in Section 9.3 we have to accept that changes may occur in the landscape that we cannot imagine today. Our choice of indicators is likely to be influenced by changes that have happened in the past. In this respect too, image data will provide a valuable source of data in the future – to go back and calculate indicators that can reflect landscape developments that are relevant for the day.

In order to understand the driving forces of landscape change in particular, it is necessary to use other data sources together with EO data. Particularly important are socio-economic data that may explain landscape management choices. Laws, regulations and economic incentives associated with agriculture, forestry tourism and rural development will be of vital importance in understanding landscape development. In order to extract as much value as possible from EO data, better use of supplementary data sources is needed.

Some aspects of the landscape, such as aesthetic qualities, are difficult to quantify adequately from image data. Technical solutions can be envisaged for these themes in the future, for example, using ortho-photographs draped over terrain models, 3D-modelling and results from landscape preference studies. Nevertheless, landscape is more than land cover and more than the sum of different components. There is a therefore a growing interest in methods to quantify “landscape character”, creating a holistic picture of a landscape.

9.7 Examples of Indicators in Nordic LLM²

9.7.1 The National Inventory of Landscape in Sweden (NILS) Programme

The National Inventory of Landscape in Sweden (NILS, formerly known as the SLÖ programme) is still in the process of development. Important tasks have included a survey of user needs and the testing of field monitoring methods. The NILS programme aims to use a combination of image data (infrared aerial photographs, scale 1: 30,000) and field recording at a sample of between 500 to 700 sample squares. Monitoring will be conducted in 5 x 5 km squares, primarily focused on a central 1 x 1 km square within this area, but with supplementary data collection for rare elements in the surrounding area.

The combination of images and field visits is seen as strengthening both data sources. Image data provides an overview of the landscape and is an ideal basis for mapping, whilst field data provides a more detailed resolution that enables control and refinement of maps, and the use of more sensitive indicators of change, such as measures of habitat quality.

Indicators have not yet been defined for the programme, but will probably include a wide range of

² For information of the use of indicators in LLM in Finland, see Chapter 3 of this publication.

measures including both landscape information derived from images, such as areas of different land types and their spatial arrangement, and indicators derived from field data, including the use of indicator species. Issues such as indicator aggregation and methods of presentation have not yet been considered.

The most valuable contribution to the Nordic indicator discussion so far is the inventory of user needs, which identifies the issues that different ministries and institutions believe to be important in different landscapes (Table 9.1).

Table 9.1. Results from an inventory of user needs made in connection with the NILS Programme.

Landscape Type	Demand for information on:
The agricultural landscape	Grazing and mowing Eutrophication Small biotopes, ponds Landscape composition Cultural remnants
Urban areas	Parks and naturally vegetated areas Old deciduous trees Small biotopes, ponds Recreation, accessibility
Wetlands and shores	Drainage Natural or disturbed water regime Grazing and mowing Exploitation and ground disturbance Chemical impact (eutrophication)
Forests	Tree cutting and other disturbances Landscape composition Forest stand properties Substrates, dead wood Forest continuity
Mountain areas	Reindeer grazing Climatic change Ground disturbance (vehicles, tourism)

9.7.2 The Norwegian programme for monitoring agricultural landscapes: 3Q

The Norwegian 3Q programme is a monitoring programme designed specifically for monitoring agricultural landscapes. Recording for the programme began in 1998 and has thus come further than the Swedish NILS programme, having moved from the theoretical phase to the practical phase. The fundamental data source for 3Q is image data, in the form of true colour aerial photographs at the scale of 1:12,500. The founding concept for the programme is the idea that image data can provide an overview of the landscape that enables rapid and cost-effective collection of landscape data at a national level. The programme is based on a sample of 1,474 squares of 1 x 1 km, spread across Norway in proportion with the amount of agricultural land.

The 3Q programme has four main topics of interest: Spatial structure, biodiversity, cultural heritage and accessibility. Most of the indicators presented are based on spatial metrics derived from the aerial photographs. In the first year of the programme, an attempt was made to derive indicators for all of these themes solely from the image data (Table 9.2). For the cultural heritage data, the result was considered unsatisfactory and from 1999 onwards, data has been collected in the field from a sub-sample of squares. Unfortunately, due to economic limitations, the number of squares visited is very small – about 30 squares per year. From this small sample it is difficult to indicate trends with the desired level of certainty for the

Table 9.2. Variables reported from the 3Q monitoring programme by theme and subject of interest.

Theme	Subject of interest	Reported variable
Spatial structure - landscape		
	<i>Land type</i>	Area of each type Percent of each type
	<i>Fragmentation of different land types</i>	Average size of coherent units Total units per km ²
	<i>Landscape diversity</i>	Shannon's diversity index
	<i>Landscape heterogeneity</i>	Heterogeneity index (HIX)
	<i>Edge types</i>	Length (km) of each type Percent of each type
	<i>Water edges</i>	Length (km) of different types Area in 10m buffer zone
	<i>Buildings</i>	Number per land type Percent on each land type Number per km ²
Spatial structure - agricultural land		
	<i>Land type (level III)</i>	Area of each type Percent of each type
	<i>Fragmentation</i>	Total number of fields Fields per km ² agricultural land
	<i>Diversity of agricultural land types</i>	Shannon's diversity index
	<i>Field shape</i>	Area weighted average shape index
	<i>Field edge types</i>	Length per km ² agricultural land
	<i>Linear elements on agricultural land</i>	Number Average length (km)
	<i>Non-crop islands in agricultural land</i>	Number Percent of different types Number per km ² agricultural land
	<i>Point objects in agricultural land</i>	Number per field Number of different types Number per km ² agricultural land Number per field
Biodiversity[#]		
	<i>Diversity of habitats</i>	Shannon's diversity index
Cultural heritage		
	<i>Historical buildings</i>	Number Number per km ²
	<i>Cultural monuments & sites*</i>	Number
	<i>Historical fences*</i>	Number Length (m)
	<i>Historical roads & paths*</i>	Number Length (m)
Accessibility		
	<i>Access routes</i>	Length (km) Percent of different types
	<i>Connectivity</i>	Gamma-index
	<i>Disturbance from roads and built-up areas</i>	Area (km ²) within 100m distance intervals Percent in each distance interval
	<i>Accessible land</i>	Area (km ²) accessible for three mobility groups Percent area accessible to the three mobility group

[#] The landscape metrics listed under the themes "Spatial structure" are used as indicators for the biodiversity theme.

* These cultural heritage indicators are recorded in the field at 10% of the monitoring squares. Since numbers are too small to use as a basis for county estimates, these indicators are reported for field squares only.

regional and national level. Future methods will therefore make more use of national cultural heritage databases, which have improved considerably since the start of the 3Q-programme and become more readily available. Although having limitations in terms of both content and accuracy, the databases may be sufficient to indicate trends, particularly when combined with land cover maps that can reveal developments in areas of cultural heritage interest.

Problems are also recognised for the biodiversity theme. Although information is gathered about the area of different land types and their spatial structure, both issues that are believed to have consequences for species, it is nevertheless difficult to obtain data of sufficient spatial resolution to make indicators that will be sensitive to change. Internationally, there is an understanding that biodiversity monitoring should take account not only of the quantity of habitat that exists, but also information about its quality (OECD 2001). This is achieved, for example, in the UK's Countryside Survey, where landscape mapping is combined with species survey data. It remains to be seen whether the Norwegian programme will find the necessary funding or co-operation with other organisations to develop in this direction.

Regardless of whether the 3Q programme increases the field component of its monitoring or not, experience so far and analysis of old aerial photographs of monitoring squares, indicates that image data provide an excellent means for indicating the extent of changes in the landscape at a coarse level that is useful for regional and national reporting. Not least, processes such as abandonment and intensification of agriculture are very clear from image data and can be quantified in terms of changes in areas of different land types and changes in the spatial structure of the landscape. Several indicators based on spatial metrics have also been shown to be correlated with numbers of species per square (Fjellstad *et al.* 2001), such that there is value in the approach at a coarse level.

Future challenges include refining methods for aggregating information from the different monitoring squares, such that opposing trends of change in different types of landscape (*e.g.* valley bottom versus mountainside) do not mask one another in the aggregated indicator values. Some kind of landscape typology may be a useful tool in this endeavour. Similarly, grouping squares according to different parameters, including socio-economic data, is likely to be useful for identifying driving forces of landscape change.

9.8 The way forward

A clear conclusion from the workshop was that there is a great need to test indicators using real landscape data. Some major themes include:

- identifying the audience for landscape indicators (who needs the indicators and what values are they interested in?)
- working more closely with policy makers to identify measurable goals
- developing methods and techniques to extract information from image data,
- refining spatial metrics and finding new measures to capture complex issues such as fragmentation and connectivity,
- developing methods to integrate data from different sources - particularly socio-economic data - to identify driving forces,
- testing existing indicators to determine whether they are sensitive to landscape change,
- identifying gaps in the existing set of indicators,
- developing better ways to communicate the implications of indicator values

It was agreed that the major problem in dealing with landscape issues is that different groups have different values and that indicators must take account of all of these. Many social groups are very active in thinking about and analysing the landscape, but they may need the help available through indicators to quantify and communicate their interests. Indicators must capture the issues thrown up in social debate and structure these in a scientific way. Only when information can be provided in an objective and balanced way is it possible to make democratic decisions about the development of the landscape. Inevitably some values will be sacrificed to the advantage of others – for example, preserving biological and recreational values may lead to a loss of possible economic values. However, the provision of indicators is not intended to decide the outcome of such trade-offs, simply to inform the debate.

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Annex 9.A – List of Participants (with affiliations at time of the workshop)

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Annex 9.B - OECD expert meeting on landscape indicators, 7 - 9th October 2002, Oslo, Norway: summary report

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9.B.1 Background

The OECD Expert Meeting on Landscape Indicators was held in Oslo, Norway, 7th - 9th October, 2002. The meeting was organised under the auspices of the OECD Joint Working Party on Agriculture and Environment (JWP) and hosted by the Norwegian Institute of Land Inventory (NIJOS), on behalf of the Norwegian Ministry of Agriculture. Around 80 participants attended the meeting, drawn from 23 of the 30 OECD Member Countries in addition to one non-member nation and also involved many international organisations. NIJOS, in agreement with the authors, published the papers that were presented at the meeting¹ and the official conclusions and recommendations of the experts will be made available through OECD publications.

The OECD undertakes analysis of agri-environmental policy issues through the JWP. As part of that work, the JWP is developing a set of agri-environmental indicators to measure the environmental performance of agriculture. The indicators are to provide information to policy makers and the wider public on the current state and changes in the conditions of the environment in agriculture, and to improve understanding of cause and effect linkages between agriculture, agricultural policy reform, trade liberalisation and environmental measures on the environment. Indicators are also required to guide policy makers in their responses to changes in environmental conditions, and contribute to monitoring and evaluating the effectiveness of policies that address agri-environmental concerns.

9.B.2 The OECD Agri-Landscape Indicator Framework

The methodological and strategic considerations discussed during the meeting were summarised in Figure 9.B.1. This was also seen as a framework for structuring landscape indicators, noting the structure, function and value facets of landscape. In general it was found useful within the framework to distinguish between 'landscape character' (representing a neutral descriptive main frame for identifying the major typological differences between landscapes, resulting from natural and cultural processes) and 'landscape appearance'. The latter is seen as a variable expression of the part of landscape that is subject to production, management and frequent alteration by agricultural activities. However it was noted that the terms 'landscape character' and 'landscape appearance' lack standardised definition. Physical structure and composition, aesthetics, cultural heritage (including recognition of the "time depth") and the demand for landscapes were seen as important elements of agricultural landscape appearance.

Four issues, seen as critical to the development of policy relevant agricultural landscape indicators were discussed: policy context, scale, indicator areas and data sources, as are represented in the framework diagram (Figure 9.B.1):

- Consideration of policy context was seen as essential in prioritising which landscape indicators to develop, at the same time as the indicator-development work can inform about landscape patterns and processes that should be taken into account in policy-making. Policy scenarios and trend analysis are tools that could facilitate the necessary iterative process between scientists and policy-makers. Indicators should measure progress towards clearly defined policy targets for landscape management, yet most OECD countries currently lack such targets.
- The relevance of different landscape indicators may vary from local to regional to international scales of investigation. Many participants at the meeting raised the issue of regional differences within countries and the difficulty of developing a national average landscape indicator. The most appropriate expression for reporting landscape indicators nationally may be the proportion of regions within a country that have documented either positive or negative change (in relation to targets).

¹ http://www.nijos.no/Publikasjoner/Rapporter/2003/Rapport07_03.pdf

- The box 'indicator attributes' in Figure 9.B.1 proposes that indicators can be organised according to whether they are indicators of agricultural landscape structure, function, management or values (*i.e.* the value and demand for landscapes by various stakeholders). Currently, the most well developed indicators quantify landscape structure, although the scope of work on other aspects has been enlarged in recent years. Structure indicators can be considered complementary, in that all these aspects may either independently or in combination capture present and future trends in agricultural landscape change. The examples listed under 'structures' and 'functions' in Figure 9.B.1 are indicators recommended by the meeting. 'Management' indicators are to be further developed under the OECD 'Farm Management' group of indicators rather than under the landscape theme. 'Value' indicators, although seen as having great potential to aid policy makers, are the least developed group and require more methodological discussion and testing before they can become operational.
- Numerous data sources can be used for calculating landscape indicators but data availability varies considerably between countries. Mapping and sample-based monitoring programmes providing information on land cover and land use are seen as most promising for establishing wide-ranging compatible data-sets.

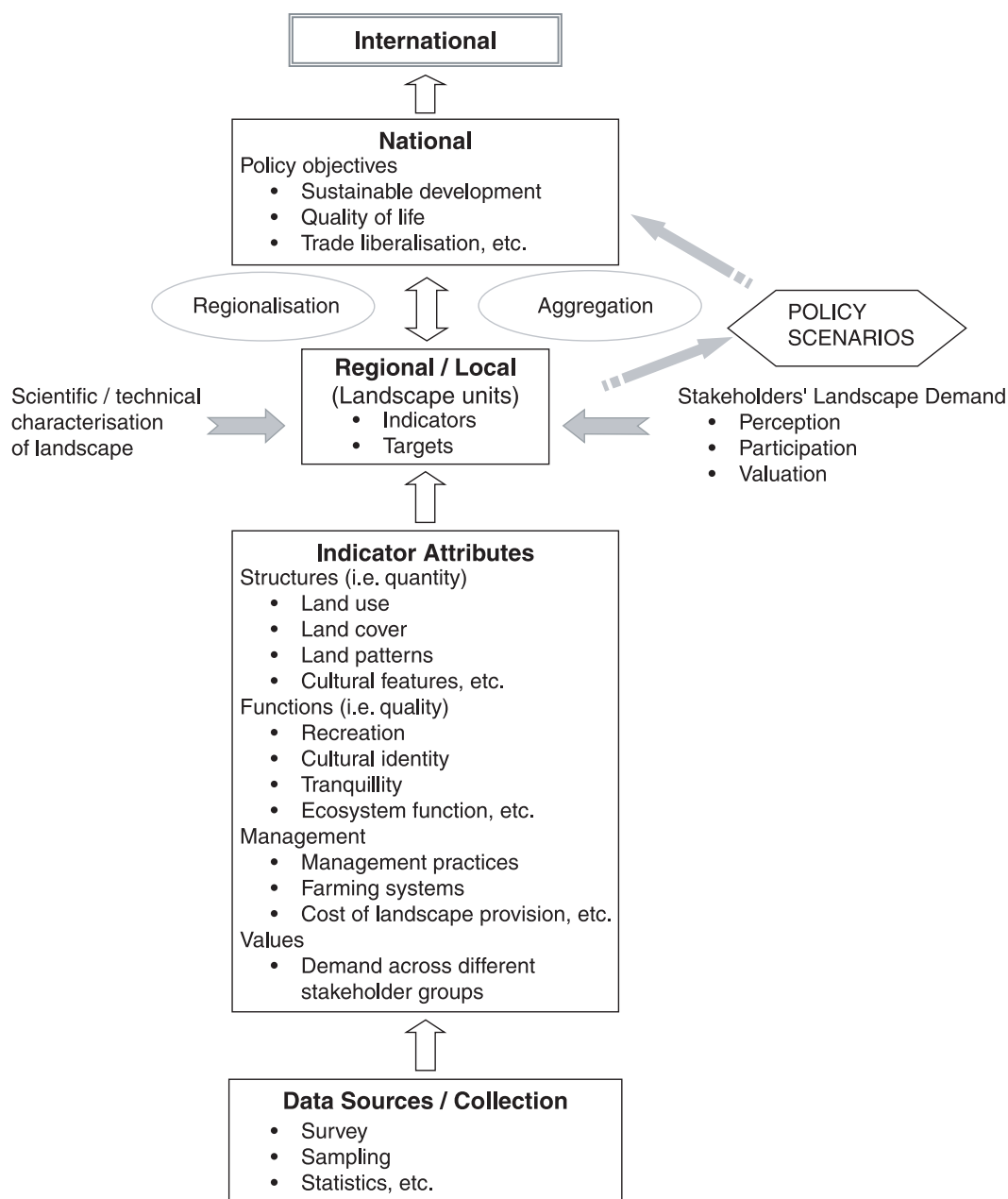


Figure 9.B.1. The OECD Agri-Landscape Indicator Framework

Landscape metrics as a contribution to the differentiation of Danish landscapes.

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Summary

The present pilot study explores the use of landscape metrics for describing and differentiating Danish agricultural landscapes – among others with the perspective of landscape monitoring. Landscape metrics for the four area types meadow/dry grass, heath/bogs, ponds and forest as well as two landscape level metrics were selected and calculated for 95 parishes distributed in 10 case-areas. Multivariate analysis of variance showed that the variance in the metrics was significantly related to area type and case-area, but not to parish. Factor analysis of the metrics at parish level showed that the first two principal components mainly described the composition of nature types in the parishes – in terms of abundance and type distribution, while aspects of configuration appeared in the third PC. A cluster analysis of the first 10 PCs showed that five main clusters of parishes could be identified, and that a differentiation of landscapes was possible. However, a number of aspects related to scale, choice of metrics and level as well as sensitivity of metrics towards driving forces such as agricultural change should be further investigated.

Keywords: landscape metrics, indicators, indices, agricultural landscape

10.1 Introduction

Landscape indicators and indices¹ have been researched for a number of years now – especially as a means for analysing landscape changes (Hulshoff 1995; Lausch & Herzog 2002). There is however no tradition in Denmark for using landscape indices in landscape assessment and monitoring, and few studies have explored the suitability of the various indices for describing Danish landscapes and changes in them (see however, Brandt & Holmes 1993; Caspersen & Fritzboeger 2002). Recently, relevant data for such purposes have been made available through a number of nation-wide digital mapping projects: a shift to digital production of topographic maps by the Geodetic Survey (KMS 2001) and the Area Information System (Nielsen *et al.* 2000). The latter is a large project for compiling and collecting national land use and other national thematic map layers in one system.

The aim of the present study is twofold. The first aim is to explore the relationship and possible redundancy between a number of landscape metrics, when used on Danish agricultural landscapes. The second aim is to explore the usefulness of the landscape metrics for describing and distinguishing Danish landscapes using case-areas from a research project covering a broad sample of Danish agricultural landscapes. The landscape structure is described both in terms of metrics of composition such as variety and abundance of patch types in the landscape, i.e. without reference to spatial attributes (McGarical, S.A. *et al.* 2003), and of configuration, being aspects of spatial character and arrangement, position or orientation of patches (*ibid.*).

While the objective is rather concrete, contributing to a description of a number of case-areas, the perspective of the study is additionally to start exploring the potential of landscape metrics for land-

¹Some confusion exists in the terminology concerning landscape metrics, indicators and indices. A landscape metric is an algorithm, which quantify categorical map patterns. An indicator can be defined as a variable or parameter summarising information relevant to a phenomenon, or with a significance beyond that directly associated with a parameter value (Christensen, N. and F. Møller (2001). *Nationale og internationale miljøindikatorsystemer*. Roskilde, National Environmental Research Institute: 161). Thus a landscape metric may be an indicator of specific aspects related to landscape structure, like heterogeneity, diversity or connectivity. An index however may be a measure indexed to a specific year or it may be an aggregated number (unit-less) based on several parameters. As a concept, landscape indices is not very precisely used, it is not hold exclusively for unitless composite numbers, but sometimes just synonymously with a metric (e.g. Hulshoff, R. M. (1995). *Landscape indices describing a Dutch landscape*. *Landscape ecology* 10(2): 101-111).

"Developments in Strategic Landscape Monitoring for the Nordic Countries." Groom, G. (ed) Nordic Council of Ministers. ANP 2004:705, pp 155-167.

scape assessment and monitoring in Denmark in general. Monitoring of landscapes is being developed in a number of countries, and indicators of landscape structure play a prominent role in this (Wascher 2003).

10.2 Background

10.2.1 Projects involved

The present pilot study is part of an ongoing research project on Nature quality in organic farming in Denmark (Fredshavn 2001). In this project 10 agricultural case-areas distributed over Denmark have been selected. They consist of a varying number of parishes totalling 95 and represent a broad spectrum of Danish geomorphologic landscape types. The number of organic farms present has determined the size of the case-areas. Former studies of the impact of organic farming on landscapes have found differences in landscape composition and the amount of semi-natural areas between conventional and organic farms. These differences could however not be definitely attributed to the farming system, as they seemed to be inherited from the landscape existing before conversion (Clausen & Larsen 1997).

To avoid conclusions that do not take the general landscape context into account, and in order to elucidate differences between the analysed case-areas and between the single parishes, it was decided that the description of case-areas should include a description of the entire landscape. This should include the structure - composition and configuration - of semi-natural areas in the landscape, comprising both conventional and organically farmed areas. The present methodological study thus contributes to this analysis.

Moreover, the project contributes to the NordLam project, which focuses on Nordic Landscape monitoring and the use of information derived from image data therein. Monitoring of the agricultural landscape by means of agri-environmental indicators has taken place for many years in Norway (Dramstad *et al.* 2002), is recently implemented in Sweden (Naturvårdsverket 2003) and are being proposed in Finland (Hietala-Koivu 2003). However the interest in monitoring of structural aspects of the agricultural landscape in Denmark has been small and methods have mainly been explored in a university based monitoring project, in which a national inventory has been conducted with five years intervals since the 1980s (Brandt *et al.* 2001). Other national change studies are referred to statistical sources on administrative levels. Very little research has been undertaken on landscape metrics as indicators of configuration of the Danish landscape.

Denmark is now covered by land use data in vector-format and land cover data in 25 x 25 m cells, the latter derived from Landsat TM satellite images during the middle of the 1990s (Nielsen *et al.* 2000). These national data sets may now provide a foundation for the exploration of landscape metrics. The present project thus aims to explore the capability of landscape metrics for distinguishing between different agricultural landscapes in terms of their content of nature types (natural and semi-natural), and to discuss the sensitivity of the selected metrics towards differences in landscape structure. This information will also contribute to knowledge on landscape metrics/indices as indicators for landscape monitoring purposes.

10.2.2 Scientific background

Several studies conclude that more than one landscape metric is needed to adequately describe landscapes (Hulshoff 1995; Riitters *et al.* 1995; Dramstad *et al.* 1998; Giles & Trani 1999). However, widely varying data models and differences in applied scales limit the comparability of these studies. Therefore, it has been put forward that for future development of common indicators it is necessary to address the issue of data and scale (Lausch & Herzog 2002). One method to select appropriate metrics, which has been of some inspiration for the present work, is an exploration of the relationship and possible redundancy of a larger number of metrics, followed by a statistically based reduction of number of metrics by factor analyses (Riitters *et al.* 1995; Cain *et al.* 1997; Herzog *et al.* 2001). A table of factor loadings shows which metrics group together on which factors, and how much the individual metrics contribute to the factor loadings. Thus, the number of metrics may be reduced, either by analysing the whole set of factor loadings or by carrying out the factor analyses for groups of metrics. For selection of a final set of metrics different methods were applied. One study explored landscape change over four map years. They used factor analysis on categories of metrics, *e.g.* patch area metrics or edge and shape metrics. Factors includ-

ing more than 10% of the total variation were kept and the metric with greatest sum of factor loadings over the four years was chosen to represent that factor (Herzog *et al.* 2001). Another study looked into the impact of scale and origin of map. They selected groups of metrics according to a high loading on each factor. For each group the metrics were selected that correlated most with the matching factor and least with the others (Cain *et al.* 1997). The study moreover used the factors for a clustering of landscapes, similar with respect to the metrics. Results from that point to a limited number of metrics needed for a comprehensive landscape description. For all three studies the analyses were carried out on land cover or land use maps on the landscape level.

10.3 Methods

10.3.1 Analytical methods

A number of choices have to be made which influence the final calculation of metrics. One of these is the typology on which the land use/cover map is produced. For the present study it was decided to produce area types that were expected to respond to changes in management and regulation of the agricultural sector, such as area extensification/intensification of grazing areas, afforestation, establishment of ponds, *etc.* Thus, the area types chosen were: Meadow/dry grassland, heath/bogs, ponds and forest, while the rest was perceived as matrix. Differences in the structure of these nature types were to be assessed individually, implying that class level metrics were to be produced for the comparison of parishes. Some landscape level aspects such as patch richness, diversity and overall aggregation were also of interest, and the calculation of metrics were consequently carried out on both landscape level and class level (the latter referring to the area types).

At the landscape level a correlation analysis were conducted among metrics (see Figure 10.1) for a selection of metrics to be carried on to the parish analysis. As an impact of area size on metrics has earlier been found (Herzog *et al.* 2001), the correlations between parish size and landscape level metrics were additionally explored.

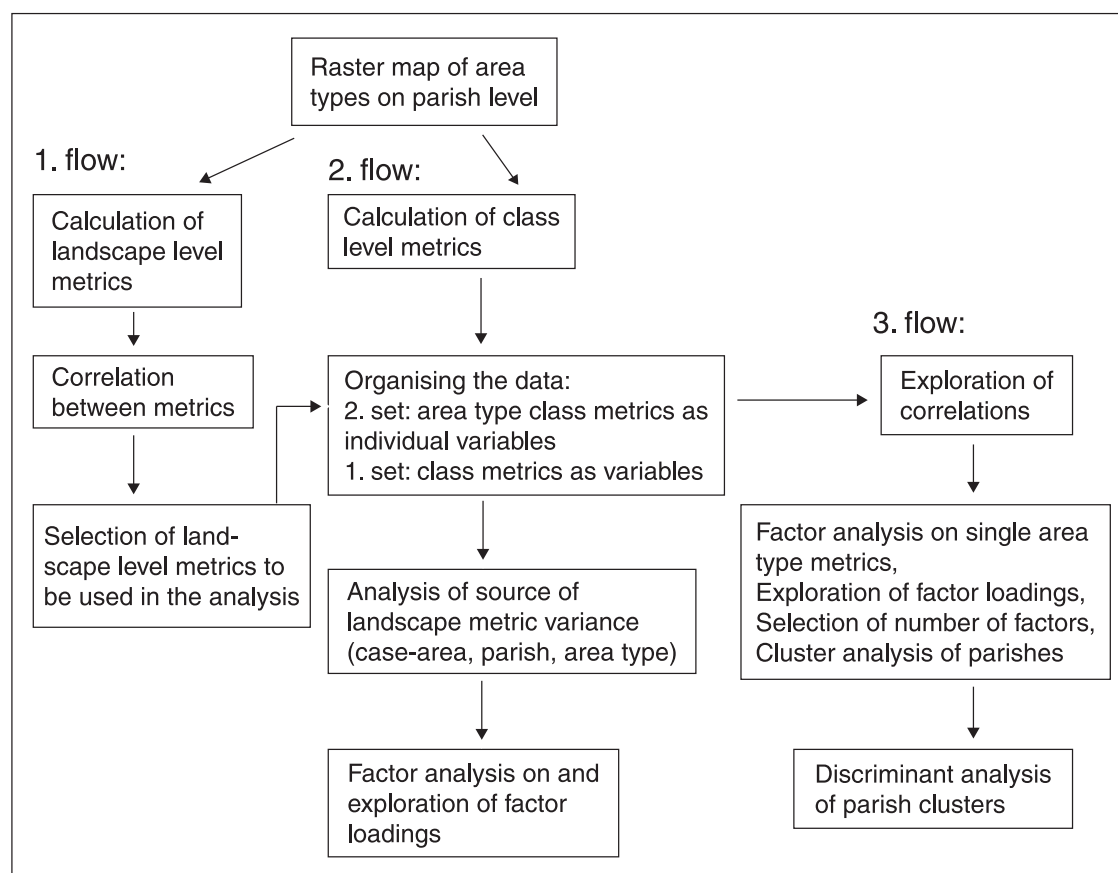


Figure 10.1 Flowdiagram of the analyses made.

At the class level two flows of analyses were conducted, based on the same data set but organised in two different ways. In the first data set the variables (columns) are the class metrics and the cases (rows) are combinations of parish/area type (95 x 4 rows), with case-areas as a third categorical variable, aggregated from parishes. The first part of the analysis based on this data set explored the variance of the metrics on class level (eight variables), to reveal if or which of the three spatial aggregation levels could explain variance: area type (four categories, whole area), case-area (10 categories) or parish (88 categories). This was explored by reducing the number of variables through a principal components analysis (PCA) followed by a multivariate analysis of variance using the GLM procedure of the SAS statistical package (SAS, version 8.02).

The data were now reorganised to the parish level so that area types became variables (four for each landscape metric). This reduced the number of rows to number of parishes, and increased the number of variables to 34 (*i.e.* 8 class level metrics x 4 area types + 2 landscape level metrics, selected on the basis of the initial analysis of landscape level metrics, see explanation later). This part of the analysis aimed at exploring if the landscape metrics could distinguish between landscapes at the parish level. Again, a PCA was carried out, followed by an exploration of the content of the principal component scores, and a cluster analysis of parishes based on the number of factors holding approximately 90% of the variance. The robustness of the cluster analysis was explored by carrying out a discriminant analysis, investigating the capability of the clusters for allocating the parishes to the clusters based on the analysis of the original landscape metrics.

10.3.2 Generation of maps

Spatial data for the study were generated as follows. The data-layers used for production of the land-use map used here were raster-maps with 25 x 25 meter cell size, converted from three sets of polygon-maps (Table 10.1). The primary layer consisted of the registration of protected nature types (called “§3 areas” as they are protected according to the 1992 Nature Protection Act) (Nielsen *et al.* 2000, pp 77-79). The remaining areas have been filled by merging the national digital topographic map (KMS, 2001) together with roads and rivers from the National Area Information System (Nielsen *et al.* 2000). It was decided that focus is upon semi-natural areas and forests, leaving all other areas as background matrix during the structural analysis. The maps combined originate from different sources and thus common borders in the landscape do not necessarily coincide between maps. Processing steps were required to achieve connectivity as well as fragmentation between the individual patches of the area in focus (*e.g.* larger rivers should separate meadows on each side of the riverbank, and small forest tracks should not separate a larger forest patch). Small slivers of matrix between patches have been removed and major roads and rivers were merged into the map to separate patches. The final map contained 12 land use types, which were reduced to the four main area types mentioned above and a background-type representing the matrix. The four main area types were forests, lakes/ponds (larger lakes are not included in the analysis, as they are outside parish border) and semi-natural areas in two classes: meadow and dry grassland as the third, and bogs and heath/salt marsh form the last (Table 10.1).

Table 10.1. Reclassification of the base-map data.

Class no. in land use map	Land use type	Main area type	map origin	precedence
0	ocean	999	Top10DK	1
1	fields	999	remaining area	5
3	roads	999	AIS	2
1000	build-up	999	Top10DK	4
3100	forest	4	Top10DK	4
3210	dry grass	1	protected nature types/Top10DK	3
3220	heath	2	protected nature types/Top10DK	3
4110	meadow	1	protected nature types/Top10DK	3
4120	bogs	2	protected nature types/Top10DK	3
4210	salt marsh	2	protected nature types/Top10DK	3
5120	lake/pond	3	protected nature types/Top10DK	2/3
5121	watercourse	999	AIS	2/3

10.3.3 Calculation of metrics

The 10 case-areas cover 95 parishes (see map in Figure 10.5). Land use maps were cut out for each parish and case-area, using a map of Danish parishes from around 1950 as a mask. Major lakes are not mapped as part of the parish areas, and this causes slivers between the parish and land use map to appear like strings of pearls along the lakeside. As these pixels would act as small ponds in analyses of landscape structure, seven of the parishes was excluded from some of the analyses, leaving 88 parishes for the analyses involving pond patches.

The Fragstats program package (McGarical *et al.* 2003) has been used to compute a number of metrics on landscape and class level. The metrics used in the analysis were selected to cover landscape composition as well as configuration measures. Furthermore they were selected so as not to be too sensitive to the parish area, as mean parish size is 2217 ha, ranging from 559 ha to 14,083 ha. Consequently densities and means were selected whenever applicable.

On landscape level seven metrics (of which four are termed indices)² were calculated, as shown in Table 10.2. On class level seven metrics were selected while one (mean edge) was computed by combining other Fragstats class metrics. Each of these was computed for each of the four area types. They are shown in Table 10.3.

Table 10.2. Landscape level metrics produced.

<i>Fragstats acronym</i>	<i>Fragstats Description (McGarical, S.A. et al. 2003)</i>
TA Total area	TA equals the total area (m ²) of the landscape, divided by 10,000 (to convert to hectares). Note, total landscape area (A) includes any internal background present.
PR Patch richness	PR equals the number of different patch types present within the landscape boundary.
RPR Relative patch richness	RPR equals the number of different patch types present within the landscape boundary divided by the maximum potential number of patch types specified by the user, based on the particular patch type classification scheme, multiplied by 100 (to convert to percent).
SHDI Shannon diversity index	SHDI equals minus the sum, across all patch types, of the proportional abundance of each patch type multiplied by that proportion. Note, P_i is based on total landscape area (A) excluding any internal background present.
SIDI Simpson's diversity index	Simpson's diversity index: SIDI equals 1 minus the sum, across all patch types, of the proportional abundance of each patch type squared. Note, P_i is based on total landscape area (A) excluding any internal background present.
MSIDI Modified Simpson's diversity index	MSIDI equals minus the logarithm of the sum, across all patch types, of the proportional abundance of each patch type squared, divided by the logarithm of the number of patch types. In other words, the observed modified Simpson's diversity index divided by the maximum modified Simpson's diversity index for that number of patch types. Note, P_i is based on total landscape area (A) excluding any internal background present.
AI_LA Aggregation index	Aggregation index on landscape level: sum of class AI weighted by the proportion of the total area (excluding background).

²Another source of confusion is that the FRAGSTATS programme differentiates between levels of metrics, such that class level computes metrics based on single area types, while landscape level metrics are computed on all patches (here covering the four area types together). Landscape is thus used as a term referring to level in FRAGSTATS, while landscape metrics/indices usually cover all levels of calculations. In this paper it is stated, whenever an analysis refers to a given level.

Table 10.3. Class level metrics produced.

<i>Fragstats acronym</i>	<i>Description</i>
PLAND percentage of area	Class area as percentage of total area
PD patch density	Number of patches divided by Total Area
ED edge density	Sum of edge length divided by Total Area
ME mean edge	Sum of edge length divided by number of patches (computed)
AREA_MN mean patch area	Sum of class area divided by number of patches
PROX_MN proximity	PROX equals the sum of patch area (m ²) divided by the nearest edge-to-edge distance squared (m ²) between a patch and the focal patch of same class whose edges are within a specified distance (here 500 m) of the focal patch. Mean is the sum of PROX over all patches belonging to same class divided by number of patches.
ENN_MN nearest neighbour	Sum of patch distance to nearest neighbour of same type (Euclidian) divided by number of patches
AI_cl class level aggregation	Aggregation index: AI equals the number of like adjacencies involving the class, divided by the maximum possible number of like adjacencies involving the same class, which is achieved when the class is maximally clumped into a single, compact patch.

10.4 Results

10.4.1 Landscape level metrics

The analysis of landscape level metrics showed that there was no significant correlation between the area of the parish and the individual metrics, as seen in Table 10.4. Such an effect may however be overridden by other differences in parishes, and the issue should be studied further. Moreover the table shows that while the three diversity indices are highly correlated, the rest are not especially correlated to each other. Looking at the original data however, it is seen that relative patch richness is 100 in all parishes except two, making this metric irrelevant. Based on this analysis it was decided to take the landscape indices SIDI and AI_LA into the parish analysis.

10.4.2 The impact of case-area, parish and area type on variation in metrics

This analysis was carried out on the class level data set. First, it was explored if the categorical variables case-area, parish and area type contribute to the explanation of overall variance among the eight class level variables (Table 10.3). A principal component analysis was performed and the first four Principal Components (PCs) contained 92% of the variance. For each of the categorical variables (area type, parish and case-area) a multivariate analysis of variance was then carried out on the first four PCs. It showed that the no-effect hypothesis could be rejected for case-area and for area type ($p < 0.0001$) but not for parish. This indicated that the area types had a significant influence on the variation in landscape metrics. This was not surprising, as a look at the total share of each area type already showed large differences (See later Table 10.5). However the case areas also seem to explain some of the variation, indicating that differences in landscapes may be described by these measures.

Plots of Principal Components illustrating the distribution of case-area symbols however, showed no visual aggregation of case-areas, while the same plots illustrating distribution of area type symbols showed

Table 10.4. Correlations between the landscape level metrics

	TA <i>Total area</i>	PR <i>Patch richness</i>	RPR <i>Relative patch richness</i>	SHDI <i>Shannon diversity index</i>	SIDI <i>Simpson diversity index</i>	MSIDI <i>Modified SIDI</i>	AI_LA <i>Aggregation index</i>
TA	1.00						
PR	0.09	1.00					
RPR	0.06	0.50	1.00				
SHDI	-0.03	-0.03	-0.08	1.00			
SIDI	0.00	-0.07	-0.10	0.98	1.00		
MSIDI	-0.03	-0.07	-0.10	0.98	0.99	1.00	
AI_LA	0.25	0.12	0.13	-0.56	-0.55	-0.55	1.00

rather clear aggregations of area types.

Figure 10.2 shows the factor loadings on the first four PCs. The corresponding eigenvalues are 4.3, 1.6, 0.8 and 0.6. As the factor loadings show, most of the landscape metrics contribute to the first PC, but with patch density (PD) contributing to a lesser degree than the other metrics. The Euclidean Nearest Neighbour distance distribution (ENNMN) evaluates opposite to the others, as large distances indicate low abundance or proximity. This could indicate that the first PC is an expression of low to high abundance and size and aggregation of nature types. Patch density dominates the second PC with a strong but negative contribution, in combination with positive nearest neighbour distance contribution. The share of total area is not involved, and this could indicate that PC2 shows something about configuration – especially distribution over the areas. This axis could be interpreted as representing a gradient from fragmented/scattered to less fragmented and closer patches. The third PC is more sensitive to share of total area, but PC3 and PC4 are not easily interpreted, as area types with opposite structures may influence the loadings.

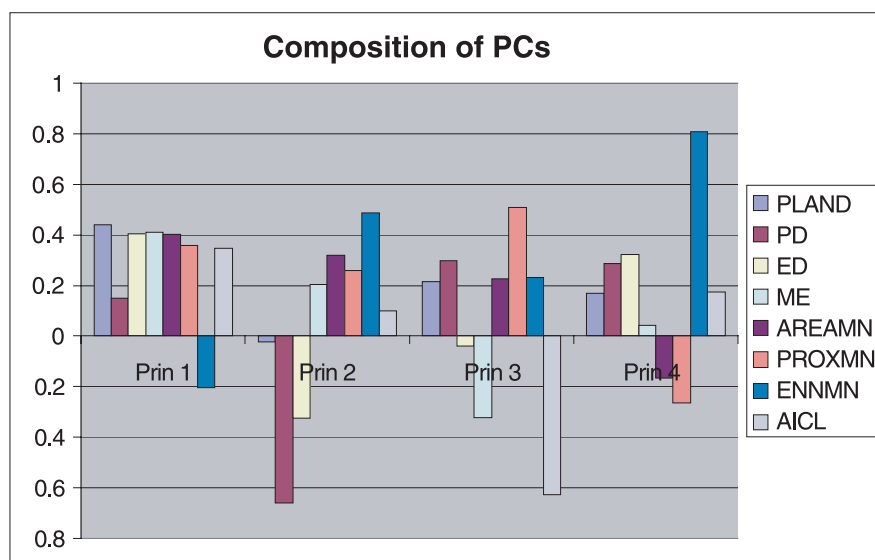


Figure 10.2. The contribution of landscape metrics to the principle components.

10.4.3 Description of parish landscapes by landscape metrics

Parishes as categorical level did not influence landscape metrics significantly, while case-areas did. Thus it was sought to classify parishes being similar in terms of landscape structure, exploring if clusters followed case-areas. This was explored in the reorganised data set, where parishes were described by a number of class level metrics for each area type supplemented by two landscape level metrics.

In Table 10.5 the descriptive statistics of these metrics are presented, and the variation among area types are illustrated. It shows that the share of forest (type 4) is largest both in terms of mean value and

Table 10.5. Means, standard deviations and ranges for the landscape metrics used.

	Mean	Std. Dev.	Min	Max
dry grass/meadow				
<i>Pland</i>	3.6	2.7	0.2	13.4
<i>pd</i>	1.4	0.7	0.3	3.5
<i>ed</i>	11.2	6.7	1.3	36.3
<i>me</i>	819.8	284.2	265.4	1566.7
<i>areamn</i>	2.7	1.7	0.4	9.4
<i>ennmn</i>	259.8	217.4	59.9	1143.2
<i>proxmn</i>	13.5	17.4	0.3	102.1
<i>aicl</i>	80.8	5.7	62.8	93.6
heath/bogs/salt marsh				
<i>Pland</i>	3.3	3.1	0.0	20.8
<i>pd</i>	1.7	0.9	0.1	4.8
<i>ed</i>	10.9	6.7	0.4	32.0
<i>me</i>	669.3	325.8	266.7	2233.3
<i>areamn</i>	2.5	4.9	0.3	46.1
<i>ennmn</i>	242.4	226.0	0.0	1690.2
<i>proxmn</i>	17.4	61.3	0.0	567.2
<i>aicl</i>	78.3	7.7	58.7	98.5
lake/pond				
<i>Pland</i>	0.7	0.8	0.0	4.5
<i>pd</i>	1.7	1.2	0.2	7.7
<i>ed</i>	3.9	3.2	0.4	16.2
<i>me</i>	227.2	92.2	100.0	691.7
<i>areamn</i>	0.4	0.4	0.1	2.8
<i>ennmn</i>	407.5	320.0	99.4	2375.1
<i>proxmn</i>	1.0	1.8	0.0	9.4
<i>aicl</i>	55.6	15.5	0.0	90.6
forest				
<i>Pland</i>	8.9	8.4	0.1	32.8
<i>pd</i>	2.2	1.0	0.3	5.8
<i>ed</i>	17.2	9.0	1.0	38.8
<i>me</i>	813.8	386.8	193.3	2513.5
<i>areamn</i>	4.3	4.4	0.2	23.3
<i>ennmn</i>	39.8	76.9	0.1	544.7
<i>proxmn</i>	218.2	105.5	83.5	622.5
<i>aicl</i>	83.2	9.4	50.3	97.1
landscape level indices				
<i>sidi</i>	0.6	0.1	0.2	0.7
<i>aila</i>	82.8	5.6	68.4	95.1

range. All the area types show quite large variations (as illustrated in the range), but as larger lakes are not included in the analysis, it is no surprise that small lakes/ponds only cover small areas and are more isolated than the other area types. The meadow/dry grass type is rather similar to the heath/bogs type as well in abundance as configuration.

In an analysis of correlation between parish area and landscape metrics, there was again no significant correlation, the highest correlation being between parish area and forest proximity and aggregation (both having $r = 0.28$).

For the other metrics, some correlation coefficients are rather high, but none of them exceed 0.90. It is interesting that the share of total area (PLAND) correlates rather well with a number of other metrics (ED, ME, AREA_MN and PROX_MN). Density measures are correlated (patch and edge density), indicating that shapes do not differ that much ($r = 0.60 - 0.87$), and the patch mean measures: mean edges and area means (ME and AREA_MN) also show high correlation ($0.70 - 0.86$). Table 10.6 exemplifies the correlation ranges for area type 1 (meadow/dry grass).

The Euclidean nearest neighbour index is the one that correlates the least with other indices, except for the forest class, where is highly (negatively) correlated with the forest density measures.

10.4.4 Factor analysis on parish metrics

The reorganised dataset contained 34 variables: eight class structural metrics for each of the four area-types, plus two landscape level metrics describing overall diversity and aggregation. 88 parishes were included in the analysis. A principal component analysis was performed on the dataset and the first 10 PCs contained 86% of the variance formerly held by the 34 variables. The first four PCs account for 60% of the variance. It is surprising that so many PCs were needed to

include a high percentage of the variation, as most other studies have reduced their variables to four PCs. This may be due to the aggregation level, where the present study works with class level variables while the three studies referred to above worked on landscape level (Riitters *et al.* 1995; Cain *et al.* 1997; Herzog *et al.* 2001). As was shown above the area type does account for a significant part of the variation. Moreover the metrics used were already from the beginning selected to cover various aspects of landscape structure, excluding a number of metrics, which measured more or less the same aspect. This however, prevented the selection of the most descriptive metric among a group, as the other studies did.

Subsequently the further analyses included 10 PCs. The eigenvalues of these were: 7.7, 4.8, 4.2, 3.7, 2.5, 2.1, 1.5, 1.1, 1.0 and 0.9. The contribution of the variables to the principal component scores is shown in Figure 10.3 for the first four principal components. Results reveal that again, mainly abundance, proximity and aggregation describe the first PC, and that ponds and forest are the dominating area types. Only nearest neighbour and diversity score negatively, and this pattern suits well with the analysis above. This axis can thus be said to be a low to high abundance and aggregation axis with dominance of forest

Table 10.6. Examples of correlations for the meadow / dry grass area type.

Metric	PLAND1	PD1	ED1	ME1	AREAMN1	PROXMN1	ENNMN1	AICL1	SIDI	AI_LA
PLAND1	1.00	0.60	0.90	0.67	0.67	0.69	-0.46	0.53	0.21	0.17
PD1		1.00	0.80	0.01	-0.04	0.22	-0.59	-0.06	0.31	-0.14
ED1			1.00	0.53	0.39	0.51	-0.53	0.24	0.24	0.01
ME1				1.00	0.87	0.56	-0.10	0.58	-0.06	0.32
AREAMN1					1.00	0.66	-0.11	0.76	-0.04	0.42
PROXMN1						1.00	-0.29	0.42	0.10	0.19
ENNMN1							1.00	-0.02	-0.11	-0.06
AICL1								1.00	-0.05	0.50
SIDI									1.00	-0.55
AI_LA										1.00

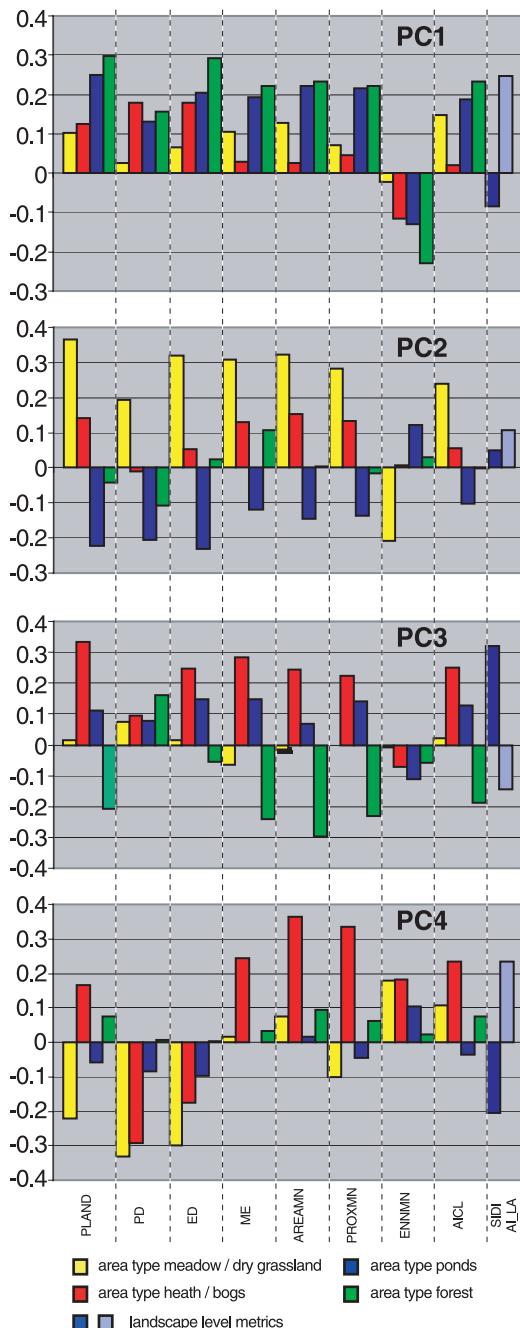


Figure 10.3. The contributions from the individual landscape metrics to the individual principal components, exemplified for the first 4 components..

and pond type. But in the second PC the area types enter with opposite loadings to each other, and the component primarily seems to be a “pond to meadow/dry grass” factor. The forest area type plays an insignificant role in this PC, while heath/bogs load like meadow/dry grass, but with smaller loadings. The third PC expresses primarily the area types that were less important in PC2, a “forest to heath/bog” factor, but showing that landscape structure counts more in this factor. Thus, landscape level diversity has a strong positive loading, and aggregation - especially aggregated forest and large mean patch areas - contributes strongly with a negative loading to this factor. Density contributes with a positive loading for all area types, including forest. In the fourth principal component bogs/heath and meadow/dry grassland play major roles while lakes/ponds and forest do not contribute significantly. The abundance and fragmentation of meadow/dry grass contributes negatively and aggregated bogs/heath positively. Density of patches contributes negatively, including heath/bogs. Diversity contributes negatively and aggregation positively, both with significant contributions.

10.4.5 Cluster analysis of parishes

A hierarchical cluster analysis³ was carried out on the first 10 PCs and the dendrogram suggested four or six classes – one of the classes however containing only one parish. Interpretation of this classification was done using plots of the first four principal components. The factor loadings are shown in Figure 10.3 and a plot of PC3 versus PC1 in Figure 10.4. These two axes showed the best separation of parish clusters. From this the clusters could be described as follows:

³Using Ward's minimum variance distance metric through the SAS system (SAS version 8.01)

- Cluster 1 and 2: parishes with low abundance of nature types - cluster 1 however with a little more bogs/heath than cluster 2, and is probably more diverse.
- Cluster 3, 4 and 5 contain a larger share of nature areas. Cluster 5 is dominated by forest with some aggregation and high mean areas of patches and mean edge as well as very high proximity.
- Cluster 3 is the class where meadow/dry grassland areas play a significant role, in terms of amount, mean size and proximity. Forest also contributes here but with lower mean area than in cluster 5.
- Cluster 4 is the only class where ponds/lakes play a role, but the other area types are also present in similar amounts – forest significantly higher. A high diversity predominates.
- Cluster 6 consisting of one parish is dominated by one large bog.

The landscape level diversity (SIDI) is not significantly different in the five clusters and the overall aggregation metric (AI_LA) increases slightly from cluster one to cluster five.

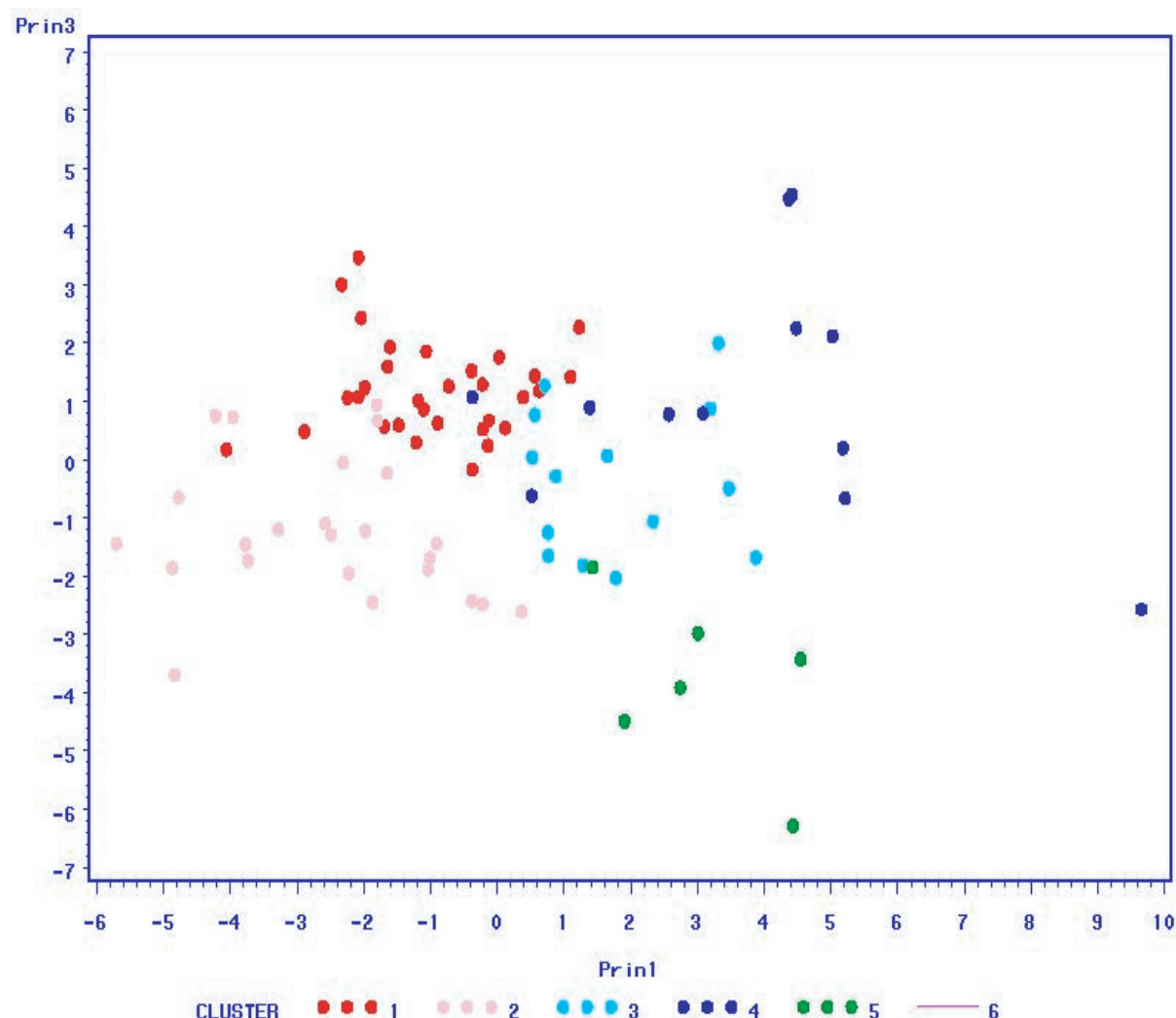


Figure 10.4. Plot of PC3 versus PC1.

Figure 10.5 shows the clusters distributed in the case-areas. It is evident that most of the case-areas show some pattern in the composition of parish-types, supporting the explanatory power of the case-area variable in the multivariate analysis. Case-areas in the southern and western part of Jutland belong to the groups of less abundance of nature areas. This is coincident with rather flat areas with a high degree of cultivation. These clusters are however also found in the north western Jutland where the topographic variation is larger, but where the degree of cultivation is also high. In the eastern part of Jutland and on Zealand, case-areas are quite inhomogeneous and contain parishes with low abundance of nature areas as well as parishes with higher density and diversity of forest, meadow/dry grass and bogs/heath. This indicates that eastern Denmark is characterised by a larger variation in landscape types

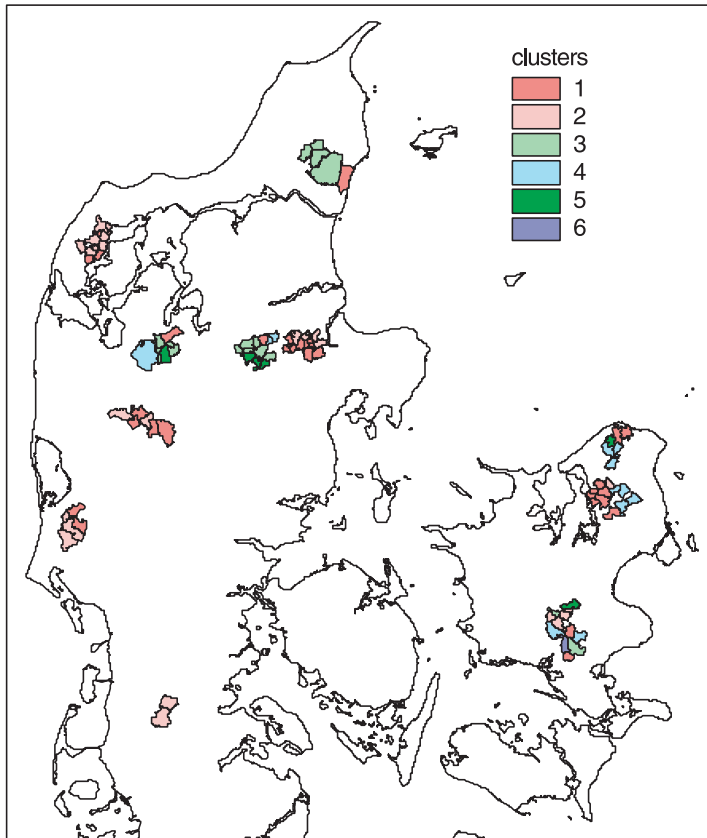


Figure 10.5. Geographical distribution of case-areas, parishes and cluster-allocation of parishes.

over shorter distances. However, this conclusion requires more detailed analyses that consider among others issues, the size of the analytical unit.

Figure 10.6 show details of one of the case-areas, where maps of nature types are showed with their cluster assignment. The Randers case-area is obviously divided into a western part with more nature areas, and an eastern part where nature areas are small and fragmented. Whether the reason is the localisation in a river valley with matching soil types, the closeness of Randers City to the east, a manor-influenced landscape in the western part or a combination has not been fully explored here.

The zoom on two parishes show that the cluster 4 parish has a higher abundance of area types (covering 24.8% of the parish area) than the cluster 1 parish (3.3% of the parish area), but only the first PC separates these two clusters well. They both load positive in PC3 indicating a relatively high content of bog/heath – and a high diversity.

A discriminant analysis⁴ showed, that 83 out of 88 parishes would be allocated to the same cluster, while four parishes in cluster 2 would be allocated to cluster 1 and one parish in cluster 3 would be allocated to cluster 1. As the contents of cluster 1 and cluster 2 are quite close, this is an acceptable result.

10.5 Discussion and conclusions

The applied approach entails some problems. Using a digital vector-based map of parishes in combination with a raster based land cover map introduced an edge effect, as patches crossing the border are cut into minor pieces. The calculation presented here used patches within the parish border without considering this edge effect. This may have serious consequences for the calculated landscape metrics. A future challenge should be to investigate how the metrics perform if computed for a larger area (e.g. a buffer-surrounded parish), followed by a selection of only those patches that are located within the parish border or crossing the border. Moreover the effects of the size of analytical units should be explored more in detail, even if parish sizes in this analysis did not correlate with the included metrics.

There is some redundancy in the data set even if it is not as high as in other studies focussing on the

⁴ Using DISCRIM, NPAR and k=10 nearest neighbours

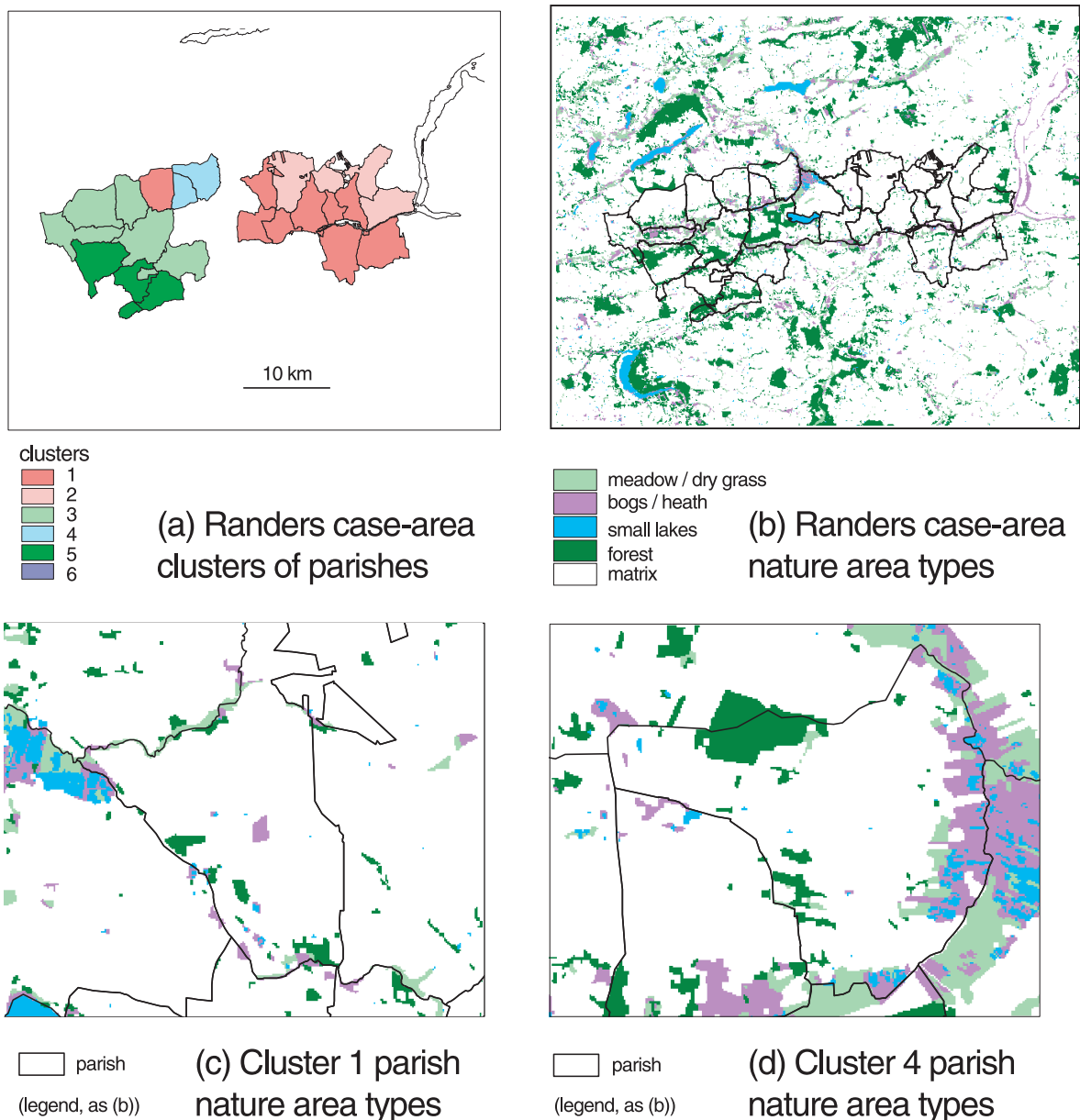


Figure 10.6. Clusters of parishes and associated nature area types in the Randers case-area.

landscape level metrics. It may however be possible to select fewer metrics describing the landscape. The share of total area is a central variable, and some of the other metrics correlate well with this – especially the mean-based metrics like AREA_MN and ME. The Euclidean nearest neighbour, the patch density and the landscape level diversity and aggregation measures seem to correlate the least and thus seem to add new information about the landscape. If such a reduced set of indices capturing most of the variation could be established it might hold some promise for monitoring of landscape change. This study has however used relatively simple metrics, but a broader study may explore the relevance of a few other metrics, focussing explicitly on aspects like connectivity and fragmentation.

The choice of area types in this study was related to the possible impact of agriculture on the types. It turned out that the dominant attribute at parish level is the abundance of the area types and secondly the presence of the various area types. Only then, the structural features entered as differentiating variables, where aggregation (of forest) and diversity seem to play a significant role. This implied that differences in Danish landscapes were captured in these metrics, but that differences in configuration were secondary to the composition in terms of abundance and types. Thus the study did not reveal any significant results as to the sensitivity of the metrics towards differences in structure of the area types, which will need further studies to explore. It demonstrated however that metrics based on remotely sensed data hold potential for development of an approach to landscape monitoring, also in Denmark.

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