Developing policy indicators of agri-environmental public goods

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Foreword; About this paper

The aim of this working paper is to document more in detail a methodology of developing indicators for agri-environmental payments to public goods of the agricultural landscape, and the resulting set of such indicators. Scientific papers have little place for all elements of a study.

The paper presents general findings about indicators and criteria for developing indicators, but also some results from an empirical study where the indicators were tested. For more information about and results from the empirical project, see Hasund (1999b). The study has been financed partly by the EU-project N° FAIR1 CT95 – 274, AEMBAC, and has been linked to AEMBAC (see Hasund 1999a). The study presented in this paper is, however, a project of its own, carried out only in Sweden.

As revealed in the following chapters, the findings of this study are not final results, the optimal methodology or set of agri-environmental payments, but rather a presentation of a first attempt to develop that field for operational use in Swedish conditions. And most probably, the indicators will also have to be refined continuously if applied in policy making. The plan is to publish scientific papers partly based on this working paper, and hopefully also to develop the methodology and the indicators further for policy imlementation.

Uppsala in March 2005

Knut Per Hasund

1. Choice of objects for indicator-based agri-environmental payments

Far from all problems could or should be addressed by the agri-environmental payment schemes and adjoining policy measures. If applying the principles of goal attainment, efficiency, fairness and equity only some clusters of agricultural non-commodity outputs will qualify. They make the delimitations for this study, and may do so in agri-environmental payment schemes aimed to enhance social efficiency. Resource constraints limit the scope even stricter in this study.

The selection of direction and scope applies to which functions, kind of values, indicators and policy measures to consider.

A first delimitation concerns which objects that qualify. Since the study deals with agri-environmental measures, it is only agricultural land that will be considered. Due to the situation in Sweden, a feasible division for carrying out the task to be applied is into:

- arable fields,
  - the cultivated area,
  - field elements: small landscape elements within or along fields, including forest edges,
- permanent grasslands:
  - pastures, and
  - meadows.

The division between arable land and permanent grasslands is motivated by the fact that their values in general are of quite different character, and it is therefore practical to treat them separately. Analogously, the values ascribed to the cultivated area differ in character from those ascribed to the field elements.

The concept “field elements” refers to landscape elements within or along fields, mainly as defined by the law SFS 2000:577, enclosure 5. Open ditches, stone walls, field roads, avenues and headlands are examples of linear elements to be evaluated, while field islets, solitary trees, ponds and cultivation cairns are among the point elements. To be considered as a field element – and not as forest, wetland or some other land category – the point element should be maximum 0.5 hectare.

Permanent wood fringes are also included in the study, while they are not entitled to the present payment schemes. The reasons for including them are that they are important for biodiversity (ecotones), scenic features, etc., and their existence and qualities depend on continued agriculture and management.

Buildings are in general not included, in spite of possibly giving large, positive externalities[1]. None of the principles of social efficiency or PCP would contradict that also farm buildings would be entitled to agri-environmental payments, (AEPs) in a future extended programme, although resource constraints have to be considered. The exception, and to be included here in accordance with the present schemes, are smaller, obsolete field buildings of no present business interest, such as meadow barns historically used in agriculture.

[1] The same could apply for any building, whether agricultural or not.

2. Identification and description of indicators

2.1 General about the agricultural landscape

By Knut Per Hasund, Svante Hultengren, Josefin Kofoed and Helle Skånes

The rural landscape of the village society was once the dominant landscape of the settled parts of Sweden (Aronsson 1980, Sporrong, 1993). Over the last 50 – 100 years it has diminished in favour of a cultural forest landscape based on intensive forestry. Within the old village society, the landscape was divided into two major types, *infield and outland (Sw: inägomark* and *utmark*). The enclosed *infield area* near the farms was mainly composed of arable fields and meadows, although there were also some smaller, special pastures for animals that were too valuable or impracticable to keep distant (Emanuelsson 2001). The *outland* consisted of outfields, rough common pasture, heathland and dense forest, situated further away from the enclosures and settlements (Aronsson 1980). In the transition zone, between the intensively used *infields* and the more extensively used *outland area,* more or less gradual changes occurred depending on fluctuations in grazing pressure and utilisation of the forests.

The major dividing line separating the *infields* and *outland* represented an intangible socio-economic border as well as a physical boundary of fencing systems between different land use types and intensity of land use. After the agricultural land reforms of the 18th and 19th centuries (*Storskifte, Enskifte* and *Laga skifte),* the concept of *infield* and *outland* ceased to exist as an administrative term and is currently only used to refer to remaining fragments of the old village society.

There are naturally big regional differences of the village and farm land structures, but also other agricultural structures. Manor environments are mostly found in more fertile districts south of an east-west line at the latitude of about Uppsala, while säter[2] environments is another example, found in the north.

The complexity of the pre-industrial landscape was high due to variability in physical and socio-economic conditions. Accordingly, the essence of the rural landscape is difficult to contain in one comprehensive term.

2.1.1 Permanent grasslands

Agricultural grasslands are temporary crops on arable land or a permanent land category by itself. Ley on arable land, used for winter fodder or grazed, has little more positive biodiversity effects or landscape amenities than other crops. It is the permanent grasslands that are the major bearers of the large biodiversity qualities, carrying out

[2] A säter is a mountain pasture settlement, common in Scandinavian mountain regions or the vast forest regions from Dalecarlia and northwards.

vital environmental functions. They are of three main types: meadows, pastures, and relics of former meadows or pastures.

Meadows are mowed, traditionally by scythe, but can in addition be grazed later in the season.

Two main types of pastures exist, cultivated pastures and semi-natural pastures. Both types may have highly valued cultural and social qualities, although the largest biodiversity is normally on the semi-natural pastures. There is a classification of meadows and pastures where the categories go in two scales: dry – moist – wet types, and open – wooded types depending which is the dominating tree species. (see Naturvårdsverket 1987b)

Cattle have been the most common pasture animal. Horses were also common, but declining in number with the mechanisation of agriculture. Since a couple of decades, the number of recreation horses has raised drastically to c. 600 000, becoming increasingly important for the grasslands. Sheep play in general a minor role in Sweden, with local and regional exceptions.

The grassland relics from historic mowing and grazing exist as fragments in field islets, along headlands and forest edges or as patches in the forest.

Policy measures directed to grasslands is important because:

- They are *ecologically* important, e.g. in terms of high biodiversity. Grassland vegetation contains some of the most species-rich and diverse habitats in the agricultural environment (Ingelög *et al*. 1993).
- They are *historically* significant due to their former economical importance for fodder production and persistence in time (Sjöbäck 1966). Prior to artificial fertilisers, they were the basis for all long-term agricultural production.
- They may have highly valued recreational and aesthetic qualities.
- They have been decreasing drastic in area as well as in biological quality.
- The market supply of permanent grasslands and their public good qualities is significantly below social optimum. The reason is that new technology and changing relative prices have made much of this land unprofitable for producing agricultural commodities, while their environmental services are public goods. Surveys of how the society values the pastureland and their environmental services (Drake 1992) show a high willingness to pay, motivating much more grassland than what would be provided by the market.

Another policy relevant feature is that grasslands can be *monitored* over time in spatial sources such as aerial photographs and old cadastral maps.

Meadows and pastures yielded fodder in previous centuries also from pollarding, lopping or coppicing deciduous trees (Sjöbäck 1966, Rackham 1989, Austad *et al* 1991). Pollarded trees represent valuable traces of a former, important function of a land use. The most common pollarded trees in Scandinavia were lime (*Tilia cordata*) and ash (*Fraxinus excelsior*), but other species have also been used, such as birch (*Betula pendula*), elm (*Ulmus glabra*) and even grey elder (*Alnus incana*) (Austad & Skogen 1990, Bergendorff & Emanuelsson 1990, 1996, Slotte 2000).

In addition to fodder production, wooded grasslands had a multi-purpose function in the old village society. They provided fuel, and materials for carpentry and building, utilisation which produced and maintained a semi-open environment favourable to many species (Ekstam & Forshed 1992, Hæggström 1992, Bergendorff & Emanuelsson 1996). These spontaneous forest successions on former grasslands are of great interest both for nature conservation and the antiquity sector (Bergendorff & Emanuelsson 1990, Nilsson *et al.* 1994, Eriksson *et al.* 1995).

Semi-natural meadows and pastures are more or less old grasslands that have been subjected to hardly any agricultural interference besides fencing, clearing of bushes and trees, and grazing or mowing. No fertilising, biocide spraying, liming, soil preparations or sowing should have occurred. Ancient meadows and pastures have a long management continuity, somewhere uninterrupted for several hundreds of years, elsewhere a utilisation varying over the time spans in a scale from intense to temporary abandonment (Emanuelsson 2001). Their long grassland history give rise to high botanical values, besides the cultural.

The meadows belonged to the traditional infield (“inägomark”), or somewhere as enclosures in the outland following the old landscape organisation of the Nordic countries. The ancient pastures belonged mainly to the outland (“utmark”) or the commons, the woodlands and the transitional zone of forests (Ihse 1995, Skånes 1996). Many of the old hay-meadows on the infields are today managed as grazed pastures, but have still components showing their origin. (Ihse & Lindahl 2000)

Both ancient meadows and pastures have high biodiversity. The flora is species-rich, and especially the meadows are found to be herb-rich (Norderhaug 1996, Norderhaug et al. 2000). The semi-natural grasslands are one of the most diverse ecosystems in the temperate climate zone. Their biodiversity is very high, and densities of 40 vascular plant species/m^2 are not uncommon (Ekstam et al. 1988). The floristic value, with the high plant species diversity and species density, could be explained according to Grime (1977, 1979). He states that co-existence of plant species in a vegetation society are caused by disturbances and stress. The ancient meadows and pastures are characterised by disturbances from mowing or grazing, and stress from resource deficiency due to nitrogen scarcity. Sustained, long-time management gives a specific disturbance regime, creating a well-developed grass-sward, characterised by high amount of species.

There may also be a rich fauna, including many different groups of organisms, such as butterflies, beetles, amphibians and wading birds. Among the lower fauna, there are many examples of species being connected to certain plant species which only exist in meadows. One example is the endangered butterfly species *Maculinea alcon*, which lives on the likewise endangered *Gentiana pneumonanthe*. Many beetles and birds are dependent on the old growth deciduous trees often growing in the meadows and pastures. Many species are endangered or rare, to be found on the red lists, some of which who were formerly common. (Ihse & Lindahl 2000)

Most of the grasslands are found outside the intensive agricultural plains, where the grasslands have almost disappeared, either because of afforestation or cultivation into arable fields. In these areas, the small landscape elements are of higher importance and will sometimes be the only remaining semi-natural vegetation present.

2.1.2 Small landscape elements

Small landscape elements in arable land, here called field elements, constitute a heterogeneous group of line and point elements, see page 150. The ecological functions of field elements and their relation to biodiversity have since long been of interest to ecologists, because they represent unique habitats, for some species serving as refuges for breeding, shelter or hibernation. They are used as indicators in qualitative landscape descriptions and in environmental indices that analyse landscape pattern and fragmentation (Kienast 1993, Ihse 1995b).

In connectivity theory it is generally accepted that residual ecotones and linear features, such as road verges and ditches, may serve as habitats and dispersal corridors for animal species (e.g., Merriam 1984, Agger & Brandt 1988, Ericson *et al.* 1988, Schreiber 1988, Saunders & Hobbs 1991, Bunce & Hallam 1993, Bunce *et al.* 1994). Recent studies, aimed at quantifying the effects of landscape connectivity and permeability on intensively used farmland, show that most wildlife live in patchy and fragmented habitats, and their future survival is dependent on maintained or increased connectivity between these habitats (Fry 1994).

Small landscape elements, scattered through the intensively managed agricultural areas, often constitute the only remaining semi-natural vegetation (Ihse 1994). In the Danish landscape, characterised by intensive agricultural management, these features are of special interest, since they represent approximately one third of the total habitat for wildlife (Agger *et al.* 1986, Brandt *et al.* 1994). The increasing dominance of large, featureless arable fields and coniferous plantations is also a serious threat to the biodiversity of the agricultural plains of south and central Sweden (Jennersten *et al.* 1993).

The width of the field element edges, as well as the existence of trees and bushes give an indirect indication whether the agriculture is intensive or extensive. The broadest zones of trees were detected by the LIM-survey along water courses, and the narrowest along ditches and avenues. (Ihse & Blom 2000)

According to the LIM-survey, the largest number of *old trees* is found in avenues, semi-open grasslands and in point objects of mid-field islands. Semi-natural grasslands have only a few, about 1 per 10 hectare, while most grow in avenues, more than three per kilometre. Many were also found in the mid-field islands, in every third. Very few have a *sun exposed* trunk, 22%, or cavities, 19%. One third had a wide crown. Only 0.5%–5% had very large trunks and were regarded as very valuable. Most of the old trees, 56%, were instead in the group for future potential old tree giants. (Ihse & Blom 2000)

As a matter of course, many field elements are important for the landscape's cultural heritage, aesthetic and recreational access services, which will be explored below.

2.1.3 Forest edges

Forest edges are of vital importance for the biodiversity, the scenery and the recreational access of Swedish agricultural landscapes. Their importance have increased as the variation of field elements, pastures and mixed, deciduous forests has declined. (Gustavsson & Ingelög 1994; Ihse 1995a)

Why the edges between forest and agricultural land are so vital for the biodiversity is explained in ecological terms of transitional ecotones, including light, temperature, nutrient, humidity and disturbance factors. The simple fact that these forest edges are relatively permanent – compare with clear cuttings inside a forest – opens for the evolution of a richer herb, bush and tree flora. Many lichens, insects and birds are favoured directly or indirectly. (Rizell & Gustavsson 1998)

What concerns scenery and the aesthetic impacts, forest edges are vertical, closing and striking features in a more or less flat and open agricultural land. Their size can be impressive from a human perspective and in comparison with other landscape elements.

The edges' wind shelter effects concern the conditions for biodiversity, agricultural production, forestry and visitors. Increased crop yields or reduced storm damages to trees accrue mainly to the landowners, and should not affect the AEPs.

Forest edges may serve as passage lines through the terrain for hiking and other open-air activities, especially when running between fields with crops and dense woods. The passability depends of the width and the management or vegetation of the edge zone. Providing open views in at least one direction and good localities for flowers and berries, their role for recreation is not to be neglected.

To understand the actual importance of forest edges, one needs to know not only the total length and the perimeter/area ratio, but also their width, content and shape. Historical comparisons of maps demonstrate that the total length and the ratio perimeter /area has declined drastically over the past century. For Sweden in general, the quantitative and qualitative decline of field-forest edges is caused by

- afforestation (where small and irregular fields are over-represented),
- field layout rationalisation implying that the perimeters are straitened out,
- forest expansion from planting trees denser and closer to the fields, and
- reduced management of the edges, with almost ceased mowing or grazing.

The qualities of forest edges may differ significantly. Structural factors are edge height, stratification, depth, density and variation. Three main categories of edges are the trunk edge, the shrub edges and the mosaic edges. Well-developed forest edges have three major zones: the interior, middle and the exterior zones. Naturally, they have different light, wind and humidity conditions with gradients of species. The average three-zonal edge is 10 m deep. Over the last decades they have in many cases been replaced by abrupt and little stratified edges. (Rizell & Gustavsson 1998)

Concerning biodiversity, the quality and the composition of the forest edges and their trees are crucial. Deciduous trees are of high importance, especially with regard to birds, not excluding some bearing also for visual qualities. More than half (54%) of the borders between open land and woods in the representative LIM-project study areas consist of coniferous trees. Deciduous trees could be detected along 17% of the edges to coniferous forests. Broad transition zones that are semi-open with different densities of trees have high potential biodiversity. Only 25% of the borders have these potentials, while most borders are very narrow and sharp between dense conifer stands and the cultivated soil. (Ihse & Lindahl 2000)

2.2 Biodiversity

By Knut Per Hasund, Svante Hultengren and Helle Skånes

Biodiversity is a complex and controversial concept. Nothing will be added to that debate here, just reminding that biodiversity is defined by the Convention of Biodiversity to “include diversity within species, between species and of ecosystems”. In the search to identify the biodiversity qualities, the aim of this text is to give a short background on which features in the agricultural landscape that are important for that task. Its first part is about where to find biodiversity: which physical factors or objects can be used to – indirectly – describe the presence of biodiversity. The second half is pointing out the prospects of using key species for identifying biodiversity in a wider sense.

High biological diversity of a given, agricultural area does not necessarily mean the highest possible number of species in a statistical sense. It could rather be that numerous species dependent on grazing, mowing and traditional agricultural practices are present. High biological diversity can also signify that an area contains one or many populations of redlisted species (Gärdenfors 2000, Arvidssson & Thor 1999, Hallingbäck 1998, Larsson 1997, Aronsson 1999), but also that many different habitats such as grass swards, old deciduous trees, ponds and wetlands, wooden and stone fences, and arable fields are present. ”*Good grassland management*” is another quality related to whether or not a natural pasture is sufficiently grazed or mowed to give high biodiversity. Cattle are supposed to eat away the overproduction of natural grass and herbal growth, giving space from a few, trivial and dominating species to a multitude of specialised or demanding plants, with accompanying invertebrates. The quality ”*Traditional types of land use*” are in Sweden mowing for haymaking, and grazing on all types of pasture. ”*Diversity*” in general alludes to the variation in terms of different types of habitat and structures in the agricultural landscape.

Biodiversity factors

Which physical objects or factors express the biodiversity of agricultural landscapes?

Areas of special interest for nature conservation in the agricultural landscape are those that:

- are diverse and rich in species and are inhabited by rare or declining plant and animal species that are favoured by grazing and mowing, or
- still have substantial biological qualities connected to traditional land use of the region. These areas represent a very long continuity in land use and host large biological values in terms of species, habitats and elements.

Permanent grasslands, deciduous groves, and small landscape elements are the key elements that mostly are pinpointed for high biodiversity in the rural landscape by Swedish landscape research and nature conservation (Emanuelsson & Johansson 1987, Ingelög *et al.* 1993, Ihse 1993, 1995a, Skånes 1996, paper II). The small landscape elements (described in chapter 2.1.2) important for biodiversity include, for example, mires and some kinds of old trees. However, biodiversity is a relative concept going far beyond species diversity. At the landscape level it is also a question of considering the every-day landscape surrounding the isolated islands of high diversity as important in the sustainable maintenance of overall diversity.

The main properties of landscape structure that are important in the dispersal of species are the area of, and distance between, biotope sites, the presence of corridors, and the barrier effect exerted by unfavourable conditions (Opdam 1991). Three principal factors can be distinguished as crucial for species survival and biodiversity at a landscape level: 1) the size and quality of a habitat patch; 2) the number of patches; and 3) the impeding effect by the surrounding landscape (Kalkhoven 1993).

Although biodiversity cannot be measured in absolute figures with a retrospective method, the prerequisites and major conditions for it can. This is possible using the attributes visual in spatial data, mainly structure and composition (Skånes 1996, paper I). Consequently, *potential biodiversity* is suggested as a sufficient approximation of real the biodiversity level. This is possible by means of using the indirect attributes, visual in spatial data, mainly structure and composition. Vegetation governs animal diversity and is itself governed by the diversity of the abiotic environment (Noss 1990).

From the purpose of nature conservation and biodiversity it is possible to allocate different values to the different features, giving a description of biotope quality. *Semi-natural, unfertilised grassland, meadows and pastures* are particularly interesting, as they contain a species-rich flora and fauna (Ihse & Blom 2000). The ecological significance of grasslands is dependent on their respective type, natural conditions, land use history, and intensity of management regime (Bengtsson-Lindsjö *et al.* 1991).

Semi-natural grasslands are the most species-rich vegetation communities in Sweden (Ingelög 1988, Svensson 1988, Ingelög *et al.* 1993). Cultivated grasslands improved through tillage or the use of artificial fertilisers, have a lower potential for species-richness and variation than semi-natural grasslands (Glimskär & Svensson 1990, Hansson 1991). However, it is important to stress the fact that although improved grasslands may lack the species-richness of the semi-natural grasslands, they may be of high cultural historical value and represent less visible but important components in habitat configuration for many species. Present-day pasture enclosures frequently comprise a composite of arable land and grasslands, with abiotic as well as biotic structures preserved from the past (Skånes 1996, paper II). This turns grasslands into key elements in the study of biodiversity at the landscape level.

The status of *management* is most interesting in semi-natural grasslands, unfertilised and with *long continuity*, since the flora as well as the fauna could be expected to be very species-rich and diverse here. Management by hay cutting is necessary to maintain the values of the small biotopes. When the pastures grow with bushes and deciduous trees in the first stage of succession to woods, the flora and fauna will change considerably and the characteristic species disappear. (Ihse & Blom 2000)

Field elements – or small biotopes – are very important for the species belonging to the agricultural landscape. Mid-field islands, stone mounds, stone walls, verges along roads, watercourses and ponds are real or potential corridors for connectivity and dispersal. They are also biotopes and refuges for the flora and fauna of semi-natural grasslands of meadows and unfertilised pastures, former widely dispersed. The width of edges is important in estimation of potential biodiversity as they could be habitats as well as dispersal corridors for many species. They may also have an important function as buffer zones along watercourses and increase nitrogen retention. (Ihse & Blom (2000)

Old trees with large trunks have a certain intrinsic value, but they are also habitats for a large amount of other species, using different parts as habitats. Trees with *cavities* and *fissured bark* offer a wide selection of habitats for many species. Old trees are stationary and have thus provided opportunities for many species with slow dispersal rates to establish themselves. Dead wood is habitat for many insect species, bryophytes and lichens. *Sun exposure* and *moisture* are important factors. (Ihse & Blom 2000) Such old trees with a high potential for biodiversity are here defined as "biorich trees", see pp 148 and 82.

The amount of *dead wood* indicates changed conditions and potential biodiversity for many insects. Sun exposure is a variable that can be used indirectly to describe habitats for many species, not being able to control temperature, and for many cryptogams. Changes in the amount of open and sun exposed areas give an indication of changed habitats for such species. (Ihse & Blom 2000)

Identifying biodiversity by confirmation species

Some species tend to occur together forming associations. This is the reason why some species nearly always are followed by others – that also may be rare or redlisted species. Analysis has shown a good correlation between species occurrence for some species groups, so called ”nested species subsets”, especially for lichens and mosses (bryophytes) in forests (Gustafsson et al. 1999). This has given rise to the concept of NSS-values (Pattersson 1987, Sjögren-Gulve 1999) for different species.

The useful concept of ”Confirmation Species” (”Kvittensarter”, Cederberg 2001) has been introduced recently. ”Confirmation species” are suggested to be used as measures (presence or abundance quantified) of the success or ”conformation” of a successful management. This kind of species is often quite rare and includes redlisted species. They are useful for the confirmation and follow-up of conservation management and are recommended for monitoring by the local landowner or by the staff of the environment unit of the county administration. An effort to develop confirmation species as biodiversity indicators is presented in Table 32 and pages 86- .

2.3 Cultural heritage

By Knut Per Hasund, Svante Hultengren, Josefin Kofoed and Helle Skånes

Most of the Swedish ancient monuments are found in the agricultural landscapes. They indicate cultural values and give invaluable information on the social conditions in earlier societies, the settlement patterns and how the resources were used. The monuments are traces from a long historic time, important for understanding the landscape of today. According to the LIM-study, about fifty percent of the monuments were visible in open cultivated or grazing land or in mid-field islands in 1961. In 1993 only 15 % were exposed in open areas, while most of them (85%) were hidden in woods or in grazing land, reverted to scrub. All monuments on mid field pockets were preserved. (Ihse & Blom 2000)

The cultural criteria describe different type of structures, created from different land use, such as a) elements from grazing practice, b) elements from fodder collection for livestock, c) elements from farming and archaeological sites, buildings, and transportation. Even if the main focus is on the living heritage, the vegetation and flora, fossil, relict or recent remnants and traces from historical land-use are important. All forms of land use make imprints in the landscape, and leave structures, which help to explain the composition of flora and fauna. They also help to explain agricultural history, tradition and management, and thus give indications on how to maintain and manage the ecosystem of ancient meadows and pastures. (Ihse & Lindahl 2000)

The cultural heritage qualities are connected to the more than six-thousand-year history of grazing and cultivation. These grasslands are thus a living archive of the oldest used land, and these values are closely correlated with the botanical values. Some of the cultural heritage qualities are historical, with many traces of the old traditional land use and management. These remnants show how natural resources were used, how grazing was practised, how winter fodder was collected, and how buildings and settlements were situated and related to the land use types. These cultural traces are thus an important knowledge bank, and important for understanding the development and growth of the cultural landscape in Sweden and the other Nordic countries (Ihse and Norderhaug 1996; Ihse 1996).

Classification of cultural functions and values

The aim of this section is to deal with the cultural aspects of the agricultural landscape. The term “cultural” shall here bee seen in its broadest sense, which means that it does not merely involve certain remaining objects in the landscape but includes every phenomenon in the landscape as a whole. There is in fact nothing in the agricultural landscape that cannot be seen as including a cultural influence, that could be ascribed a cultural value. The agricultural landscape is one of the most basic products of human activity. This means that culture is an important factor in the very definition of the agricultural landscape as a phenomenon.

The overall cultural function might be expressed as a *cultural meaning*. Cultural meaning concerns the feeling of belonging and recognition in relation to the landscape. This can be divided into different aspects, such as an aesthetic aspect, symbolic aspect, pedagogic aspect, continuity, etc. The classification of different aspects shall be seen as both rough and vague, and one should be aware of the intersection between them.

In the text below, various sets of criteria for identifying cultural historic values are presented, as well as physical phenomena that are declared to be carriers of cultural values. All sets are compiled from the literature or official documents, which makes the presentation summary and compressed.

Within the LiM-project, that study the landscape situation by aerial photos and field surveys in 20 reference areas throughout Sweden, these features are used for describing the cultural historic values:

- Agricultural buildings
- Infields with long continuity
- Linear elements such as fence systems and other traces of former land use
- Cultural remains
- Natural pastures

The main threat was described as losses of original functions, which often causes discontinued maintenance (SBA, 1998).

The Norwegian Institute of Mapping of Agricultural and Forest Areas is currently working with a program called the 3Q program. It aims at mapping the current changes in the agricultural landscape (www.nijos.no), using the criteria in the boxes below as indicators for cultural and social functions and values (Brandtzaeg 1998):

Structure of land use

Amount and distribution of different kinds of land use

Fragmentation of different kinds of land use

Length and distribution of different kinds of edges

Amount and distribution of islets

Cultural remains

Amount and length of old stonewalls

Amount and length of old roads and paths

Amount of intact and …?

Amount of old buildings of different kinds

Amount and distribution of burial cairns, burial mounds, mounds of stones, ?? and ruins.

Accessibility and experience qualities

Amount and length of paths for transportation

Index for possibilities to make tours

Assessment of roads an urban areas

Extent of the total area that is assessable for transportation

Index for the extent of visual entirety in the agricultural landscape

Index of diversification, expression of the amount of different types of land use in a landscape

Index for heterogeneity, expression of the distribution of these

Another agricultural historic survey, by Tollin (1998), concerning the county of Halland in the south-west of Sweden, also uses physical phenomena in the landscape for identifying its cultural values, as exemplified in the boxes below:

Graves Gates Ancient court areas Cholera graveyard Traditional agricultural buildings Buildings of regional uniqueness Mills Windmills Bridges Shelter-belts Village borders Allotment borders Parish borders Stone walls Tree fences Earth banks Infields	Former arable land Pastures Coastal pastures Dry hay meadows Wet hay meadows Hay meadows with pollards Elderly parish centre with traditional and typical buildings Coastal villages with elderly cottage buildings Manorial estate environment Changes in the land use and structure of the landscape that is possible to apprehend Pollards Ancient fields	*Ancient remains such as*: Dolmens Tombs Grave mounds Burial fields Carvings Paintings Inscriptions Runic stones Mile stones Boundary stones

The Swedish Board of National Antiquities have stated these criteria for identifying cultural historic values:

- Continuity
- Quality
- Pedagogic value
- Uniqueness – representativity
- Patina
- Identity value
- Traditional value
- Symbolic value
- Genuineness, realness

(Unnerbäck, 1995)

Due to the recommendations by Swedish National Environment Protection Agency (Naturvårdsverket, 1991), areas of special interest for conservation of the national cultural heritage (values) are those that:

- represent the agricultural colonisation of Sweden, ranging from the pasture areas where the megalit-culture started, the central areas of the iron-age where an agricultural organisation with arable fields and meadows was created, through the farmland expansion when small villages where constructed and the medieval colonisation of the outback, to the 19th and 20th century when the northern parts of Sweden were colonized,

- represent the traditional agricultural farming systems, where land use was characterized by a strong connection between arable fields and the breeding of cattle. In those days the farmland was divided into infields and outland (Sw: inägor and utmark), where the infields and the farm buildings formed the core of the agricultural activity. The traditional farming system is represented by different types of agricultural land, fences, borderlines, stone piles and other attributes and elements, reflecting different historical epochs.

- are regional examples of different agricultural systems. During the ages these have evolved along with the natural conditions, but their present state may reflect cultural heritage and the development of agriculture.

Elements in the agricultural landscape that are recognised as carriers of cultural values and that have been eligible for agri-environmental payments are:

- Open ditches
- Headlands between arable fields
- Earth walls
- Field roads
- Stone walls
- Wood fences
- Shelter plantations
- Tree rows, bush rows, hedges
- Cattle lanes, fenced by stone walls
- Cattle lanes, fenced by wood fences
- Stone cairns
- Sites of ancient monuments
- House foundations, ruins
- Wells, springs
- Alleys
- Solitary trees
- Rows or hedges of lopped trees
- Pollards
- Marl-pits, flax ponds, constructed dams
- Field islands
- Obsolete farm buildings
- Small fields, difficult to cultivate
- Traditional hay-drying racks or large hay-drying racks still in use

(Ministry of Agriculture. 1999)

2.4 Other agricultural landscape values

By Knut Per Hasund and Josefin Kofoed

Many values besides biodiversity and cultural historic values are ascribed to phenomena in the landscape that would qualify for agri-environmental payments if applying the criteria of social efficiency and Producer Compensation Principle, PCP. These values can be classified into *cultural* and *social values* of various kinds. Categories often used include:

- aesthetic values, beauty, scenic values,
- emotional values of intimacy, openness, sublimity, freedom, etc.
- national, regional and local identity
- religious, moral and spiritual values
- access for recreation
- health values

Most of these values can be considered as immaterial assets, although founded upon physical objects.

Aesthetic qualities, especially of some rural landscapes, have inspired artists as painters, photographers, film producers, authors, poets and composers. To some little extent, these values are expressed in the market economy, although their public good character make them positive externalities. The meadows and pastures have also been an inspiration to fairy tales and folklore. However, perhaps the largest aesthetic values appear as direct values ascribed by landscape visitors or as a view for travellers, residents and workers in daily life. There is at least empirical evidence that they are considered as important, appearing to account for about a third of the values that the Swedish population in general ascribe to agricultural landscapes, according to a CVM-study by Hasund (1998).

One social – or even psychological – value is national, regional and local identity. In the minds of many Swedes, much of the identity of the home district is connected with nature and the landscape. Likewise may many individuals' personal identity be developed and experienced in relation to their surrounding agricultural landscape, their "roots", who they are or see themselves as.

Recreation, tourism, artistic work, education and research are examples of *activities* in the landscape that may give rise to values. Goal values arising from these activities are the aesthetic, emotional, health values discussed here, but of course these could be accounted also in relation to the activities, as recreation values, etc.

Touristic landscape values evolve – in a welfare economic perspective – when the visitors ascribe values that could be derived from the physical landscape. A part of these gross values may go the tourist as a net benefit from the trip, while the other part goes to cover costs for it. Hotel owners, bus drivers and other get revenues that give them income values and means to cover their own costs. Hence, touristic values partly go to the visitors themselves as for any recreation practiser, other values fall on service people contributing more or less to the local economy. In both cases they are almost entirely positive externalities, although a part of the values are expressed in the market economy and the GNP. The tourist image of Sweden is to quite some extent based on the landscape of meadows and pastures.

Recreation in the Swedish agricultural landscapes involves hiking, rambling, skiing, picnics, the picking of flowers and berries, children playing, riding, hunting, etc. as in all European countries. Specific to Sweden would, however, be some tastes, habits and institutions. For cultural and historic reasons, at least many native Swedes have relatively high preferences for rural recreation. Cross-country skiing and riding are popular and extensive in an international comparison. Hunting is also giving large values, but these are not motivating agri-environmental payments since they are related to private goods belonging to the landowners, whether hunting or selling hunting licences. Enhancing the values of the Swedish landscapes significantly is "allemans-rätten", the ancient law of open access to almost all land[3], giving everybody the right to walk, camp for one night, pick flowers and berries, etc.

Pre-Christian beliefs and popular beliefs fairly widespread until the late 19th century could ascribe religious or spiritual values to specific places in the landscape. As Christian and modern outlooks have penetrated the culture such values have become more obscure. A common moral standpoint, not the least among farmers, is that it is a sin not to use arable land for cultivation, and even a worse sin to destroy it, giving arable land some kind of existence values.

Health values may arise from physical activities in the landscape as demonstrated by plenty of medical studies. It has also been demonstrated that people in general recover from illness faster by just passively being in a natural environment (Grahn 199X).

Factors and criteria for identifying socio-cultural values

Lynch´s work within the field of landscape analyses is considered as one of the key-stones in the discipline of landscape architecture. His survey concerning people's experiences of their hometown, is probably his most well-known and frequently used work (Lynch 1960). The survey was done on the urban environment but the fundamental features of his results have been used also for other types of landscapes by for example Elfström (1991). The phenomena in the landscape identified by Lynch are:

- Paths
- Edges
- Districts
- Nodes
- Landmarks

Paths are lines apprehended in the landscape or the routes which people are moving along. *Edges* are linear elements like borders or barriers. *Districts* are more or less homogenous areas that are experienced as an entity. *Nodes* are strategic points like for example the core of a district. *Landmarks* are easily observed reference points to which is it possible to navigate in the landscape. What separates theses phenomena from the ones previously mentioned is that they describes the visual relationship in between the phenomena instead of focusing on the object meanings in them-selves.

[3] The law does not apply for motor vehicles, nor for private gardens, fields with growing crops, military grounds and similar exceptions.

Elfström (1991) has described the landscape out of its visual identity. The work is done at the landscape scale but includes both the object and landscape level. He has expressed some often-used criteria for valuation of the aesthetic aspects of the landscape:

- Variation
- Representativity
- Uniqueness
- Water contact
- Contrast
- Spatial variation

Elfström has a point of departure that beauty is highly individual and dependent upon the current paradigm of society and thus question the tendency to scientifically measure and value beauty.

An overall description of the values connected to the landscape from a cross-disciplinary viewpoint is made by Gustavsson (1994). From the perspective of landscape scenery his work deals with the phenomena and criteria listed in the two boxes below:

Richness in variation	Scale
Accessibility	Patterns
Grown old and elderly	Contrasts
Landscape that reminds us of our history	Framing
Character of nature	Mobility lanes
Bright landscapes (open fields, deciduous forest, birch, aspen, pine)	Visual lanes
Flora and fauna that is rich in species	Mental lanes
Flowering landscapes	Connection
Signs of social status and care	Grouping together
New components in the landscape	

Rapaport and Snickar (1999) have worked with social indicators in connection with the EIA process for road building. Their objective was to develop a strategy to integrate the environmental, economic and social factors in the early stages of the road building process. Indicators such as expert based selection of historical values at both the object and structural level are used, but not exemplified. Contrary to the previously mentioned works, they have had a quantitative approach for their indicators.

3. Aim of the indicators

The indicators are intended to serve the implementation of the landscape policy, especially the agri-environmental payment schemes. These payments aim at internalising the positive externalities of agriculture, such as scenery and biodiversity.

The idea is that the object indicator values should be used as direct inputs into the application of the policy. In other words: the payments will be based on the values that the indicators take. If, for example, there is in some respect a good change in a pasture, an indicator is supposed to reflect this change and take a higher, “better”, value. This should in the next step enhance the payment to the farmer. Hence, a value based landscape policy will be formed by linking the policy instruments to the values in the landscape through the indicators.

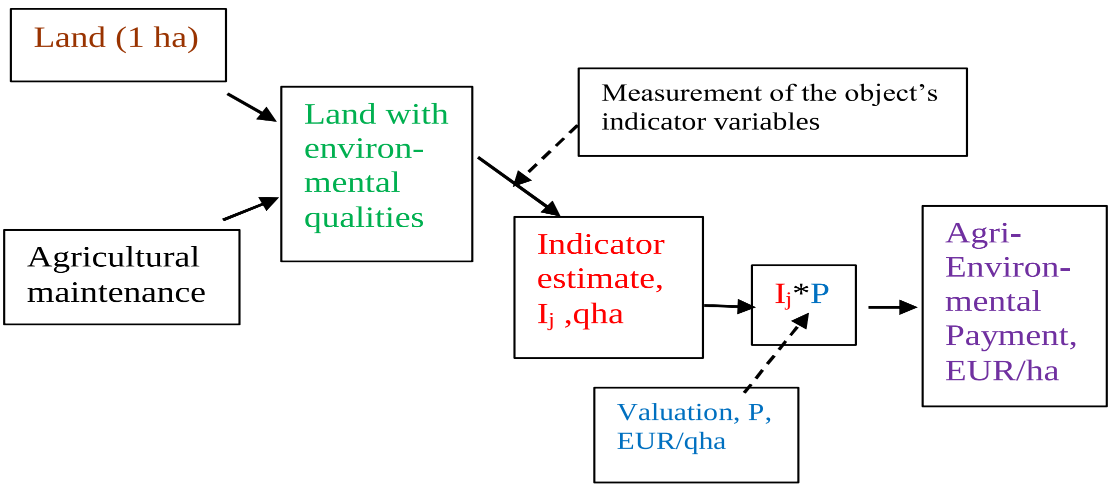


Figure 1. The operation of Indicator Based Agri-Environmental Payments

As the task is to develop a system of indicators that could be used as direct inputs into the implementation of the agri-environmental payment schemes, the indicators should indicate the state as well as significant changes, whether positive or negative.

In short, the task is to develop indicators that are operational in the everyday work of landscape management. The indicators have to be operational to the farmers or the officials so that they could apply them when making or modifying contracts, when adjusting the payment levels, or when deciding upon management practices. It implies that the indicator values should be reasonably easy to measure by field inspection or by remote sensing (air photography). More about the criteria for developing indicators is found in chapter 0 below.

Indicators are developed for two levels: the landscape level, as exemplified by the study areas, and the object level. At the landscape level the indicators serve the aim of monitoring the overall state and effects of agriculture. If there are indications of a non-sustainable situation or trend, there may be a demand for strengthening the policy measures in the region. The *landscape indicators* are thus directed to the politicians and civil servants. The aim of the *object indicators* is twofold. They should allocate the agri-environmental payments efficiently, that is, according to each objects value. They should also provide economic incentives to farmers to maintain or improve the qualities in the landscape. It is thence necessary to direct the measures to each object: each field, pasture or field element. See chapters 6.2 and 6.3 for more about respective indicators.

4. Methodology for developing indicators

An impression when studying indicators in operation or the literature on indicators is that they often seem to be designed and chosen on vague grounds. Also when assessed, the design and choice process often show to have been more or less by chance or intuitive. This does not necessarily mean that the indicators are poor, but the costs for developing the indicators may have been unnecessarily high in terms of time and other resources. What may be worse is that the methodological shortcomings will in some cases entail that potentially better indicators are not developed or implemented.

The process of establishing indicators may be more or less elaborated. Usually it involves a series of steps which can follow a planned structure (/methodology) or be more tentative or ad hoc. See, for example, Jesinghaus (1998) who presents the fourteen-step process of the Eurostat Environmental Pressure Indices Project. This chapter will not give an overall methodology, but rather focus on two steps of the process. In accordance with the request for further development advertised by OECD (1997), the aim of this paper is to root and strengthen the design and choice of indicators as concerns the use of criteria.

Indicators are not "identified", "found" or "picked", as the literature often convey the impression of. Indicators are constructed, created, designed. The following text start from the premise that indicators are aimed at serving as means for improving specified conditions by decision-making and actions, including policy making, and specifically here the agri-enviro programmes. The indicators have two purposes, to identify conditions that would be desirable to address by policy measures, and to reflect policy impacts (the feedback function). In order to develop a methodology for developing such indicators, the text will follow three levels of analysis:

- Criteria with Indicator verdicts
- Indicators with Indicator values
- Variables with Data on variables

If assuming that there is some kind of "reality", the first level of abstraction would be to distinguish phenomena, identify them as concepts and define them as variables. By measuring these variables (whose realisation may be quite controversial) we get data. A higher level of abstraction would be the indicator-level. The indicators serve one or more specified functions, and could be composed of several variables or a single one. What distinguishes an indicator from any variables is that it is designed and chosen to serve those specified functions.

To be able to develop Best Policy Indicators, BPI, we have to assess alternative, candidate indicator variants, indicators, or sets of indicators. The assessment requires, of course, criteria. It will in turn require meta-criteria, for the choice of criteria. The systematic use of criteria fits in the general methodology for designing a system of indicators that includes the following major moments:

I) Identify a) purpose of the indicators, and b) the policy objectives
II) Choice of indicator criteria
III) Generation of candidate indicators
IV) Assessing candidate indicators according to criteria
V) Selection of indicators
VI) Implementation, Monitoring, Application
VII) Revision

4.1 Purpose of indicators

Policy motivated indicators serve two major functions. They should provide information for identifying problems that may be required to attend to by policy measures, in our case the agri-enviro policy. This may be called *The Warning Lamp Function*. Another major purpose would be to monitor the impacts of the policy, a feedback function with the purpose of policy revision. This may be called *The Policy Gauge Function.* An overall function, common to the warning and feedback functions, is that the indicators should provide information.

Firstly, a distinction between environmental indicators and policy motivated indicators[4] is called for, since they differ in aims and character. Environmental indicators are mostly used as a concept synonymous to environmental parameters, or as a representative aggregation of data on some environmental phenomenon. Such a connotation is in line with the definition by the US Council on Environmental Quality. Policy motivated, or socio-ecological indicators on the other hand, aim at information and foresight for possible decision making, and are consequently not as restricted to solely represent symptoms and effects (Holmberg & Karlsson 1992, p. 91). This ambiguity in the terminology is a source of confusion in the communication between biologists and other actors. In this paper, the term *indicator* stands for policy motivated indicators.

The overall function of indicators lies in providing relevant and potentially useful information. Human welfare and the environment are interrelated to policy, agriculture and other sectors in a most complex web of causes and effects. Spatial variations and temporal properties, such as lagged, gradual and cumulative effects, further complicate these linkages. A primary purpose of indicators is to increase the understanding about the system and its trends by revealing and quantifying these linkages and communicating the most relevant information in a comprehensible form (cf. OECD 1997, p. 9, 15; Jesinghaus 1998, p 9). The receivers may be the general public, experts, politicians and other decision-makers (Jesinghaus, 1998, p. 13; Reid et al., 1993, p. 3). However, indicators alone are not sufficient to show the causal linkages, although a necessary component of an analysis to explain the empirical relationships between the environment and the factors that may influence it (Reams et al.,1990, p. 1248). Indicators are useful tools, but only one tool among others (OECD, 1994, p. 13). Indicators should thus improve communication about the problems by which the results of measurement are provided, and make the debate more transparent (Gouzee, 1996, p. 15; Jesinghaus, 1998, p. 9; OECD, 1994, p. 9). Besides giving conditions for better

[4] The term *socio-ecological indicators* is frequently used for this type.

decisions, improved information and communication may improve democracy and make the decisions better supported and stable (Jesinghaus, 1998, p. 10).

Simplification is a key information role for indicators (Gilbert & Feenstra, 1994, p. 254). Highly aggregated indicators are needed to communicate the most relevant information without inundating the users with details (Jesinghaus, 1998, p. 9), but the benefits of giving a general survey have to be balanced against loosing information by too far-reaching aggregation. Indicators are supposed to be significant, in the sense that they are central accounts of states or trends, beyond what is directly associated with parameter values. A two-sided concentration can be achieved when focusing on factors of crucial importance for sustainable development and when stressing the essential parts of our influences on nature (Holmberg & Karlsson, 1992, p. 91). By reducing the number of variables that need to be monitored, and by providing spatial and temporal averaging of environmental conditions they furthermore reduce costs (Landres, 1990, p. 1296). As concerns information, indicators may highlight social or environmental problems and emphasise them on the policy agenda.

The Warning Lamp Function is about monitoring the state and detecting changing conditions and trends of the environment, the agriculture or other parts of society. In providing information for identifying problems, risks and benefits, the indicators in a primary stage serve to alert decision-makers and initiate action (Gouzee, 1996, p. 15; OECD, 1994, p. 8; OECD, 1997, p. 11)(Bastian & Lutz 2006). Given a general warning function, it is to be noted that indicators should not just indicate when apprehensions become verified, but also have a potential to alarm when yet unknown problems arise. By reflecting some alarming state or change of a key variable, directed investigations may then further elucidate the causes and possible counter-measures.

Indicators may facilitate decision-making and give more informed decisions throughout all of the policy process. They may get an important role in all stages from notification of possible problems to contributing to the formulation of local and regional environmental goals, determining priorities for action, mobilisation, legitimisation, planning, allocating resources, guiding policy formulation, integrating environmental concerns into sectoral policies, economic policies or national accounting, improving the targeting of programmes, implementation and policy assessment (Gilbert & Feenstra, 1994, p. 254; Gouzee, 1996, p. 15; Holmberg & Karlsson, 1992, p. 89, 91; OECD, 1994, p. 8; OECD, 1997, p. 11; Reid et al.,1993, p. 3, 31; Jesinghaus, 1998, p. 15)(Bastian & Lutz 2006).

The Policy Gauge Function, or feedback function, refers normally to the use of indicators for assessing the overall performance of a given social institution. More specifically, it may imply measurement of environmental performance and evaluating how well the authorities are doing in their efforts to implement their domestic environmental policies and international commitments. Included in the task is to help determining if goals and targets are attained and clarify where problems exist in the current policy framework (Gilbert & Feenstra, 1994, p. 3 254; Nilsson & Bergström, 1995, p. 176; OECD, 1994, p. 8; OECD, 1997, p. 9, 11, 49; Reid et al., 1993, p. 3). As Verbruggen and Kuik (1991) emphasise: “Unless there is some clear measure or at least some indicator ---, the effectiveness of environmental or other policy towards this goal can not be assessed”. Indicators should further, according to Reams et al. (1990), be an integral part in the measuring of program effectiveness. Another object for evaluation, pointed out by Jesinghaus (1998), is that indicators enable the public to judge the performance of their elected candidates.

What is optimal, as concerns the choice of criteria, then depends on how the policy objectives are stated. These should be identified initially in the process. Effects and conditions can be evaluated by indicators only if the objectives are operable.

With this background of indicator purposes in general, developing an indicator or a system of indicators in a certain situation should, following the methodology presented on pages 6 above, start by stating the purpose of this actual case. Stating the purpose involve to decide upon function, generality, target group, and duration. Are the indicators mainly aimed at signalling for defined threats, or to contribute to the public debate? Do they have a continuing, long-term purpose of warning when negative environmental conditions arise, or will they primarily be used as tools for evaluating some policy measures?

5.1 Definitions, classifications and categories of indicators

The OECD (1997) definition of an indicator is: "A parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon /environment /area with a significance beyond that directly associated with a parameter value". A common definition state that indicators are key statistical series that serve policy forming, while for example Nilsson & Bergström (1995) restrict it to be "performance measurements". Another general description is that indicators are quantitative descriptors or simplified representations of a more complex reality (Opschoor & Reijnders, 1991; Jesinghaus, 1998, p. 30).

The terminology that will be used here is in line with the general OECD definition. As emphasised above, indicators are distinguished from any of variables by being formed and chosen to serve policy objectives. Indicators are thus operationally defined by the purposes discussed in the previous section. The indicators could accordingly be described in *The Indicator Tree*, having the four levels:

- indicator systems
- core indicators,
- subindicators, and
- pre-indicators.

Indicator systems are composed of a set of core indicators that together should cover the essential aspects, according to which aims that have been stated. A core indicator may be a composite of sub-indicators, who sometimes may be interesting in themselves. For example, the core indicator "Income" may be derived from the sub-indicators "Farm revenues", "Farm costs", "Off-farm salary", etc. The indicators are derived by transformation, aggregation and integration from pre-indicators, that is, from variables, generic figures and data sets that are judged as less useful as indicators in themselves. Note that an alternative to systems or sets of multiple indicators could be to aggregate the core indicators even more into a single index.

In the development of operating indicator systems, it will be crucial what type of indicators that will be adopted. Choosing type of indicator is the first step in the indicator design and selection process. A deliberate choice of indicator types or combination of types could be based on: what are the purposes of the indicators, what is the character of the problem, which financial and other resources are available, and which qualities of the indicators that are requested (see section 5.2 about criteria below).

There are numerous types of indicators described or advocated in the literature. The most widespread is the OECD-typology of driving forces, state, and response indicators. *Driving force indicators* reflect those elements which cause changes in the state of the environment. These include natural processes and factors, as well as economic and other societal driving forces. The latter factors encompass changes in technology, cultural attitudes, social structures, population growth, market behaviour and government policy. *Pressure indicators* are a sub-category describing pressures on the environment caused by human activities, such as nitrogen deposition in kg N/ha/y. *State indicators* refer to the conditions or changes in conditions of the environment. It concerns indicators on ecosystems, natural resources or health and welfare. *Response indicators* reflect reactions to the environmental changes by consumers, producers and the authorities or policy system. See OECD, 1994, p. 9 - 15 and OECD, 1997, p. 14 – 18 for further information. A more developed typology is used by Eurostat in the Driving force – Pressure – State – Impact – Response model with a set of indicators corresponding to each of these phases, where *impact indicators* describe the ultimate effects of changes of state. The number of people suffering from cadmium-induced kidney damages is an example (Jesinghaus, 1998, p. 6).

The driving force, state and impact indicators can be highly relevant as an input for policy purposes, the warning and the feedback functions, while the response indicators would be less interesting.

Braat (1991, p. 59) distinguishes between indicators for scientists, for policy makers, and for the public, where the latter are the most condensed and communicate a smaller quantity of information while indicators for scientists are the most detailed.

Depending on the aim of the indicators, they can be geographically defined or not. It is also common to direct and then classify indicators by environmental issue, which resource or which process they illustrate. Examples of resource indicators are land, water, atmosphere, landscape, and biodiversity indicators. Examples of process indicators are deforestation, erosion, desertification, pollution, waste disposal, eutro-phication, acidification, and ozone layer depletion indicators. Cross-tabulating such classes of indicators with the driving force – state – impact classes of indicators may give large sets of indicator categories. OECD presents, for instance, a structure of indicators where 14 major environmental issues are combined with the three pressure, state, response classes, giving a total of 42 categories of indicators. (Gouzee, 1996, p. 21; OECD, 1994, p. 12)

A classification of indicators discussed by Braat (1991, p. 65 – 68) distinguish between 1) predictive indicators and 2) retrospective indicators, including 2a) policy evaluation indicators and 2b) trend indicators. Predictive indicators are, by definition, designed to provide numerical values with direct information about a possible or likely future situation that is immediately interpretable in forecasting terms. Such future indicator values must be generated. Among all forecasting techniques, three quite popular ones are trend extrapolation, regression models, and theory based simulation models. The author conclude that the scientifically most appropriate approach would be to use simulation models to simulate trajectories of future values for selected socio-economic and environmental variables.

Other, dichotomous classifications of indicators for policy purposes are factor indicators ↔ effect indicators, direct indicators ↔ indirect indicators, state indicators ↔ change indicators, and composite indicators ↔ simple indicators.

5.2 Criteria for designing and choosing indicators

Criteria are assessment dimensions, and thus guiding principles for the choice of, in this case, indicators. Any non-random choice is based on criteria.

So, which criteria to use? To start with, we note that there is an infinite set of possible criteria. The following text gives brief presentations of criteria that have been recommended or referred to in the literature, applied in practice, or that could be deducted from theory. Actually, each of them can be considered as a class of criteria, since they can be designed in variants that are used differently in practice.

Table 1 lists the criteria. Since the list is assembled from various sources, there is overlapping among the criteria, some of them are more or less synonymous. Seemingly similar criteria could, however, operate significantly different, so it is not just a matter of choice of words. The list of criteria, or rather classes of criteria, is incoherent, so some of the criteria may be used as sub-criteria for more general ones. It may also be useful to distinguish between end-criteria and instrumental criteria, where instrumental criteria are subordinated. For example, "Predictive Capacity" can be an instrumental criterion among other necessary for compliance with the end-criterion "Policy Relevance".

To provide a structure, the criteria are clustered into four groups. This is somehow gratuitous since they all in some respect are about relevancy for policy making and they all are about informative quality of the indicators.

Table 1. Possible criteria for assessing policy-motivated indicators

Criteria concerning Relevance and Utility for Users
Policy Relevance
Adequacy
Representative
Sensitivity
Quantitative Responsiveness
Distributional Responsiveness
Temporal Responsiveness
Predicting Capacity
Persistency
Compatibility
Commensurability
Comparability
Criteria concerning Quality of Measures
Validity
Precision
Reliability
Stability
Data Availability
Measurability
Monitoring Costs
Efficiency
Aggregatability
Applicability
Criteria concerning Scientific Quality
Theoretically Well Founded
Analytical Soundness
Conciseness
Criteria concerning Information Quality
Informative Value
Pedagogic Value
Interpretability
Simplicity
Transparency
Unambiguousness
Conceptual Clarity

The three more commonly applied or recommended criteria are *policy relevance*, *analytical soundness* and *measurability*, although these are then often used as generic terms for a set of criteria. The chapter below is a survey that treats also the other general criteria for indicator assessment.

5.2.1 Criteria concerning Relevance

Policy Relevance

A commonly employed criterion is *relevance*. *Relevance* or *policy relevance* has been used as a generic term for various qualities of indicators that improve their usefulness for policy makers, but the criterion has also a more specific, genuine meaning.

To demand *relevance* implies answering the question: “Relevant to what?” In an environmental policy indicator setting, the criterion “Relevance” could refer directly to either:

- goals and objectives (as stated by policy makers),
- specified targets,
- values (as ascribed by citizens),
- environmental and socio-economic phenomena (whether acknowledged by policy makers or not), or
- policy measures.

Certainly, *relevance* will somehow indirectly relate to all the points above, but for designing indicators it may be important which one it is directly aiming at. Such a specification of the criterion is, however, rarely done. An interpretation how the criterion implicitly have been stated or used is that it mostly has been orientated towards policy goals and objectives. *Relevance* in this respect measure how well the indicator reflect a problem in terms of (or in the perspective of) the policy goals, which will vary depending how these are stated. The criterion could be about assessing the explanatory power of an indicator for a situation as concerns the policy goal, but it could also reflect the pace by which the situation approach towards or retreat from the goal.

An interpretation how the criterion implicitly have been stated or used is that it mostly has been orientated towards policy goals and objectives. *Relevance* in this respect measure how well the indicator reflect a problem in terms of (or in the perspective of) the policy goals, which will vary depending how these are stated.

OECD (1994) is using the criterion *policy relevance* in a generic sense, stating that indicators should:

- provide a representative picture of environmental conditions, pressures on the environment or society’s responses;
- be simple, easy to interpret and able to show trends over time;
- be responsive to changes in the environment and related human activities;
- provide a basis for international comparisons;
- be either national in scope or applicable to regional environmental issues of national significance;
- have a threshold or reference value against which to compare it, so that users are able to assess the significance of the values associated with it.

Several of these demands can, besides being treated as sub-criteria or instrumental criteria to *policy relevance*, be treated as separate criteria. They will be dealt with below in sections labelled by respective criterion.

The stricter, genuine meaning of *policy relevance* refers to the first of the above listed OECD requirements. The criterion is expressing a demand that the indicator should comply with its aims to warn or provide other inputs into the policy process.

It has been pointed out that indicators should offer implications for policy, as insights on the effectiveness of past policy, or options for future policy (Braat, 1991, p. 60 – 61; Gilbert & Feenstra, 1994, p. 255; (Piorr 2003)). It implies that indicators should focus on factors of crucial importance and quantify significant components in relation to the issue (Holmberg & Karlsson, 1992; OECD, 1997, p. 19). Holmberg and Karlsson (1992) extend the criterion so that indicators should also relate to the various potential problems. As illustrated by Gilbert and Feenstra (1994), indicators have to be problem oriented to be policy relevant. A relaxation of the criterion is that indicators have to be relevant only to problems that the policy can potentially address (OECD, 1997, p. 19).

Adequacy

The problem is usually not that environmental information is missing, but that it is fragmentary, often qualitative and of a detailed nature that hampers its usefulness in policy making. Verbruggen and Kuik (1991) thus demand information that is *adequate* and tailored to quantitative objectives, where *adequate* means:

- clearly indicate whether objectives will be met,
- cover the system as a whole,
- be quantitative,
- understandable for non-scientists, and
- containing parameters which can be used for longer time periods.

Representativity

The criterion *representative* enact that the indicator should be representative for the system of concern or a specified part of it. A literature survey by Gilbert & Feenstra, (1994) conclude that indicators should ideally be based on empirically tested models. At least, they should be based on verified correlations or scientific knowledge for which there is consensus among experts. Indicators should be uniquely representative for the problem under consideration. OECD (1994, p. 10) declare that indicators should be representative of affecting factors to, conditions of, or responses to environmental problems.

Sensitivity and Responsiveness

Sensitivity or *responsiveness* is a class of criteria about the capacity of the indicator to react to changes. It may be divided into the three subclasses of criteria *quantitative*, *distributional* and *temporal responsiveness* discussed below.

Quantitative or Qualitative Responsiveness

Quantitative and qualitative responsiveness mean that the indicators should be able to pick up and demonstrate changes that are interesting as causes or effects for the purpose of the indicator. Indicators should accordingly be responsive to changes in the society, agriculture or environment, but the demand could also concern factors that influence these things of primary concern. (OECD 1994, p. 10).

In contrast to that, Jesinghaus (1998, p. 6, 26-27) is defining *responsiveness* to exclusively refer to the relation between indicators and political action. Solely indicators that react significantly to measures comply with this variant of the criterion. He advocates that indicators, in accordance with this criterion, is designed to point only at those aspects that can be strongly influenced by policy. The reason given is that there must be incentives by chances to improve the indicator values, otherwise decision-makers will not act. Indicators should thus be responsive to policy actions so that a decision-maker by launching appropriate actions could reduce the problem and thus the indicator value.

The demand for *sensitivity* has to be balanced to not disguise important changes by expressing noise. Compare with the criterion *reliability*, demanding that monitoring noise should not blur the indicator values.

Distributional Responsiveness

Just as important as getting scalar information of first orderxx about states or changes, may be to get measures that are sensitive to the distribution of conditions within a population or over a geographic region. S*ensitivity to change across space* and *sensitivity to change over social distribution* are examples of criteria to take account of such demands. Another criterion used in selecting indicators is *sensitivity to reversibility*. (Liverman, 1988, pp. 135 – 136; Opschoor & Reijnders, 1991)

Temporal Responsiveness

Temporal responsiveness refers to how quick the indicator is to reflect changes in the factors or effects that it is measuring. It hinges on existing time lags of the observed system and how frequently data are collected for the indicator. To detect significant trends and variations and be able to separate them from normal fluctuations, an indicator should ideally be a part of a historic time series (Liverman, 1988). The criterion should not be confused with *predicting capacity*, discussed below.

Predicting Capacity

Indicators that focus on parts early in the cause-effect chain will give better possibilities for foresights (Holmberg & Karlsson, 1992, p. 89). Hence, pressure indicators are in general superior to state or response indicators in this respect. Note however, that a state indicator can represent a factor early in the chain. Besides using prefacing indicators, a second strategy for anticipation is to design indicators suitable for time series that could be extrapolated or used in model simulation (Liverman, 1988). Braat (1991) stresses that indicators should have direct predictive meaning to be useful for sustainable development planning, and not be restricted to retrospective values.

Indicators should according to this criterion provide early warning signals (Jesinghaus, 1998, p. 181; Holmberg & Karlsson, 1992, p. 91). The possible predictive qualities of an indicator originate in the combination of *temporal responsiveness* (how quick), the forestalling virtues by measuring on an early link in the chain of factors and effects (how early), and the size of the indicated factor impact on the goal related effects (how significant).

Persistency
Indicators should be based on parameters that can be used for longer time periods. (Verbruggen and Kuik, 1991)

Compatibility, Commensurability, Comparability
These criteria are for assessing whether the indicators are suitable for regional and international comparisons or for comparisons across farms, technologies (Nilsson & Bergström, 1995), time, regions, ecosystems, etc. Another characteristic is how commensurable they are with other indicators of production, environmental effects, etc. They should also be capable of being linked to scientific models, forecasting, and information systems.

According to Hutchinson (1996, p. 9), is it difficult to use straightforward physical indicators of environmental pressures for meaningful international or even interregional comparisons. Absolute levels of indicators are devoid of meaning for international comparisons when the relation between the phenomenon that the indicator represents and the environmental situation is site specific. They are useful only when applied to similar agri-ecological zones. Physical indicators on trends and changes may be more appropriate for geographic comparisons, but even these are not free of the influence of site specific interactions. (cf. Hutchinson, 1996, p. 9). Hutchinson requests a set of national and regional threshold and target levels for indicators for comparisons, to signal whether the changes are taking place above or below reference levels. Also Jesinghaus (1998) stress that indicators to be useful have to be presented within their framework and linked to standard socio-economic statistics.

Indicators that easily could be combined with different ones are advantageous, since models that incorporate, for instance, bio-physical and economic information is more useful for decision-makers. (Walpole & Sinden, 1997, p. 56)

Use of a common methodology will facilitate international comparisons. Gouzee (1996) accordingly request a core set of indicators in the form of a set of methodology sheets. It will also guide collecting data. Practice has shown that harmonisation at a later stage is very time-consuming and cumbersome activity.

The general rule is that indicators that are quantitative are more suitable for plain comparisons than qualitative, linear more than non-linear forms, and cardinal indicators are more suitable than ordinal ones.

5.2.2 Criteria concerning Quality of Measures

Validity
A most widespread and accepted criterion for any data is that they should be *valid*. Validity is defined as the degree to which an instrument measures that which is supposed to be measured. The criterion thus concerns the quality of the data that the indicator is based on. Additional demands in this direction stated in the literature is that indicators should be *rigorous* (Landres, 1990, p. 1313), of known quality (OECD, 1994, p. 10; Reid et al., 1993, p. 3), *adequately documented* (OECD, 1994, p. 10), *controllable* (Piorr 2003), *free from bias* and *neutral*. *Neutral* denote as non-controversial or correct

as possible, which does not prevent that they can support controversial political debates (Jesinghaus, 1998, p. 7 – 9).

Precision

This criterion is for assessing whether the indicator could be measured by sufficiently good *precision* or *accuracy* (see e.g. OECD, 1994 or Reid et al., 1993). It may be considered a sub-criterion to *policy relevance*. Furthermore, the margins of uncertainty must be stated explicitly (Braat, 1991).

Balancing *precision* against the criterion *measurement costs*, Nilsson and Bergström (1995) advocate the "hit-the-board"-principle. It states that "rough and relevant is preferable to precise and inexpedient. To hit the board is enough, since hitting the bull's eye requires too much effort".

Reliability

The reliability of the data that an indicator is based upon will be reflected in the *reliability* of the indicator. The extent to which the indicator value vary with random or unexplained factors decide its reliability. It is a commonly demanded quality for data, but has only occasionally (e.g. Gilbert & Feenstra, 1994) been explicitly stated for indicators, probably because it has been taken for granted.

Stability

Stability has been applied as a criterion by Costanza et al. (1995), claiming that the indicator should have small natural or random fluctuations. It is akin to *reliability*.

Data Availability, Measurability and Monitoring Costs

This is a cluster of criteria, where the outcome of their application depends on technology, costs of monitoring, availability of official statistics, legal restrictions, etc. The cluster can include assessments on the extent to which the indicator is *reproducible* and *realisable*. Visual indicators should also be *mappable*, that is, possible to locate spatially and to express by maps (Ode, Tveit, & Fry 2008).

The literature survey by Gilbert & Feenstra (1994, p. 255) emphasise that *measurability* and *quantifiable* indicators depend on if appropriate data are available or obtainable with present technology. OECD (OECD, 1997, p. 21) asserts that indicators should be developed from established databases, preferably with long time series. Reams et al. (1990, p. 1270) reports from a survey that lack of data on environmental quality is a deterrent to the use of environmental indicators. *Data availability* or the mere existence of suitable data was used by Peco et al. (forthcoming, p. 6) as a major criterion guiding the selection of indicators. *Data suitability* has two dimensions. Firstly, whether the spatial scale of the data, and secondly, whether the type of data in available statistics are relevant (ibid. p. 6 – 7). For maximum benefit, indicators should be based on data that are available at the level of decision-making as well as at biologically defined levels of observation (Reid et al.,1993, p. 3).

Measurability is together with *policy relevance* and *analytical soundness* one of the three "basic" criteria in the OECD indicator work. OECD (1994, p. 9 – 10) and (Piorr

2003) is using the concept as a generic criterion, involving that: “the data required to support the indicator should be:

- readily available or made available at a reasonable cost/benefit ratio;
- adequately documented and of known quality;
- updated at regular intervals in accordance with reliable procedures”.

Efficiency

Efficiency has in various documents been declared as a criterion for indicators, mostly without further explanation. It is a composite criterion meant for assessing the ratio between policy usefulness and monitoring costs (Romstad 1998).

Landres (1990, p.1270) discusses the *cost-effectiveness* of using indicator species. Costs may be reduced by using indicator species that are abundant, conspicuous, and easily recognised, but may still become very high if estimates are to reliably detect a 10% change between years. He concludes that as the number of indicator species increase, expenses rise drastically and subjective decisions have to be taken “to balance precision, accuracy and cost, potentially abrogating the effectiveness and reliability of indicator species”.

Aggregatability, Integrativity

Aggregatability and *integrativity* express a demand that indicators should be constructed so that indicators for smaller units could be transformed and aggregated into larger indicators, covering more variables or bigger regions. (cf. Liverman, 1988; OECD, 1997)

Applicability

Indicators with a capacity for a larger scope or more important issues are preferred to more restricted ones, according to the criterion *applicability*. OECD (1997) state, for example, that indicators should be *applicable* to a wide set of farming systems. Indicators expressed by physical measures are in general less *applicable* in respect of interpretation, since the environmental threats that they imply may be quite different depending on the framing site conditions (cf. Jesinghaus 1998). The *applicability* also depends on inherent character of the problem it is reflecting. An erosion indicator may for instance have a larger potential application area than a salinity indicator, and the political concerns for heavy metal pollution may be more widespread than those for landscape conservation.

5.2.3 Criteria concerning Scientific Quality

Analytical Soundness, Theoretically Well Founded

The qualities of *analytical soundness* and *theoretically well founded* are widely established as indicator criteria. An interpretation by OECD (1994, p. 10) of *analytical soundness* implies that “an indicator should:

- be theoretically well founded in technical and scientific terms;
- be based on international standards and international consensus about its validity;
- lend itself to being linked to economic models, forecasting and information systems”.

There seem in all references to be an implicit idea that the concepts involve that the indicators are related to some kind of theoretical model. Nilsson and Bergström (1995, p. 177) write that all questions and answers should be rigorously formulated in theoretical terms before looking for empirical indicators. The principle renders it possible to relate hypotheses and conclusions to a model structure, which improves the quality of the decision-making.

Having a model basis, Gilbert & Feenstra (1994, p. 255) conclude from their literature survey that the indicator should be chosen to clearly represent a distinct part of the cause-effect chain. It has to be made clear what part is represented and what is not. In the next step, *analytical soundness* concerns, in particular, the extent to which the indicator can establish links between activities and environmental conditions (Ode, Tveit, & Fry 2008). It is then important to focus on the decisive characters of the causality, the relevant attributes that exert the influence (Piorr 2003). The indicator should be formed to reflect these as close as possible. An example, the number of cars would be inferior to tons of car emissions, which would be inferior to harmful emissions (weighted) from cars when choosing indicators for health purposes. The reason is that cars themselves are not the problem, they can be more or less polluting, as emissions can be more or less hazardous. (OECD, 1997, p. 20; Jesinghaus, 1998, p. 26) To promote understanding and decision-making, it is furthermore necessary to link the indicators to each other, to underlying trends and to policy measures. (Jesinghaus, 1998, p. 20, 21)

Conciseness
Conciseness has been brought forward as desirable quality of policy motivated indicators without further explanation.

5.2.4 Criteria concerning Information Quality

Informative and Pedagogic Value
Since an overall function of indicators is to provide information (cf. section 4.1 above), it may seem natural to apply criteria that control for such qualities. A compilation of general statements in the literature to illustrate or give the concept a meaning come to: indicators should be *simple*, *readable* and *easy to interpret*, *unambiguous*, possess *conceptual clarity*, send correct messages, be able to show trends and ranges over time, and give insights. (Braat, 1991, p. 60; Jesinghaus, 1998, p. 7, 11; OECD, 1994, p. 10; OECD, 1997, p. 9, 20, 21; Reams et al., 1990, p. 1270) Many references stress that the indicators have to be *quantifiable*. Indicators should furthermore provide a maximum of relevant information and thus contribute to the observing, analysis, interpretation and understanding of the issues of concern. (cf. Jesinghaus, 1998, p. 10, 11; OECD, 1997, p. 20; Peco et al., forthcoming, p. 1)

Another implication of pedagogic demands could be that indicators should be so simple and straight that users should be able to link them to reality (cf. Jesinghaus, 1998, p. 10, 11) *Realistic* and *transparent* indicators are, ceteris paribus, preferred to more abstract alternatives because they are more easily understood. An indicator measured in tons per year or number of “x” would in this respect (!) be better than an abstract, dimensionless figure.

Elaborating the indicators’ technical design can enhance the informative or pedagogic values. As mentioned in section 5.4.4, it has for example been recommended that indicators for comparative reasons should be normalised to become dimensionless

(Holmberg & Karlsson, 1992, p. 97), take positive values for benign changes/states and negative for bad (Gilbert & Feenstra, 1994, p. 258 – 259), or range from 0 – 1, where a higher number is better than a lower (Nilsson & Bergström, 1995, p. 179). Indicators should have a threshold or reference value against which to compare it, so that users are able to assess the significance of the values associated with it (Braat, 1991, p. 60); Jesinghaus, 1998, p. 30; Liverman, 1988, p. 136; OECD, 1994, p. 10). According to Hutchinson (1996), the key pedagogic questions are: 1) how to set reference levels, and 2) how to measure objectively the distance to the reference level.

All measurements should be independent of scale, that is, the same measurement of performance should be able to use at site, local or regional level (see Nilsson & Bergström, 1995, p. 177). Condense indicators that are highly aggregated from the most important data give relevant and more assimilative information then a confusing abundance of detailed measures (cf. Jesinghaus, 1998, 9 – 11, 15, 16).

Peco et al. (forthcoming, p. 6) assert that state indicators that express conditions subject to time lags or natural trends or that are subject to a multitude of other non-policy influences are problematic by not revealing useful information.

5.2.5 Indicator System Criteria

Indicators could be developed and assessed separately or jointly in systems. The criteria for indicators that have been discussed above could be applied also to sets or systems of indicators. When assessing multiple criteria jointly, some additional criteria are applicable as well. They can, if desired, be considered as sub-criteria to *policy relevance, theoretical soundness* or *informative value*.

Covering
Covering measures to what extent the set of indicators captures the essential aspects, in this case, all major cultural, social or environmental factors and effects. Considering the “warning lamp function”, it could imply to *cover* an economic or ecological system to also detect potential or even unexpected problems. It is determined by the *number of indicators* (see below), and how these are constructed, individually but more so how they are constructed as a system.

In accordance with this request, Jesinghaus (1998) advocate to set up a system of indicators, and not just a basket. The approach of setting up a system of indicators is related to the request to link the indicators to a cause-effect model, proposed within the criterion of *theoretical soundness*.

Non-overlapping
The purport of this criterion is minimising the overlapping of indictors. A motive for this criterion is that with extensive overlapping the amount of information would be less manageable. More serious would be if it caused misleading signals, for instance, if one effect was registered by three seemingly “independent” indicators, thus exaggerating the risks or positive conditions.

Non-redundancy was applied by Peco et al. (forthcoming, p. 3) to each indicator following an initially established list. The procedure appears to be path-dependent, that is, which indicators that will be included partly depend on their position in the initial list.

Number of indicators

The more common attitude to *the number of indicators* as a criterion is that few indicators would be preferred to many. An alternative formulation would recommend a manageable number of indicators. Owing to the limited time or other capacity constraints of decision-makers to assimilate overwhelming number of figures, it is for pedagogic reasons better to use a few, highly aggregated indicators or indices than a vast number of indicators that are more precise. The optimal number of indicators depends, however, on many things, such as the character of the problem, the purpose of the indicators, the policy objectives, monitoring costs, and the organisation of how information is achieved. Some ecologists have pointed to the need for a large number of indicator species to get reliable signals whether any negative change has been taking place. Their demand for a *relevant, problem orientated* and *reliable* system by using many indicators could be solved by transforming the indicator species (pre-indicators) into a core indicator that may register if any of the species show alarming tendencies. (cf. Jesinghaus, 1998, p. 11, 16, 17; Landres, 1990, p. 1297; Opschoor and Reijnders, 1991; Zalidis et al. 2004)

The "cluster" principle suggests that it is better to design a cluster of rough indicators than to strive for a single perfect one. A cluster of indicators consists of "close" but independent measurements. The principle is recommended by Nilsson & Bergström, (1995, p. 177) for situations demanding reliable information but where available indicators are too rough. If all indicators in a cluster give consistent signals, it can normally be considered as reliable information.

Jesinghaus (1998, p. 28) present a figure which express coverage of environmental problems as increasing with the number of environmental pressure indicators at a decreasing rate. It also tells how the *number of indicators* supposedly influences the *policy relevance* and indicator usage in policy-making. According to the figure, 40 – 60 indicators would give optimal coverage, including all relevant issues. It would entail that indicators were used as standard tools. With as little as 5 – 15 indicators they would get a more symbolic coverage to highlight only top issues. The *coverage* would be dangerously low and indicators would not be considered a serious tool since too many important issues would be missing if only 10 – 40 indicators were introduced.

Under the section above on *efficiency* it was referred to Landres (1990) who points to the conflict between reliability and skyrocketing costs as the number of indicator species is increased.

Flexibility

The set of indicators should be *flexible* so as to be adaptable for incorporating new issues or abandon old ones. Using it as an evolving tool, it may take different forms over time as new experience is gained or new situations arise, and vary geographically, from region to region. (Gouzee 1996; OECD 1997)

Unbiassed
In a set of unbiased indicators, no indicator is given more weight than what corresponds to its weight in the system it describes.

5.3 Meta-criteria

If indicators sometimes seem to be taken on loose grounds, criteria are even more so. Criteria are hardly ever treated analytically in the literature. When at all treated, it is mostly in normative terms, “indicators should”. Also in the scientific literature, the criteria appear to be taken for granted, out of the air.

It is inherent in the role of indicators to be in operation over longer spans, sometimes they are intended to last for decades. They may also get to play a decisive role in the policy process. It is consequently important that the indicators are well chosen. Criteria are, as noted, indispensable tools in the process of developing the indicators. As evident from the previous section, there is an infinite number of possible indicators or variants thereof. What then, is a good criterion?

There is no scientific, correct criterion as such. Criteria will, as pointed out by Reid et al.,1993, p. 43), for instance differ for regional or national use, depending on perspectives and needs. It is always up the decision-maker to choose the criteria. In the end (or rather beginning), any rational choice has to be based on a normative declaration in addition to the positive conditions. This does not mean that the problem cannot be dealt with scientifically. Given that there are superior goals, for instance of environmental quality, welfare, or efficiency defined somehow, scientific methods could be used to analyse how alternative criteria operate to comply with these goals. Meta-criteria would be the tools in such an analysis to make the dimensions operational according to which the criteria are to be assessed. Analogously, meta-criteria are necessary in the policy process to design and select criteria for assessing the indicators.

The meta-criteria are of two kinds, end criteria and instrumental criteria. The end criteria are normative declarations (ultimately given to the scientists or state officers in charge). All other meta-criteria are instrumental, in the sense that they are subordinated to serve the normatively stated objectives and the end criteria.

Below is a discussion on six meta-criteria in the, in principle, infinite set of possible meta-criteria. They may be used together, but one or more of them may also be disregarded. When using more than one, they may be given different weights. Each one of them could be implemented in alternative ways, thus they may rather be considered as classes of meta-criteria.

Normative Declarations on Value
A criterion is “good” just because the decision-maker(s) say(s) so. If the Ministry or any mandator declare that, for instance, “relevance” is an important criterion when

choosing indicators, this would be the normative basis from which to start a positive analysis. Without any normative basis, the series of meta-levels could be extended into infinity. When lacking an explicitly stated normative meta-criterion, the meta-criterion “Logical consistency with stated goals” (see below) may serve as a substitute.

This class of meta-criteria includes *importance to the proper decision-maker or authority*, and *accordance with public conception of importance*.

Logical Consistency with Stated Goals[5]

Whether a criterion is to be assessed as good or not depends on if it serves the underlying aims of the exercise. In the development of indicators for a policy aiming at, for instance, improving the environment, the criterion *validity* is consistent with the stated goals. Indicators based on data with less validity would be inferior according to the aim of improving the environment. Applying the inverse criterion, “Non-validity” would counteract the underlying aim by advocating misleading indicators. Analogously, the meta-criterion “Logical consistency” could be tested against its inverse when choosing instrumental meta-criteria.

Generality

Generality refers to whether the criterion is applicable to all kind of indicators, problems, or relations (effects, factors). This meta-criterion is thus for assessing the scope of applicability of a criterion.

Unambiguousness, Interpretability

Criteria has, according to Landres (1990, p. 1313), to be *unambiguously* and *explicitly defined*. According to this meta-criterion, a criterion is preferred when having a more precise and less ambiguous interpretation. The indicator-criterion *Good*, for example, is inferior to the criterion *Measurability, as indicated by these and those costs of monitoring*, in terms of making clear what the criterion is assessing.

Comparability

When assessing policy indicators, a criterion that could range the indicators in an unambiguous scale is to prefer to criteria that do not, according to the meta-criterion *comparability*. A cardinal scale for the alternative indicators would, if possible to implement, be superior to scales that are ordinal, since they would not just tell that a certain indicator is better than another one, but also tell how much better. For example, it could be measured to what extent indicators comply with the criterion *quantitative responsiveness*; one indicator could be twice as good as a rival. If properly defined, the criterion *quantitative responsiveness* fulfils the meta-criterion *comparability* more than what the criterion *relevance* does, at least the way the latter usually is adopted. In real choice situations, *comparability* would probably be used more for assessing alternative

[5] I am grateful to Helene Carlsen for the development of this meta-criterion.

definitions of criteria, for instance, how to design the criterion *quantitative responsiveness* so that the indicators could be ranked satisfactory.

Informative and Pedagogical Value

Related to the previous classes of meta-criteria would be the meta-criterion to assess the extent to which the criterion is informative and transmitting understanding of importance for the decision-making or acting. A criterion, say "Relevance to the Pakistan train departures", would comply less well in this respect than the criterion "Relevance for flora objectives" when assessing criteria on indicators for European agri-enviro policies. There is nothing preventing a criterion like *Informative value* that is used in assessing indicators from being used on a meta-level assessing other criteria.

5.4 Generation of candidate indicators

5.4.1 Strategy for creating candidate indicators

The third main step in the process of developing indicators, after identifying the purposes and choosing criteria, is to generate candidate indicators. In order to create BPIs, the advantages and disadvantages of alternative indicators and variants of indicators have to be compared. The matter is how to conjure up these alternative candidates, not to miss potentially potent solutions. Various strategies for creating candidate indicators can be employed. Among these are:

- intuitive strategies,
- analogy transference,
- model based induction,
- Delphi-technique, and
- iterative strategies.

Intuitive strategies seem to be commonly applied. The experience of the searcher tells what might be feasible candidates. This strategy can definitely be saving time and other resources, but there is an obvious risk that such an unsystematic approach when used isolated may fail to produce indicators that cover the problem in an optimal way.

Analogy transference refers to a systematic search of indicators that have been used in other contexts and then adopting them to the actual case for testing. Other countries, problems or sciences could be sources for direct transfer, transformation or inspiration. The strategy is open for transfer of technical design, choice of denoted phenomenon, reference point, monitoring and other dimensions.

Model based induction refers to attempts to suggest candidate indicators by rational methods from a model on the real system in focus. If having a cause-effect model that covers the problem, the task would be to exploit its structure and significance implications. The process involves searching for suitable levels and essential components of the cause-effect chain, and translation of boxes or arrows (or equation variables) into candidate indicators.

The *Delphi-technique* implies that the generation of candidate indicators is performed by the responsible developer in co-operation with a choice of experts in an iterative process. A standard procedure is to first confront the experts with the problem. The experts, who work independently, suggest candidate indicators. These candidates are then circulated among the experts, who may suggest new candidates and judge upon the suggested ones in rounds until there is consensus or a dominating view, or simply a list of recommended candidates to be tested. The technique has been applied by, for instance, Eurostat Environmental Pressure Indices Project (see Jesinghaus, 1998).

The prominent advantage of the technique is that the base of knowledge, experience and intellectual capacity is extended as regards scientific fields, theoretical backgrounds, methodologies and applications. A prerequisite, not to be overlooked, is that the experts get sufficiently engaged to take the task seriously and devote enough time.

Actually, the Delphi-technique is not a strategy in itself, in the sense that it may be a mix, possibly unknown, of the three previous strategies. Since the idea of the technique is not to genuinely generate candidates, but transmit the task to the experts, it is open which strategies that are used in reality. There is certainly no guarantee that the experts will develop elaborated models for the task or approach it systematically.

Iterative strategies can be combined with any of the three previously mentioned strategies, without necessarily using the Delphi-technique. Starting from a model or intuitively suggested candidates, alternative variants or new candidates can be developed by synthetic, sequential assessments or a trial and error process.

5.4.2 Model of real system in focus

No seriously applied indicator could exist without a model on the system it is supposed to represent and the objectives it should serve, whether the model is consciously and explicitly expressed or not. This is valid independent of strategy for creating indicators. Landres (1990, p. 1313) exhort to develop a conceptual and statistical model for every use of an ecological indicator, treating the indicator as a formal statistical estimator (e.g., as in a path regression analysis). This allows the accuracy and precision of an ecological indicator to be determined quantitatively.

Hence, to develop indicators inherently implies developing a model. The type and the size of model will vary depending the goals of policy, the purposes of indicators, available resources and the character of the problem, but it would normally imply to identify the important effects and factors that are relevant. Using the “model based induction” strategy, the next step would be to find indicators that possibly could express as well as possible those that according to the model have proved to be more significant. The translation of effects and factors into indicators will depend on the objectives and criteria for the indicators.

5.4.3 Choice of indicator type

Before launching any system of indicators, the *scope of the indicators* has to be settled. Which *dimensions* should be incorporated into them? Depending on the purpose of the project, the indicators could express

- environmental but also social conditions,
- states of direct interest but also influencing (pressure) factors, and
- policy relevant conditions (environment, society) but also policy responses and potentials for management and control.

The indicators could be stated in terms of sustainability, efficiency (welfare) or equity, or numerous other dimensions. (Opschoor and Reijnders, 1991, p. 17)

The objectives and criteria for the indicators will also decide when it would be more appropriate to have state (kg N applied) or change (± in N-applications) indicators, state or force indicators, etc.

For the sake of the pedagogic criterion, pre-indicators could be transformed into cardinal indicators that are monotonic and linear relative the objectives. (see **5.4**.4)

A fourth kind of choice as refers to indicator type is the choice of indicator measure. The task is to investigate whether it would be more appropriate to measure by, for instance, hours of management/ha, number of rare species/ha, or in botanical classes. The choice is associated to the previous issues, and especially to the design of the indicator, but remains to be deliberately solved.

5.4.4 Technical design of indicators

Another crucial step in the methodology for forming and choosing indicators is how to design them in a technical sense. This section contains a few notes on the matter. The issue is closely related to the indicator criterion “pedagogic” or “informative” value discussed in section 4.2.

§1. Holmberg and Karlsson (1992, p. 97 – 102) advocate that indicators should be normalised to become dimensionless. A general layout for such an indicator I_x is:

$$I_x = \frac{A/B}{C/D}$$

where A is the quantity to be indicated; B is the compartment for which A holds, and C/D is a relevant normalisation of A/B expressed in the same unit. If, for example, A is measured in kg and B in hectare and year, also C/D would be in kg/ha,y. Normalisation should, according to the authors, preferably be done versus the critical load. If such definite values are lacking, normalisation could be with comparisons to natural flows, potential flows, best available technology, or desirable value.

A similar approach is suggested by Gilbert and Feenstra (1994, p. 258 – 259) who design a soil quality indicator I_{Cd} which compares the cadmium concentration in the soil with a standard:

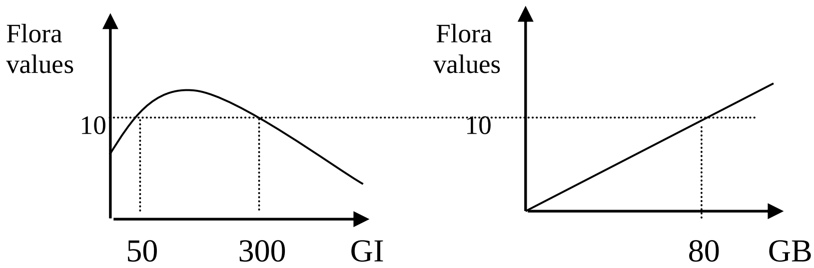
$I_{Cd,t} = -(S_t/S_s - 1)$,

where S_t = aggregate cadmium concentration at time *t*, and S_s = soil quality standard for cadmium. The indicator takes negative values at concentrations higher than the standard, which correspond to an unsustainable situation, but positive values at concentrations lower than the standard. Some authors recommend indicators ranging from –1 to +1, while Nilsson and Bergström (1995, p. 179) recommend that they always take a number from zero to one, $0 \leq X_I \geq 1$, where a higher number is better than a lower one. In their case, the indicator is calculated by the number of samples found to meet the norm divided by the total number of samples taken. Note that this may still be an ordinal scale.

The concept of using critical loads or other standards for normalisation of indicators may be dubious in the sense that the indicator values are highly dependent upon which reference level that is chosen, and sensible to shifts of that level. The reference level may shift significantly over time owing to increased policy ambitions or changed risk assessments, without any corresponding changes having taken place in the physical, underlying conditions.

§2. Another issue refers to whether to use average, median, cumulative or spot check measures. A next question is whether to present solely such, single values or also present information about the distribution, for instance by histograms, standard deviation figures, percent of population in lowest decile.

§3. Peco et al. (forthcoming) discuss a problem of hump-shaped indicators, applying an example of grazing intensity. The hump-shape is due to the fact that abandonment and very low grazing intensity is negative for the biodiversity, while some grazing is optimal and over-grazing is detrimental. This confuses the interpretation of a straightforward grazing indicator: higher indicator values are better to a certain point, but even higher values are worse. For the sake of the pedagogic criterion, such pre-indicators could be transformed into cardinal indicators that are monotonic and linear relative the objectives. If, for instance, there is a variable "grazing intensity" that influences the flora values by a non-linear function that is not monotonic, but has a maximum (minimum), it could be transformed into a "grazing benignity" indicator. In the example illustrated below, a grazing intensity (GI) of 50 would give the same indicator value of 80 grazing benignity (GB) as the GI 300 would give.



GI Grazing Intensity as measured by cattle unit days per hectare and year
GB Grazing Benignity indicator

Figure 2. Example of transformation of a hump-shaped pre-indicator into a monotonic and cardinal indicator.

5.4.5 Strategy and scale for indicators

When choosing indicators, a decision has to be taken regarding the resolution of the indicators as concerns spatial size, period length, and the number of components that is modelled. The choice hinges upon the more fundamental choice of *strategy of representation*. Normally, indicators that are aggregates or transformations of more specific subindicators and larger data sets are preferred. The alternative strategy, applied when it is infeasible to develop indicators which comprise all the essential parts of the variable of interest is to develop an indicator that is fragmentary but representative, typical or critical to the phenomenon to be measured. (Opschoor & Reijnders, 1991, p 18)

In both ecology and economics, primary information and measurements are usually collected at relatively small scales and the data are then used for indicators at a radically larger scale. The process of scaling is directly tied to the problem of aggregation, which in complex, non-linear, or discontinuous systems is far from a trivial problem. The optimal level of aggregation is at a scale that is useful for the decision-makers, which means that the indicator could be meaningfully applied for policy purposes without concealing more than it reveals. (Costanza et al., 1995, p. 48 – 51; OECD, 1997, p. 22; Walpole & Sinden, 1997, p. 56) According to OECD (1997), there is no unique way to address the aggregation issue for each indicator. It is most effectively tackled on a country-by-country, issue-by-issue, and indicator-by-indicator basis. The choice could be made pragmatic or on an explicit analysis based on criteria such as monitoring costs, precision, relevance and pedagogic value.

The spatial, geographical scale concerns whether the indicators should be registered on field, farm, watershed-area, district, regional, or national level, for example. A common problem is that data are often collected on the basis of administrative units, such as sub-national regions, rather than in terms of agro-ecological zones, which may be more appropriate. The discussion on the level of aggregation is also directly related to the extent to which indicator information can be compared internationally. Another issue connecting to aggregation is how to design indicators to express spatial or temporal diversity. (OECD, 1997, p. 22, 23, 47)

5.5 Assessing indicators according to criteria

In the first place, the indicator approach could be assessed relative to other solutions, such as ad hoc investigations, or the repeated, problem oriented analyses of present conditions, cf. the Countryside Surveys of Great Britain. Secondly, indicators or systems of indicators could be assessed relative each other or specified targets.

Once decided to implement indicators, the fourth main step in the general methodology for designing indicators treated in this paper would be to systematically and explicitly assess the candidate indicators against the stated criteria. It would imply testing procedures to find out covering, relevance, sensitivity, monitoring costs etc. of indicators relative to alternative designs, including the null-alternative of no indicator.

The assessments act on candidate indicators that are recommended or rejected, ranked or marked. The procedure involves the use of criteria, which in turn have been chosen from meta-criteria. Criteria thus have to be defined, and could then be used strictly or more subjectively. Landres (1990, p. 1313) emphasise that researchers and managers must clearly state the reasons for choosing selected criteria and underlying assumptions for their choice. Every source of subjectivity in the entire process should be identified and defined. By treating them formally, the subjectivity could be discussed and judged.

In reality, criteria are often indistinctly applied. When at all stated, this is in some cases done without sufficient or any explanation of the purport of the criterion. Nor is there always a critical discussion underlying the choice of how to design the criterion. A crucial step is to give the criteria a meaning. The general declarations of *policy relevance* or *analytical soundness*, for instance, have to be made operational. For a rational and transparent assessment procedure it implies defining clear and unambiguous grading scales (cf. the meta-criteria). So, how is policy relevance assessed, according to which rules are two alternative, candidate indicators competing?

The use of meta-criteria is accentuated when there are conflicting demands between the criteria. There always are. The conditions are such that there almost always is a conflict between the criteria *low monitoring costs* and *informative value* or *policy relevance*. Which rule to balance them? Trade-offs between the criteria will be necessary. Another example, discussed by Jesinghaus (1998, p. 11) is whether to develop a more abstract indicator to *cover* more factors, versus a more *transparent* to be interpreted more easily.

The technique options for carrying out the assessments include empirical testing, model simulation testing, various deductive approaches, or Delphi-procedures.

5.6 Choice of indicators

The choice of which indicators to implement is a political decision, irrespective of whether the decision is made by politicians, officials or scientists (, since indicators in operation will influence future understanding of the problems and policy decisions). The only thing that will be pointed out here is the distinction between the results of an assessment of possible indicators and the final decision. An assessment does not automatically lead to implementation. Even the most strictly piloted assessment following given directives has subjective elements and restrictions in scope. These should as far as possible be clarified and documented. The political decision could then hopefully use the assessments simply as well-founded and documented recommendations on which indicators to run.

5.7 Concluding remarks

This chapter points to the potential of improving indicators and systems of indicators by the more systematic and rational use of criteria as a part of a coherent methodology. The review of criteria illustrates the wealth of options.

In practice, lack of data, insufficient knowledge about causal relations, restricted resources for refinement and measurement may enforce indicator designs that are far from perfect, and where the advanced use of criteria may seem to overdo it. As Opschoor and Reijnders (1991, p. 18) write: “The development of appropriate sets of indicators is a laborious undertaking and is likely to involve many ‘arbitrary’ decisions”. Still, even with this situation, criteria may serve as powerful means not just to get better indicators, but also to bring some confidence that they are better than the known alternatives, if not BPIs.

The distinction between indicator criteria and indicator system criteria should promote the development of more comprehensive approaches and a better total performance of the indicators. By introducing the concept of meta-criteria for indicators, the paper also aims at establishing or confirming the scientific foundation for the use of criteria.

The next step from this general, methodological basis would be to make the criteria operational. It is important that any criterion definition does not halt at the level of an intuitive term, like *relevance*, but is developed into an instrument capable of grading the indicators according to clearly stated, unambiguous scales. Not until then could alternative, candidate indicators be properly compared. There is a demand for general methodological development in this field, which does not exclude that the criteria in most cases will still have to be ultimately defined for the specific situation. This general demand with the demand to develop testing methods for assessing the indicators in terms of representativity, temporal responsiveness and other criteria is another challenge.

6. Developed indicators

6.1 Survey over the developed indicators

Two kind of indicators are developed: *landscape indicators* and *object indicators*. *Landscape indicators* are measured at the landscape level, while *object indicators* express the environmental qualities of a demarcated, single object in the landscape, for instance an alley or a field. All of them are listed in Table 2 and Table 3 below.

Intentionally, the very same indicators are proposed to be used all over Sweden. The reason is to increase the comparability between regions and the simplicity of the system. Between the regions may, however, be differences in the criteria for attaining a certain indicator value. And the outcome for the indicators' estimates may of course differ within between regions, study areas and objects.

Table 2. Preliminary list of landscape indicators for the Swedish agricultural landscape

Nº	Landscape indicator name	Page
L1	Area permanent grasslands	56
L2a	Qualitative area of grasslands	57
L2b	Area coastal and lake shore grasslands	58
L3	Dry, linear field elements (DLFE)	59
L4	Dry, point field elements (DPFE)	60
L5	Wet, linear field elements (WLFE)	61
L6	Wet, point field elements (WPFE)	62
L7	Forest edges (FE)	63
L8	Biorich trees (BT)	64
L9	Historic Relics (HR)	65
L10	Confirmation species of birds (CSB)	66
L11	Confirmation species of vascular plants (CSVP)	67
L12	Confirmation species of bryophytes and lichens (CSL)	68

* Whether the indicator will be monitored within the AEMBAC project in the study areas, or if it is proposed for the complete theoretical list of indicators, but cannot be monitored within the project owing to its resource constraints. AEMBAC/p signifies that the indicator will be partly, but not completely monitored according to its criteria by the project.

Table 3. Preliminary list of object indicators for the Swedish agricultural landscape

Nº	Object indicator name	Page
O1	Arable field indicator	70
O2	Permanent grassland indicator	72
O3	Linear elements indicator	73
O4	Point field elements indicator	79
O5	Forest edge indicator	77
O6	Biorich trees indicator	82
O7	Historic relic indicator	84

* Whether the indicator will be monitored within the AEMBAC project in the study areas, or if it is proposed for the complete theoretical list of indicators, but cannot be monitored within the project owing to its resource constraints. AEMBAC/p signifies that the indicator will be partly, but not completely monitored according to its criteria by the project.

There are seven object indicators developed, aimed to cover the biodiversity, cultural historic and socio-cultural landscape values of the Swedish agricultural land, as specified in Table 3 above. As stated above, they should accordingly cover all main, positive externalities of the agricultural landscape that are public goods.

Two of the indicators, O1 and O2, refer to the two main land use types, arable fields and permanent grasslands respectively. Accordingly, they are hectare based. Weighting for differing environmental variables, they are measured by qualitative hectares, qha. The next three object indicators refer to landscape elements within or along the fields, in order to detect the values with higher precision. Linear elements and forest edges are measured by qualitative meters, qm. Point elements are measured by qualitative numbers, qN°. A further focusing on specific value generating objects are the two final indicators, reflecting the qualities of biorich trees respective relics. These are two types of single entities related to extra high values.

6.2 Landscape indicators

The objective of the *landscape indicators* is to monitor the overall state and effects of agriculture at the landscape level, acknowledging that the object level sometimes is too myopic to handle the problem. There are at least two reasons.

First, even if impairments in some respect at each object is not important enough to give sufficiently strong incentives to improve the management, the aggregated effects at the landscape level may be alarming. None of the farmers may for example find it worthwhile to change his management to increase the population of some butterfly population for the little extra money it would give. The effect on a single object would not be worth it, but if the population declines at many objects the overall effects may call for reinforced measures.

Second, if land is abandoned the environmental state of a region may approach critical limits, even if the quality of the remaining objects are maintained.

The *landscape indicators* will thus operate on a “higher” regional or landscape level as a feedback and warning system, and only indirectly against the farmers. If they approach critical values, higher payments and other measures may be introduced for the region. It is about adjusting the policy measures rather than their application. (While, for example, a shift of an object indicator may rise some object from payment level 2 to 3, a shift in a landscape indicator may occasion the payments level 3 to be increased from 2 000 to 2 500 SEK/ha.)

Table 4. Area permanent grassland indicator at the landscape level. Preliminary design

Indicator n°, Indicator name	L1 (Landscape indicator 1); Area permanent grasslands
Definition	Total acreage of permanent pastures and permanent meadows, of all types within the landscape area. The grasslands are still managed, or have been managed at least three out of last five years. The grassland is registered as pasture or meadow.
Scale. Unit of measurement	Landscape level. Measure: Hectare/km^2 (= percent of total land area)
Purpose	Overall indication for the values and functions concerning: - Maintenance of fauna and flora populations /genetic resources - Maintenance of meadow and pasture biotopes - Preservation of historic landscape structure - Provision of aesthetic qualities - Provision of access - Maintenance of landscape character - Maintenance of fertile land
Limitations of the indicator	Crude measure since it does not pay regard to different qualities of grassland, or to different, non-substitute types of grasslands. Incomplete measure of biodiversity, cultural and social values, despite of having a wide covering of vital objects.
Alternatives	A set of similar but less aggregated indicators for different types of grasslands and different qualities of grassland.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	LS2: LS1 has a wider area covering than LS2 (includes all LS2-land) and a wider function/value covering than LS2. LS1 has less reliability (lower correlation co-efficient) to biodiversity than LS2, and thus less biodiversity relevance.
Measurement methodologies	GIS-survey or existing databases with maps over land use.
Data needed to compile the indicator,	Air photos, preferably in scale ≥ 1:15 000. Field survey data
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district. Land data bases are fairly reliable and up-to-date.

Table 5. Qualitative area grasslands indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L2a; Qualitative area grasslands
Definition	Acreage of permanent meadows and pastures in the two classes of highest biodiversity rank, according to the classification of biological object indicators.
Scale, unit of measurement	Landscape level. Measure: qualitative grassland area in percent of total land area: qha_{PG}/km^2, where the hectares, qha_{PG}, are calculated according to Table 19 and Table 20.
Purpose	Overall indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Preservation of historic landscape structure - Maintenance of traditional, rural cultural environments - Maintenance of flora from historic land use - Provision of aesthetic qualities - Provision of access - Maintenance of landscape character - Maintenance of meadow and pasture biotopes
Limitations of the indicator	Although it has a wide biodiversity covering, the indicator is too aggregated to show if some specific organism or habitat is threatened. Incomplete measure of landscape biodiversity, since it does not include biodiversity of field elements and other land use.
Alternatives	A set of similar but less aggregated indicators for different types of grasslands. A set of species based indicators only.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	LS1: LS1 has a wider area covering than LS2 (includes all LS2-land) and a wider function/value covering than LS2. LS1 has less reliability (lower correlation co-efficient) to biodiversity than LS2, and thus less biodiversity relevance. LS2b is horizontally related to LS2a. The reason for separating LS2b on shore pastures from other grasslands (LS2a) is that they are important for different species and that the former cover a much larger area while. Hence, important changes of other grasslands could be hidden by the large coastal area if covered by the same indicator.
Measurement methodologies	Air photos or existing land data bases (acreage) combined with field surveys (qualities).
Data needed to compile the indicator,	Air photos, preferably in scale ≥ 1:15 000. Sub-indicator values concerning structural qualities and species presence.
Data Availability and sources (including time series)	Fairly good, but quality measures have to be updated regularly, at least by 5-year intervals. The previous National Grassland Survey (Ä&H) is a useful as an intermediate measure, and the forthcoming survey (Ä&B) will serve as an input.

Table 6. Coastal and lake shore grasslands indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L2b; Area coastal and lake shore grasslands
Definition	Qualitative acreage of permanent meadows and pastures that are wet, humid or flooded and that border on lake or sea.
Scale, unit of measurement	Landscape level. Measure: qualitative water shore grassland area in percent of total land area: qha_{CG}/ha_{CG}, where the hectares, qha_{CG}, are calculated according to Table 19 and Table 20.
Purpose	Overall indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Preservation of historic landscape structure - Maintenance of traditional, rural cultural environments - Provision of aesthetic qualities - Provision of access - Maintenance of landscape character - Maintenance of meadow and pasture biotopes
Limitations of the indicator	Covers only biodiversity values. Although it has a wide biodiversity covering, the indicator is too aggregated to show if some specific organism or habitat is threatened. Incomplete measure of landscape biodiversity, since it does not include biodiversity of field elements and other land use.
Alternatives	A set of similar but less aggregated indicators for different types of grasslands. A set of species based indicators only.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	LS1: LS1 has a wider area covering than LS2 (includes all LS2-land) and a wider function/value covering than LS2. LS1 has less reliability (lower correlation co-efficient) to biodiversity than LS2, and thus less biodiversity relevance.
Measurement methodologies	Air photos or existing land data bases (acreage) combined with field surveys (qualities).
Data needed to compile the indicator,	Air photos, preferably in scale ≥ 1:15 000. Sub-indicator values concerning structural qualities and species presence.
Data Availability and sources (including time series)	Fairly good, but quality measures have to be updated regularly, at least by 5-year intervals. The previous National Grassland Survey (Ä&H) is a useful as an intermediate measure, and the forthcoming survey (Ä&B) will serve as an input.

Table 7. Dry, linear fields indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L3; Dry, linear field elements (DLFE)
Definition	Meters of qualitative DFLE per km^2 of agricultural land, multiplied by qualitative factors according to the criteria of respective object indicator as stated in Table 21 and Table 22. DFLEs are headlands, stone walls, field roads, alleys and soil embankments within or along the sides of arable fields, or stone walls within or along pastures .
Scale, unit of measurement	Landscape level. Measure: qm/km^2 (qm = qualitative meter)
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Maintenance of lichen, moss and fungi populations /genetic resourc.(stone walls) - Maintenance of field element biotopes - Preservation of historic landscape structure - Maintenance of traditional, rural cultural environments - Maintenance of small landscape elements representing historic agriculture - Maintenance of flora from historic land use - Provision of aesthetic qualities - Provision of access - Maintenance of landscape character
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, the indicator is too aggregated to show if some specific organism is threatened.
Alternatives	A set of similar but less aggregated indicators for different types of field elements. A more aggregated indicator for all types of field elements. A set of species based indicators only.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to L1-2, L4-12 for concerned values/functions. Non-overlapping with L1-2, L4-9 as concerns physical objects. Complementary to L10-12.
Measurement methodologies	Air photos or existing data bases.
Data needed to compile the indicator,	Quantitative measures of lengths and widths. Qualitative measures of grass/herb management status and occurrence of bushes and trees.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district. Land data bases are fairly reliable and up-to-date (??).

Table 8. Dry, point field elements indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L4; Dry, point field elements (DPFE)
Definition	The number of qualitative DFPE per km^2 of agricultural land, multiplied by qualitative factors according to the criteria of respective object indicator as stated in Table 25 and Table 26. DFPEs are permanent field islets, boulders, bedrock outcrops, and cultivation cairns within arable fields, according to the definitions for respective object indicators.
Scale, unit of measurement	Landscape level. Measure: qN°/km^2 (qN° = qualitative number)
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Maintenance of lichen, moss and fungi populations /genetic resources - Maintenance of field element biotopes - Preservation of historic landscape structure - Maintenance of small landscape elements representing historic agriculture - Maintenance of flora from historic land use - Provision of aesthetic qualities - Maintenance of landscape character
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, the indicator is too aggregated to show if some specific organism is threatened.
Alternatives	A set of similar but less aggregated indicators for different types of field elements. A more aggregated indicator for all types of field elements. A set of species based indicators only.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to L1-3, L5-12 for concerned values/functions. Non-overlapping with L1-3, L5-9 as concerns physical objects. Complementary to L10-12.
Measurement methodologies	Air photos or existing data bases.
Data needed to compile the indicator,	Quantitative measures of lengths and widths. Qualitative measures of grass/herb management status and occurrence of bushes and trees.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district. Land data bases are fairly reliable and up-to-date (??).

Table 9. Wet, linear field elements indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L5; Wet, linear field elements (WLFE)
Definition	Meters of qualitative WFLE per km^2 of agricultural land, multiplied by qualitative factors according to the criteria of respective object indicator as stated in Table 21 and Table 22. WFLEs are natural streams, excavated streams and ditches within or along the sides of arable fields or pastures.
Scale, unit of measurement	Landscape level. Measure: qm/km^2 (qm = qualitative meter)
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of mammal populations /genetic resources - Maintenance of reptile and batrachian populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Maintenance of moss populations /genetic resources - Maintenance of field element biotopes - Preservation of historic landscape structure - Maintenance of small landscape elements representing historic agriculture - Provision of aesthetic qualities - Maintenance of landscape character
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, the indicator is too aggregated for some specific organism to show if they are threatened.
Alternatives	A more aggregated indicator for all types of field elements. A more simple, but less relevant indicator for the same objects, but not considering qualitative differences. A set of species based indicators only.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to L1-4, L6-12 for concerned values/functions. Non-overlapping with L1-4, L6-9 as concerns physical objects. Complementary to L10-12.
Measurement methodologies	Air photos or existing data bases.
Data needed to compile the indicator,	Quantitative measures of lengths and widths. Qualitative measures of grass/herb management status and occurrence of bushes and trees.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district. Land data bases are fairly reliable and up-to-date (??).

Table 10. Wet, point field elements indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L6; Wet, point field elements (WPFE)
Definition	The number of qualitative WFPE per km^2 of agricultural land, multiplied by qualitative factors according to the criteria of respective object indicator as staed in Table 25 and Table 26. WFPEs are permanent ponds, marl pits, mires, and wells within arable fields or permanent grasslands, according to the definitions for respective object indicators.
Scale, unit of measurement	Landscape level. Measure: $qN°/km^2$ (qN° = qualitative number)
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of mammal populations /genetic resources - Maintenance of reptile and batrachian populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Maintenance of moss populations /genetic resources - Maintenance of field element biotopes - Preservation of historic landscape structure - Maintenance of landscape elements representing historic agriculture (marl pits) - Provision of aesthetic qualities - Maintenance of landscape character
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, the indicator is too aggregated to show if some specific organism is threatened.
Alternatives	A set of similar but less aggregated indicators for different types of field elements. A more aggregated indicator for all types of field elements. A set of species based indicators only.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to L1-5, L7-12 for concerned values/functions. Non-overlapping with L1-5, L7-9 as concerns physical objects. Complementary to L10-12.
Measurement methodologies	Air photos or existing data bases.
Data needed to compile the indicator,	Quantitative measures of lengths and widths. Qualitative measures of grass/herb management status and occurrence of bushes and trees.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district. Land data bases are fairly reliable and up-to-date (??).

Table 11. Forest edge indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L7; Forest edges (FE)
Definition	Meters of qualitative FE (qm) per km^2 of total land, where qm = meters of FE multiplied by qualitative factors according to the criteria for the object indicator of forest edges as stated in Table 21 and Table 22. It implies considering width of edge, occurrence of biorich trees, bacciferous shrubs, etc. FEs are measured along the sides of arable fields or permanent grasslands.
Scale, unit of measurement	Landscape level. Measure: qm/km^2 (qm = qualitative meter)
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of mammal populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Maintenance of lichen, moss and fungi populations /genetic resources - Maintenance of agricultural landscape biotopes - Preservation of historic landscape structure - Maintenance of small landscape elements representing historic agriculture - Maintenance of flora from historic land use - Provision of aesthetic qualities - Provision of access - Maintenance of landscape character
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, the indicator is too aggregated to show if some specific organism is threatened.
Alternatives	A more aggregated indicator involving FE plus all types of field elements. A more simple, but less relevant indicator for the same objects, but not considering qualitative differences. A set of species based indicators only.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to L1-6, L8-12 for concerned values/functions. Non-overlapping with L1-6, L8-9 as concerns physical objects. Complementary to L10-12.
Measurement methodologies	Air photos or existing data bases, combined with field surveys.
Data needed to compile the indicator,	Quantitative measures of lengths and widths. Qualitative measures of grass/herb management status, and occurrence of bushes and biorich trees.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district. Land data bases are fairly reliable and up-to-date (??). Little information about qualitative status of FEs.

Table 12. Biorich trees indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L8; Landscape's biorich trees (BT)
Definition	The number of BT per km^2 of agricultural land, according to the definition of BT in Table 27 and Table 28. BTs are trees with big, positive impacts on biodiversity, such as old, sun-exposed oaks. BTs may stand within arable fields and permanent grasslands, in forest edges or on field elements of any type (including alleys). See further the definition of BT in the definition of the BT object indicator.
Scale, unit of measurement	Landscape level. Measure: qN°/km^2 (qN° = qualitative number)
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of mammal populations /genetic resources (bats, rodents) - Maintenance of invertebrate populations /genetic resources - Maintenance of moss and fungi populations /genetic resources - Provision of aesthetic qualities - Maintenance of landscape character
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, the indicator is too aggregated to show if some specific organism is threatened.
Alternatives	A set of similar but less aggregated indicators for different types of field elements. A more aggregated indicator for all types of field elements. A set of species based indicators only.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to L1-7, L9-12 for concerned values/functions. Non-overlapping with L1-7, L9 as concerns physical objects. Complementary to L10-12.
Measurement methodologies	Air photos or existing data bases.
Data needed to compile the indicator,	Quantitative measures of lengths and widths. Qualitative measures of grass/herb management status and occurrence of bushes and trees.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district. Land data bases are fairly reliable and up-to-date (??).

Table 13. Historic Relics indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L9; Historic Relics (HR)
Definition	The number of HR per km^2 of agricultural land, according to the definition of HR in Table 29 and Table 30. HRs are obsolete agricultural buildings such as field barns, windmills and earth cellars, but also cultivation cairns, rune stones, ruins or grave mounds. BTs may stand within arable fields and permanent grasslands, on field elements of any type, or in edges between agricultural land and other land use. See further the definition of HR in the definition of the HR object indicator.
Scale, unit of measurement	Landscape level. Measure: N°/km^2
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of lichen and fungi populations /genetic resources - Maintenance of small landscape elements representing historic agriculture - Maintenance of traditional, rural cultural environments - Provision of aesthetic qualities
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions.
Alternatives	A more aggregated indicator for all types of field elements.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to L1-8, L10-12 for concerned values/functions. Non-overlapping with L1-8 as concerns physical objects. Complementary to L10-12.
Measurement methodologies	Air photos or existing data bases.
Data needed to compile the indicator,	Measures of the number of each type.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district. Land data bases are fairly reliable and up-to-date (??).

Table 14. Bird confirmation species indicator landscape level. Preliminary design

<table>
<tr><td>Indicator n°; Indicator name</td><td>L10; Confirmation species of birds (CSB)</td></tr>
<tr><td>Definition</td><td>The number of breeding locations of selected CSB within the demarcated land-scape area, including locations on non-agricultural land. The Selaö CSB and their criteria are:
<table>
<tr><th></th><th>Critical levels, Nº locations Rank -1</th><th>Acceptable, Nº of locations Rank 0</th><th>Good levels, Nº of locations Rank 1</th><th>Very good, Nº of locations Rank 2</th></tr>
<tr><td>Acanthis cannabina</td><td>0</td><td>1 – 3</td><td>4 – 6</td><td>> 6</td></tr>
<tr><td>Calidris alpina</td><td>0</td><td>1</td><td>2 – 3</td><td>> 3</td></tr>
<tr><td>Columba oenas</td><td>0</td><td>1 – 3</td><td>4 – 6</td><td>> 6</td></tr>
<tr><td>Jynx torquilla</td><td>0</td><td>1</td><td>2 – 5</td><td>> 5</td></tr>
<tr><td>Hirundo rustica</td><td>0</td><td>1 – 3</td><td>4 – 6</td><td>> 6</td></tr>
<tr><td>Lanius collurio</td><td>0</td><td>1 – 3</td><td>4 – 6</td><td>> 6</td></tr>
<tr><td>Limosa limosa</td><td>0</td><td>1</td><td>2 – 5</td><td>> 5</td></tr>
<tr><td>Motacilla flava</td><td>0</td><td>1 – 3</td><td>4 - 10</td><td>> 10</td></tr>
<tr><td>Numenius arquata</td><td>0</td><td>1 – 3</td><td>4 – 6</td><td>> 6</td></tr>
<tr><td>Oenanthe oenanthe</td><td>0</td><td>1 – 3</td><td>4 – 6</td><td>> 6</td></tr>
<tr><td>Sturnus vulgaris</td><td>0</td><td>1 – 5</td><td>6 – 20</td><td>> 20</td></tr>
<tr><td>Tringa totanus</td><td>0</td><td>1 – 3</td><td>4 - 10</td><td>> 10</td></tr>
<tr><td>Vanellus vanellus</td><td>0</td><td>1 – 3</td><td>4 - 10</td><td>> 10</td></tr>
</table></td></tr>
<tr><td>Scale, unit of measurement</td><td>Landscape level.
Measure, a 1·2-vector: (N° of CSB whose habit number rank = -1; average CSB-rank).[6]</td></tr>
<tr><td>Purpose</td><td>Indication for the values and functions concerning:
- Maintenance of bird populations /genetic resources</td></tr>
<tr><td>Limitations of the indicator</td><td>Concerns only some bird species directly, although it relevance also for some other biodiversity functions and values. The indicator is too selective to guarantee that no other bird specie is threatened. The indicator depends on regular field surveying.</td></tr>
<tr><td>Alternatives</td><td>An extended indicator of the same construction, based on more CSBs.
A set of indicators based on individual species.
No species based indicator, only structural indicators.</td></tr>
<tr><td>DPSIR category</td><td>State indicator</td></tr>
<tr><td>Linkages (relationships) to other state or pressures indicators</td><td>LS1- LS8: Supplementary to LS1,2,3,4,5,6,7,8 for bird values/functions. Overlapping with LS1,2,3,4,5,6,7,8 as concerns physical objects. LS10 is intended to double the control of the bird situation mutually with LS1,2,3,4,5,6,7,8. Independent indicator measurements from those of LS1,2,3,4,5,6,7,8.
LS8, LS9, LS11: No links.</td></tr>
<tr><td>Measurement methodologies</td><td>Field surveys, farmers self reporting.</td></tr>
<tr><td>Data needed to compile indicator,</td><td>Number of locations for each selected CSB.</td></tr>
<tr><td>Data Availability and sources</td><td>Local inventories, ATLAS inventory, Country board inventories, Farmland Bird Index, NILS</td></tr>
</table>

[6] Example: A landscape area with four *Charadrius hiaticula* locations (rank 1), only one *Motacilla flava* location (rank 0), c. 15 *Tringa totanus* locations (rank 2), and more than 100 *Vanellus vanellus* locations (rank 3) will take the indicator value (1; 2).

Table 15. Vascular plants confirmation species indicator at the landscape level. Preliminary design

Indicator n°; Indicator name	L11; Confirmation Species of Vascular Plants (CSVP)
Definition	The number of habitats for selected CSVP. (If, for example, two CSVP are observed on one field islet and six CSVP are observed on one pasture, it adds in total eight units to the indicator.) The selected CSVP are: *Antennaria dioica, Arnica Montana, Botrychium spp., Briza media, Carex pulicaris, Centaurium spp., Cirsium acaule, Crepis praemorsa, Dianthus arenarius, Dianthus deltoides, Euphrasia micrantha, Filipendula vulgaris, Gentianalla spp., Helianthemum nummularrium, Hieracium pilosella, Hypochoeris maculata, Koeleria glauca, Ophioglossaceae, Orchidaceae, Parnassia palustris, Pedicularis palustris, Pedicularis sylvatica, Polygala vulgaris, Primula farinose, Primula veris, Pulsatilla vulgaris, Rhinanthus serotinus, Ranunculus bulbosus, Ranunculus polyanthemos, Scorzonera humilis, Silene nutans, Thymus serpyllum, Trifolium montanum and Trollius europaeus.*
Scale, unit of measurement	Landscape level. Measure, qNº/km^2.
Purpose	Indication for the values and functions concerning: - Maintenance of vascular plant populations /genetic resources
Limitations of the indicator	Concerns only some vascular plants directly, although it has a wide biodiversity covering by being positively correlated to many other functions and values. The indicator is too selective to guarantee that no other specie is threatened. The indicator depends on regular field surveying.
Alternatives	An extended indicator of the same construction, based on more CSVPs. A set of indicators based on individual species. No species based indicator, only structural indicators.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	LS1- LS7: Supplementary to LS1,2,3,4,5,6,7 for vascular plant values/functions. Overlapping with LS1,2,3,4,5,6,7 as concerns physical objects. LS11 is intended to double the control of the vascular plant situation mutually with LS1,2,3,4,5,6,7. Independent indicator measurements from those of LS1,2,3,4,5,6,7. LS8, LS9, LS10: No links.
Measurement methodologies	Field surveys, farmers self reporting, existing survey data.
Data needed to compile the indicator,	Number of habitats for each selected CSVP.
Data Availability and sources	A national survey covering most permanent grasslands with a rich flora was carried out in 1988, and another is planned for 2002 – 2003, but neither will cover the flora of field elements and forest edges.

Table 16. Bryophyte, lichen and fungi confirmation species indicator at the landscape level. Preliminary design

<table>
<tr><td>Indicator n°; Indicator name</td><td>L12; Confirmation species of bryophytes and lichens (CSL)</td></tr>
<tr><td>Definition</td><td>The number of habitats of selected CSL. A CSL-habitat is distinguished from another CSL-habitat if the objects (pasture, field element) where the CSL grow are separated by ≥200m of other land use (forest, water, arable field, etc.). The Selaö CSL and their criteria are:
<table>
<tr><th></th><th>Critical levels, N° of habits /km^2. Rank 0</th><th>Acceptable, N° of habits/km^2. Rank 1</th><th>Good levels, N° of habits /km^2. Rank 2</th><th>Very good, N° of habits/km^2. Rank 3</th></tr>
<tr><td>Cliostomum corrugatum</td><td>0 – 0.5</td><td>0.5 – 1.0</td><td>1.0 – 2.0</td><td>> 2.0</td></tr>
<tr><td>Cyphelium inquinans</td><td>0 – 0.2</td><td>0.2 – 0.5</td><td>0.5 - 1.0</td><td>> 1.0</td></tr>
<tr><td>Lecanographa amylacea</td><td>0 – 0.5</td><td>0.5 – 1.0</td><td>1.0 – 2.0</td><td>> 2.0</td></tr>
<tr><td>Lobaria pulmonaria</td><td>0 – 0.5</td><td>0.5 – 1.0</td><td>1.0 – 2.0</td><td>> 2.0</td></tr>
<tr><td>Gyalecta ulmi</td><td>0 – 0.5</td><td>0.5 – 1.0</td><td>1.0 – 2.0</td><td>> 2.0</td></tr>
<tr><td>Cyphelium tigillare</td><td>0 – 0.5</td><td>0.5 – 1.0</td><td>1.0 – 2.0</td><td>> 2.0</td></tr>
<tr><td>Squamarina and Psora spp.</td><td>0 – 0.2</td><td>0.2 – 0.5</td><td>0.5 - 1.0</td><td>> 1.0</td></tr>
<tr><td>Hapalophilus croceus</td><td>0 – 0.2</td><td>0.2 – 0.5</td><td>0.5 – 1.0</td><td>> 1.0</td></tr>
<tr><td>Hygrocybe spp.</td><td>0 – 0.5</td><td>0.5 – 1.0</td><td>1.0 – 2.0</td><td>> 2.0</td></tr>
</table></td></tr>
<tr><td>Scale, unit of measurement</td><td>Landscape level.
Measure, a 1,2-vector: (N° of CSL whose habit number rank = 0; average CSL-rank).[7]</td></tr>
<tr><td>Purpose</td><td>Indication for the values and functions concerning:
- Maintenance of bryophytes and lichen populations /genetic resources</td></tr>
<tr><td>Limitations of the indicator</td><td>Concerns only some species directly, although it has a wider biodiversity relevance by being positively correlated to other functions and values. The indicator is too selective to guarantee that no other moss or lichen specie is threatened. The indicator depends on regular field surveying.</td></tr>
<tr><td>Alternatives</td><td>An extended indicator of the same construction, based on more CSLs.
A set of indicators based on individual species.
No species based indicator, only structural indicators.</td></tr>
<tr><td>DPSIR category</td><td>State indicator</td></tr>
<tr><td>Linkages (relationships) to other state or pressures indicators</td><td>L1-4,7-9: Supplementary to L1,2,3,4,7,8,9 for moss and lichen values and functions. Overlapping with L1,2,3,4,7,8,9 as concerns physical objects. L12 is intended to double the control of the moss and lichen situation mutually with LS1, 2,3,4,7,8,9. Independent indicator measurements from those of L1,2,3,4,7,8,9.
L8, L9, L10: No links.</td></tr>
<tr><td>Measurement methodologies</td><td>Field surveys, existing survey data.</td></tr>
<tr><td>Data needed to compile the indicator,</td><td>Number of habitats for each selected CSL.</td></tr>
</table>

[7] Example: A landscape area with c. 0.3 *Arnica montana* habitats/km^2 (rank 0), c. 0.4 *Gentianella spp*. habitats/km^2 (rank 1) and more than 3 *Pedicularis sylvatica* habitats/km^2 (rank 3) will take the indicator value (1; 1.33).

6.3 Object indicators

Object indicators are bounded to the separate object, be it either a pond or a pasture. Preferably they each express some values of the object in a form that could be directly transferred into policy measures targeted to that object. The payment to a pasture may, for instance, rise by 200 SEK/ha if its flora indicator (index) goes up from 3 to 4. An advantage of such a combination of object indicators and object targeted policy measures is that it gives clear signals of what is valuable and precise allocation of the resources.

It is necessary to have these *object indicators* to get an efficient policy, and it is these indicators that the farmers will confront.

Object indicators should be developed for all agricultural land. Since they differ in character, separate sets of indicators are developed for:

- arable fields, for
- permanent grasslands (pastures, meadows), and for
- landscape elements within or along fields, such as stone walls, field islets and permanent wood edges.

Table 17. Arable Fields indicator. Preliminary design

Indicator n°; Indicator name	O1 (Object indicator 1). Arable Fields (AF) indicator.
Definition	Hectares of qAL, qualitative AF, as calculated by $\mathbf{qAF = A \cdot C \cdot (R + \Sigma Q_B + \Sigma Q_H + \Sigma Q_S)}$. A is the acreage of the AF-object. AF-objects are arable fields as registered and delimited in the Agricultural Register by Statistics Sweden, SCB. C signifies the Cultivation status of the AF-object as stated in Table 18. R signifies the Region or district of the AF-object, for the case that society's demand for open fields is higher in some areas, whether because of primary interest for tourism, relative scarcity of agricultural land in the region, or other. Q_H signifies possible cultural historic priority for the PG as stated in Table 18. Q_S signifies the extra, cultural and social qualities of the PG as stated in Table 18.
Scale, unit of measurement	Object level. The smallest object is 0.2 ha. Measure: qha, qualitative hectares as calculated above.
Purpose	To indicate functions and values of arable fields related to merely the cultivated acreage, that is, that the landscape is kept open, etc. These values come in excess of those other connected to the AF but covered by the field element, forest edge and biorich trees indicators. Its purpose is mainly to indicate the values and functions concerning: - Maintenance of bird populations /genetic resources - Preservation of historic landscape structure - Maintenance of traditional, rural cultural environments - Provision of aesthetic qualities, openness - Provision of access (winter, cross country skiing) - Maintenance of landscape character - Maintenance of fertile land
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions.
Alternatives	- No indicator for AF. - A more relevant, but more complicated indicator, having a larger number of quality classes ($R+M+Q_H+Q_S$).
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to O2-6 for concerned values/functions. Non-overlapping with O2-6 as concerns physical objects.
Measurement methodologies	Air photo, maps or existing data bases.
Data needed to compile the indicator,	Quantitative measures of acreage of each PG. Qualitative measures for Q_S. Information about society's relative preferences for maintaining cultivated land in each region/district.
Data Availability and sources (including time series)	Good: maps and reliable databases are available.

Table 18. Preliminary parameter values and related criteria for quality factors to calculate the indicator Arable Fields, O1, of Table 17.

Arable Fields, AF	Factor*	Criteria (Comments)
Region/district	**R =**	
Nn, Nö (the Upper Norrland and Lower Norrland regions)	2	(Motivated by historic and aesthetic functions and values.)
Ssk, Gsk (Forest regions of Götaland and Svealand)	1.5	(Motivated by historic and aesthetic functions and values.)
Specific districts of primary interest	2	(Motivated by historic and aesthetic functions and values, including touristic.)
Other regions	1	
Cultivation	**C =**	
Active cultivation	1	The AF-object carried agricultural crops (but not energy forest) at least three of the five last years. It has no ligneous plants.
Grass fields	1.1	The AF-object carried a grass sward that was cut or grazed at least three of the five last years. It has no ligneous plants.
Other arable fields	0	
Biodiversity	**Q_B =**	Suggested variable, not applied in this study.
Spring flooded fields	($5 \cdot f$)	The field is tilled and flooded more than 2 weeks between 15/3-31/5. f is flooded/affected area in % of A.
Sandy fallows	(3)	Sandy fields in Skåne in fallow but cultivated at least once previous three years.
Cultural historic quality	**Q_H =**	
Old field	(1)	Cultivated before 1850. Suggested variable, not applied in this study.
Village or farm centre environment	0.5	The PG-object is not more than 50m far from farm or farm village in its closest edge. Max 5 ha
Historic importance	(0.5)	The field is classified by the Board of Antiquities as especially important for preserving historic landscape structures or cultural environments.
Other cultural and social qualities	**Q_S =**	
Visibility	0.5	The DLE can be seen from a road or a railway with more than XXX passengers/y.
Shape	(1)	Non-rectilinear contour, contour following terrain.
Slope fields	(0.5)	Average slope >5%.

* Factor weights in parentheses are for suggested variables, not included in this survey.

Table 19. Permanent Grassland indicator. Preliminary design

Indicator n°; Indicator name	O2. Permanent Grassland (PG) indicator.
Definition	Qualitative hectares of PG, as calculated by : $\mathbf{qha_{PG} = A \cdot C \cdot (T+M+G+I+\Sigma Q_B+\Sigma Q_H+\Sigma Q_S)}$ A is the acreage of the PG-object. PGs are meadows or pastures registered in the Agricultural Register by Statistics Sweden, SCB. T signifies the Type of grassland object, for the case that some kind of PGs are valued higher than others are. T can be motivated by general biodiversity, cultural and social values of the PG. It is thus a quality factor to multiply with the acreage, A. As with the other quality factors, the value of T can easily be changed if preferences change or new knowledge becomes available. See Table 20 for the preliminary criteria for T. Q_B signifies the biodiversity quality (besides qualities of biorich trees) of the PG-object as stated in Table 20. Q_B is supplementary to T, expressing biodiversity qualities not covered by T. Q_H signifies the cultural historic quality of the PG as stated in Table 20. Q_S signifies the extra, cultural and social qualities of the PG as stated in Table 20.
Scale, unit of measurement	Object level, or part of PG-object. The smallest object is 0.2 ha. If an object is divided into parcels of different qualities, the sum of parcels in each quality is ≥ 0.2ha. Measure: qha_{PG}, qualitative hectares as calculated above.
Purpose	Overall indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Maintenance of fungal and moss populations /genetic resources - Preservation of historic landscape structure - Maintenance of traditional, rural cultural environments - Maintenance of flora from historic land use - Provision of aesthetic qualities - Provision of access - Maintenance of landscape character - Maintenance of meadow and pasture biotopes
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, this structural indicator can not show directly if some specific organism is threatened.
Alternatives	- No indicator for PG. - A less relevant but simpler indicator on just the acreage of the PG-types: meadows, semi-natural pasture and cultivated, permanent pasture. - A more relevant, but more complicated indicator, having a larger number of quality classes ($T+Q_B+Q_H+Q_V$).
DPSIR category	State indicator
Linkages to other state or pressures indicators	Supplementary to the other proposed object indicators for all concerned values or functions. Non-overlapping with the other object indicators as concerns physical objects.
Measurement methodologies	Air photo: L, W, T, Q_B for trees and bushes, Q_H for width of stone walls, Q_V. Maps and existing data bases: Q_H for old village borders, Q_V for road traffic. Field survey/control: Q_B for vascular plant status, Q_H for conditions of stone walls
Data needed to compile the indicator,	Quantitative measures of acreage of each PG. Qualitative measures for $T+Q_B+Q_H+Q_S$.
Data Availability and sourc-es (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district.

Table 20. Preliminary parameter values and related criteria for quality factors to calculate the indicator Permanent Grassland, O2, of Table 19.

Permanent Grass-lands, PG	Fac-tor	Criteria (Comments)
Type of grassland	**T =**	
Meadow	10	
Semi-natural pasture	4	The pasture has never been cultivated, fertilized or sprayed.
Other maintained PG	1	
Farming	**C =**	
Active grazing or mowing	1	At least some non-negligible grazing or mowing
No grazing or mowing	0	Not grazed or mowed.
Maintenance	**M =**	
Poorly maintained	0	Some grazing or mowing but accumulated organic litter is > 5cm
Well Maintained	3	The grass sword is, in general, not higher than 0.2m at the end of the grazing or mowing season, and the accumulated organic litter is ≤ 5cm.
Trees and bushes	**G =**	
0 – 25 %	0.5	Trees and bushes cover 0 – 25 % of the surface
25 – 70 %	0	Trees and bushes cover 25 – 70 % of the surface
Invading brushwood	**I =**	
0 – 3 %	0	Young trees and bushes cover 0 – 3 % of the surface
3 – 10 %	-0.25	Young trees and bushes cover 3 – 10 % of the surface
>10 %	-0.75	Young trees and bushes cover > 10 % of the surface
Biodiversity quality	**Q_B =**	
Bird species	(0.5)	The object has well established breeding of at least three of the confirmation species listed in Table 14. Suggested variable, not applied in this study. May be rejected.
Invertebrate species	(0.5)	The object has well established populations of at least three of the listed confirmation species. Suggested variable for farmers' self-reporting, not applied in this study.
Vascular plant species: 1 – 3 4 – 6 > 6	 0.5 1 2	The object has well established populations of 1 – 3, 4 – 6, respective more than 6 of the confirmation species listed in Table 15.
Fungi and lichen species	(0.5)	The object has well established populations of at least 10 of the listed confirmation species. Suggested variable, not applied in this study. May be rejected.
Tree diversity	0.25	There are at least six of the species valued in Table 28.
Bushes diversity	0.25	There are at least six of the species: *Corylus avellana, Crateagus sp., Juniperus communis, Lonicera xylosteum, Lonicera perialymen, Prunus padua, Prunus spinosa, Rhamnus catharticus, Ribes alpinum, Ribes uva-crispa, Rosa sp., Sambucus nigra*
Cultural historic quality	**Q_H =**	
Historic land use	(0.5)	The PG exhibits clear, physical tracks of the historic land uses: flooding systems, archaic draining, etc. Suggested variable, not applied in this study.
Village or farm centre environment	0.2	The PG-object is not more than 50m far from farm or farm village in its closest edge.
Social qualities	**Q_S =**	Other cultural and social qualities
Visitors	0.4	The PG-object is less than 1 km away from a village /town with more than 200 inhabitants, or the PG-object has more than 100 different visitors/y for other reasons.
Visibility	0.5	The DLE can be seen from a road or a railway with more than XXX passengers/y.

Table 21. Linear field element indicator. Preliminary design

Indicator n°; Indicator name	O3. Linear elements (LE) indicator.
Definition	Meters of qLE, qualitative LE, calculated by: $\mathbf{qm_{LE} = L \cdot W \cdot (T+M+G+I+\Sigma Q_B+\Sigma Q_H+Q_V)}$ Headlands, stone walls, field roads, alleys, soil embankments natural streams, excavated streams and ditches within or along the sides of arable fields are eligible as LEs if they are at least 10m long and at least 0.1 m wide. Stone walls within or along pastures are also eligible. Except for stone walls and wood fences, LEs around point field elements of indicator O4 are not eligible as O3 LEs. L is the length and W is the width of the LE-object measured in meters. T signifies the Type of element, for the case that some kind of linear elements are valued higher than others are. T can be motivated by general biodiversity, cultural and social values of the LE. It is thus a quality factor to multiply with the length, L. As with the other quality factors, the value of T can easily be changed if preferences change or new knowledge becomes available. See Table 22 for the preliminary criteria for T. M, G and I signify the maintenance, tree & bush, respective invading brushwood status of the LE as stated in Table 22. Q_B signifies the biodiversity quality of the LE, besides the frequency of biorich trees, as stated in Table 22. Q_B is supplementary to T, expressing biodiversity qualities not covered by T. Q_H signifies the cultural historic quality of the LE as stated in Table 22. Q_V signifies the extra, visual qualities of the LE as stated in Table 22.
Scale, unit of measurement	Object level, or part of object (LE). The smallest object is 10m, and the smallest segment (or sum of separate but equally classified segments) of a larger LE is 25m. Measure: qm_{LE}, qualitative meters as calculated above.
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of reptile and batrachian populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Maintenance of lichen, moss and fungi populations /genetic resources - Maintenance of field element biotopes - Preservation of historic landscape structure - Maintenance of small landscape elements representing historic agriculture - Maintenance of flora from historic land use - Provision of aesthetic qualities - Provision of recreational access - Maintenance of landscape character
Relevance for environmental functions	Highly relevant for maintenance of bird, batrachian, invertebrate, bryophytes and lichen populations/genetic resources. Highly relevant for maintenance of field element biotopes, historic landscape structures, elements representing agricultural history, aesthetic, access and landscape character functions and values. Relevant for mammal, reptile, vascular plant and fungi populations/genetic resources and flora representing historic land use.
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, this structural indicator can not show directly if some specific organism is threatened.
Alternatives	- No indicator for LE. - A less relevant but more simple indicator on just the length and type of LE. - A more relevant, but more complicated indicator, having a larger number of quality classes. - An indicator based on arable fields only, and not directed to each LE. Such an indicator would take account of the amount of field elements within or along each field, and convert them into a value per hectare of the field.

Table continued.

Table 21 continued:

DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to the other proposed object indicators for all concerned values or functions. Non-overlapping with the other object indicators as concerns physical objects.
Measurement methodologies	Air photo: W, T, G, I, Q_B for trees and bushes, Q_H for width of stone walls, Q_V. Maps and existing data bases: Q_H for old village borders, Q_V for road traffic. Field survey/control: Q_B for vascular plant status, Q_H for conditions of stone walls Farmer self reporting: M, Q_B
Data needed to compile the indicator,	Quantitative measures of lengths and widths of each LE. Qualitative measures for $T+Q_B+Q_H+Q_V$.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district.

Table 22. Preliminary parameter values and related criteria for quality factors to calculate the indicator “Linear elements”, O3 of Table 21.

Linear elements, LE	Factor	Criteria (Comments)
Width	**W =**	
Vegetation strip	2	The LE has a vegetation strip wider than 2 m in total. (For a field road it refers to the sum of both strips on each side of the paved track, for a ditch the sum of strips beside water surface, etc.)
Other LE	1	
Type of element	**T =**	
Stone walls	5	
Wood fences	3	Traditional style; maintained
Streams	7	Natural groove, or restored to undulating groove.
Ditches	5	
Field road	3	
Alley	3	(Biorich trees in alleys and elsewhere are indicated by a separate indicator.)
Other LE	1	Including. headlands
Maintenance status	**M =**	
Not maintained	0	Constructed elements (stone walls etc.): in decay, or: Vegetation strip: not grazed or mowed
Poorly maintained	0.5	Constructed elements: < 10 % of length in decay, or: Some grazing or mowing but accumulated organic litter is > 5cm
Well maintained	3	Constructed elements: no parts in decay, and Vegetation strip: the grass sword is not higher than 0.2m at the end of the grazing or mowing season, no accumulated organic litter
Trees and bushes	**G =**	
0 – 10% 10 – 25% 25 – 50% > 50%	1.5 2 0.5 0	Tree & bush cover of the LE or the LE-segment in percent of its length.
Invading brushwood	**I =**	
0 – 3 %	0	Young trees and bushes cover 0 – 3 % of the surface
3 – 10 %	-0.5	Young trees and bushes cover 3 – 10 % of the surface
>10 %	-0.75	Young trees and bushes cover > 10 % of the surface
Biodiversity quality	**Q_B =**	
Vascular plant species: 1 – 3 4 – 6 > 6	 1 2 4	The object has well established populations of 1 – 3, 4 – 6, respective more than 6 of the confirmation species listed in Table 15.
Bushes diversity	0.25	There are at least four of the species: *Corylus avellana, Crateagus sp., Juniperus communis, Lonicera xylo-steum, Lonicera perialymen, Prunus padua, Prunus spinosa, Rhamnus catharticus, Ribes alpinum, Ribes uva-crispa, Rosa sp., Sambucus nigra*
Cultural historic quality	**Q_H =**	Suggested variables, not applied in this study.
Headland historicity	(5)	Older than 1850 or property border
Stone-walls historicity	(10)	> 1850, village border, or otherwise specific
Ditches historicity	(10)	Older than 1850 or hand-digged traditional
Field road historicity	(20)	Older than 1945 and > 100 m long
Alley historicity	(20)	Older than 1900
Visual quality	**Q_V =**	
All LE	0.4	The LE can be seen from a large road or a railway.

Table 23. Forest edge indicator. Preliminary design

Indicator n°; Indicator name	O4. Forest Edge (FE) indicator.
Definition	Meters of qFE, qualitative FE, calculated by $\mathbf{qm_{FE} = L \cdot (D+W+T+M+\Sigma Q_B+Q_V)}$. Edges between forest and arable land or permanent grasslands are eligible if longer than ≥10m. Heterogeneous FE can be divided into separate objects according to criteria classes of Table 24. Minimum length of segments = 40 m. The FE-zone is 20 m wide from cultivated soil towards forest land. L is the length of the LE-object measured in meters. D states if the FE is dominated be deciduous trees according to Table 24. W, T and M signify depth, type and maintenance of FE as stated in Table 24. Q_B signifies the biodiversity quality of the LE as stated in Table 24, besides the frequency of biorich trees. Q_B is supplementary to W, T and M, expressing biodiversity qualities not covered by them. Q_V· signifies the extra, visual qualities of the LE as stated in Table 22.
Scale, unit of measurement	Object level, or part of object (FE). The smallest object is 10m. The smallest segment (or sum of separate but equally classified segments) of a larger LE is 40m. Measure: qm_{LE}, qualitative meters as calculated above.
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of reptile and batrachian populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Maintenance of lichen, moss and fungi populations /genetic resources - Maintenance of field element biotopes - Preservation of historic landscape structure - Maintenance of small landscape elements representing historic agriculture - Maintenance of flora from historic land use - Provision of aesthetic qualities - Provision of recreational access - Maintenance of landscape character
Relevance for environmental functions	Highly relevant for maintenance of bird, batrachian, invertebrate, bryophytes and lichen populations/genetic resources. Highly relevant for maintenance of field element biotopes, historic landscape structures, elements representing agricultural history, aesthetic, access and landscape character functions and values. Relevant for mammal, reptile, vascular plant and fungi populations/genetic resources and flora representing historic land use.
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, this structural indicator can not show directly if some specific organism is threatened.
Alternatives	- No indicator for FE. - A less relevant but more simple indicator on just the length of FE. - A more relevant, but more complicated indicator, having a larger number of quality classes. - Indicators only for arable fields respective grasslands, and not separate for each FE. Such land-indicators would still take account of the amount of FE along each field or pasture, and integrate them into their value of the field (pasture).

Table 24. Preliminary parameter values and related criteria for quality factors to calculate the indicator "Forest edges", O4 of Table 23.

Forest edges, FE	Fac-tor	Criteria (Comments)
Deciduous edge	**D** =	
Deciduous edge	2	≥50% of the FE has canopies of deciduous trees. The FE-zone is 20 m wide from cultivated soil towards forest land.
Other FE	1	
Depth	**W =**	(Motivated by flora, invertebrate and recreation access)
Open forest edge	1	Strips or patches of grass and herbs with total width from cultivated soil to dense forest > 10m in average for the segment. (Dense forest: >70% of surface covered by tree canopies.)
Other FE	0	
Type of forest edge	**T =**	
Stratified FE	3	>33% of the FE (20 m zone) are covered by bushes or low tree species.
Other FE	0	FE is more or less a compact wall of trees
Maintenance	**M =**	
Poorly maintained	0,5	Some grazing or mowing but accumulated organic litter is > 5cm
Well maintained	3	The grass sword is, in general, not higher than 0.2m at the end of the grazing or mowing season, and the accu-mulated organic litter is ≤ 5cm.
Biodiversity quality	**Q_B =**	
Vascular plant species: 1 – 3 4 – 6 > 6	 1 2 4	The object has well established populations of 1 – 3, 4 – 6, respective more than 6 of the confirmation species listed in Table 15.
Visual quality	**Q_V =**	
All LE	0.4	The LE can be seen from a road or a railway with more than XXX passengers/y.

Table 25. Point field elements indicator. Preliminary design

Indicator n°; Indicator name	O5. Point field elements (PFE) indicator.
Definition	Field islets, boulders, flat rocks, ponds and wetlands within arable fields are eligible as PFEs if they are at least 2m long or 0.0002 – 0.5 ha. All the PFE-area is included in the PFE, which means that there are no headlands or other linear elements circumfering the PFE to be included in the LE-indicator O3. To be considered as a separate field islet, it has to be surrounded by ≥2m of cultivated soil in all directions. Biorich trees in alleys and elsewhere are measured by a separate indicator. Cultivation cairns and other historic relics are also measured by a separate indicator, see Table 27 and Table 29. Qualitative PFE, qPFE, as calculated by **qFE = S·(T+G+M+ΣQ$_B$+ΣQ$_H$+Q$_V$)**. S is the seize of the PFE-object as stated in Table 26. T signifies the Type of element, for the case that some kind of point elements are valued higher than others are. T can be motivated by general biodiversity, cultural and social values of the LE. It is thus a quality factor to multiply with the seize factor, S. As with the other quality factors, the value of T can easily be changed if preferences change or new knowledge becomes available. See Table 22 for the preliminary criteria for T. Q_B signifies the biodiversity quality of the PFE, besides the frequency of biorich trees, as stated in Table 26. Q_B is supplementary to T, expressing biodiversity qualities not covered by T. Q_H signifies the cultural historic quality of the LE as stated in Table 26. Q_V signifies the extra, visual qualities of the LE as stated in Table 26.
Scale, unit of measurement	Object level. Measure: unit of qPFE as calculated above.
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of mammal populations /genetic resources - Maintenance of reptile and batrachian populations /genetic resources - Maintenance of invertebrate populations /genetic resources - Maintenance of vascular plant populations /genetic resources - Maintenance of bryophyte and fungi populations /genetic resources - Maintenance of field element biotopes - Maintenance of small landscape elements representing historic agriculture - Maintenance of flora representing historic land use - Provision of aesthetic qualities - Maintenance of landscape character
Relevance for environmental function	Highly relevant for maintenance of bird, batrachian, invertebrate, bryophytes and lichen populations/genetic resources. Highly relevant for maintenance of field element biotopes, elements representing agricultural history, aesthetic, and landscape character functions and values. Relevant for mammal, reptile, vascular plant and fungi populations/genetic resources and flora representing historic land use.
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, this structural indicator can not show directly if some specific organism is threatened.
Alternatives	- No indicator for PFEs. - A less relevant but simpler indicator on just the existence of a PFE (no differentiating in seize or quality classes). - A more relevant, but more complicated indicator, having a larger number of quality classes (T+M+Q_B+Q_H+Q_V). - An indicator based on arable fields only, and not directed to each PFE. Such an indicator would take account of the amount of field elements within each field, and convert them into a value per hectare of the field.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to the other proposed object indicators for all concerned values or functions. Non-overlapping with the other object indicators as concerns physical objects.

Measurement methodologies	Air photo: S, T, G, M, , Q_V. Maps and existing databases, GIS: S and T. Field survey/control: Q_B, Q_H, M (supplementary to air photo) Farmer self reporting: Q_H , vascular plant confirmation species
Data needed to compile the indicator,	Quantitative measures of units and sizes of LEs. Qualitative measures for $T+Q_B+Q_H+Q_V$.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district.

Table 26. Preliminary criteria and their parameter values for quality factors to calculate the indicator "Point field elements", O5 of Table 25.

Point field elements, PE	Fac-tor	Criteria (Comments)
Type of element	**T =**	
Field islets	1	
Ponds, not sun-exposed	1	
Ponds , partly sun-exposed	3	25-75% of pond is in shadow
Ponds, sun-exposed	5	<25% of pond is shaded. (Motivated mainly by batra-chian, invertebrate and aesthetic functions and values.)
Wetland	3	
Pollards	1	(Possible criteria: size: trunk diameter of pollard. Tree species qualified)
Flat rock or boulder	0.25	
Other LE	1	
Seize of field islet	S =	
Large field islets	2	If field islet is larger than 0.1 ha. (i.e. 0.1 – 0.5 ha)
Small field islets + other PE	1	
Trees and bushes	**G =**	
0 – 10%, open grass herb 10 – 50% 50 – 90% > 90%, deciduous > 90%, conifer	3 4 1 1 0	Tree & bush cover of the PE or the LE-segment in percent of its area. Deciduous grove, > 50% of canopies are deciduous
Maintenance status	**M =**	
Poorly maintained	0	Some grazing or mowing but accumulated organic litter is > 5cm
Well Maintained	3	The grass sword is, in general, not higher than 0.2m at the end of the grazing or mowing season, and the accu-mulated organic litter is ≤ 5cm.
Biodiversity quality	**Q_B =**	Suggested variable, just partly surveyed in this study
Vascular plant species: 1 – 3 4 – 6 > 6	 1 2 4	The object has well established populations of 1 – 3, 4 – 6, respective more than 6 of the confirmation species listed in Table 15.
Bushes diversity	0.25	There are at least four of the species: *Corylus avellana, Crateagus sp., Juniperus communis, Lonicera xylo-steum, Lonicera perialymen, Prunus padua, Prunus spinosa, Rhamnus catharticus, Ribes alpinum, Ribes uva-crispa, Rosa sp., Sambucus nigra*
Cultural historic quality	**Q_H =**	
Marl-pits	1	
Fish-ponds at manor houses	1	
Visual quality	**Q_V =**	
All LE	0.5	The LE can be seen from a road or a railway with more than XXX passengers/y.

Table 27. Biorich trees indicator. Preliminary design

Indicator n°; Indicator name	O6. Biorich trees (BT)
Definition	qBT = the number of qualitative biorich trees on agricultural land. BTs are trees with big, positive impacts on biodiversity, such as old, sun-exposed oaks. BTs may stand within arable fields and permanent grasslands, in forest edges or on field elements of any type (including alleys). See further the definition of BT in Table 28. qBT is calculated by $\mathbf{qBT = S \cdot (T + Q_B + Q_V)}$, where S = Size of BT as stated in Table 28, T = Type, species of the BT as stated in Table 28, Q_B= Biological Qualities of the BT in addition to those of factors S and D, as stated in Table 28, Q_V = Visual qualities of the BT as stated in Table 28
Scale, unit of measurement	Object level. Measure: qBT, number of qualitative BTs.
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of mammal populations /genetic resources (bats, rodents) - Maintenance of invertebrate populations /genetic resources - Maintenance of bryophyte and fungi populations /genetic resources - Provision of aesthetic qualities - Maintenance of landscape character
Relevance for environmental function	Highly relevant, especially for some bird, invertebrate and lichen populations and genetic resources, as well as for landscape aesthetic and identity qualities.
Limitations of the indicator	Only partial covering of the physical base for the listed values and functions. Although it has a wide biodiversity covering, the indicator is too aggregated to show if some specific organism is threatened.
Alternatives	- Not considering the values of BTs. - Integrating the values of the BTs into the quality factors for the indicators on arable fields, permanent grasslands, linear and point elements, O1, O2, O3, O4.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to the other proposed object indicators for all concerned values or functions. Non-overlapping with the other object indicators as concerns physical objects.
Measurement methodologies	Air photos, or in the future satellite photos: Canopy width, sun-exposed, Q_V Field survey: Tree species, coarse trunks Farmers' self reporting: Hollow trunks
Data needed to compile the indicator,	Quantitative measures of number of trees. Qualitative measures on status of the BTs.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district.

Table 28. Preliminary criteria for calculating the indicator “Biorich trees”, O6 of Table 27.

Biorich trees, BT	Factor*	Criteria (Comments)
Size	**S =**	
Canopy width	1	Canopy width is ≥ 8 in diameter
Coarse trunks	(8)	Trunk chest perimeter ≥ 1.5 m
Other trees	0	.
Species of the BT	**T =**	
Aspen, *Populus tremula* Beech, *Fagus silvatica* Oak, *Quercus robur/petraea*	2	(Motivated by mammal, bird, invertebrate and lichen functions and values.) *Populus tremula* valuable if old, coarse.
Ash, *Fraxinus excelsior* Crap-apple, *Malus sylvestris* Elm, *Ulmus glabra* Lime, *Tilia cordata, T. platyphyllos* Maple, *Acer platanoides* Rowan, *Sorbus aucuparia* Swedish whitebeam, *Sorbus intermedia* Wild cherry, *Prunus avium* Willow, *Salix caprea*	1	
All other trees	0	
Biodiversity quality	**Q_B =**	
Sun-exposed BT	(1)	If S = 1 and there is no object closer to the BT then its own height in 180° E-S-W directions
Hollow trees	(1)	The BT has well-marked hollows. (Motivated by bat, bird and invertebrate functions and values.) May add to sun-exposed factor.
Visual quality	**Q_V =**	
Sight BT	0.2	The BT is a solitary BT and can be seen from a road or a railway with more than XXX passengers/y.

* Factor weights in parentheses are for suggested variables, not included in this survey.

Table 29. Historic Relics indicator. Preliminary design

Indicator n°; Indicator name	O7. Historic relics (HR)
Definition	qHR = agricultural relics and cultural historic monuments on agricultural land. HRs may stand within arable fields and permanent grasslands, in forest edges or on field elements of any type (including alleys). See further the definition of HR in Table 30. qHR is calculated by **$qHR = T \cdot (M + Q_B + Q_V)$**, where T = Type of HR as stated in Table 30, M = Management status as stated in Table 30, Q_V = Visual qualities of the HR as stated in Table 30.
Scale, unit of measurement	Object level. Measure: qHR, number of qualitative HRs.
Purpose	Indication for the values and functions concerning: - Maintenance of bird populations /genetic resources - Maintenance of bryophytes and lichen populations /genetic resources - Maintenance of small landscape elements representing historic agriculture - Maintenance of traditional, rural cultural environments - Provision of aesthetic qualities - Maintenance of landscape character
Limitations of the indicator	Some covering of the physical base for the listed biodiversity values and funct-ions. Good covering of the physical base for the listed historic values and funct-ions.
Alternatives	- A more aggregated indicator, integrating HR-indicator O6 with field element indicators O3 and O4. - No indicator for HR.
DPSIR category	State indicator
Linkages (relationships) to other state or pressures indicators	Supplementary to the other proposed object indicators for all concerned values or functions. Non-overlapping with the other object indicators as concerns physical objects.
Measurement methodologies	Air photo and existing GIS data bases: T, Q_V Field survey/control: M
Data needed to compile the indicator,	Measures of the number of each type.
Data Availability and sources (including time series)	Air photos are presently taken with many years interval, why the up-to-dateness varies from district to district. Land data bases are fairly reliable and up-to-date (??).

Table 30. Preliminary criteria and their parameter values for quality factors to calculate the indicator “Relics”, O7 of Table 29.

Historic relics, HR	Fac-tor	Criteria (Comments)
Type of relic/monument	**T =**	
Stone cairn	1	Stone cairn from past cultivation
Rune stone	10	
Ancient grave field	10	
Ruin, house foundations old	10	Older than 1750
Ruin, house foundation young	2.5	< 1750
Wind-mill	8	
Field barn, plank type	2.5	
Field barn, timbered	8	
Linen house	8	
Other historic field buildings	8	
Management status	**M =**	
Detached HR	1.5	There are no bushes or trees in front of the HR, and the grass and herb vegetation is cut or grazed ≤10 cm at least once in the period June 15 – August 15 on the HR or in a 3m radius of it. (Motivated by visibility and access.)
Other HR	1	
Very good state of buildings	2	The roof is water-proof, no broken exterior parts, only traditional building materials
Good state of buildings	1	
Poor state of buildings	0,5	The roof is leaching, significantly broken walls or other essential parts
Biodiversity quality	**Q_B =**	
Stone cairn	0.5	
Field barn	0.2	
Visual quality	**Q_V =**	
All LE	0.5	The LE can be seen from a road or a railway with more than XXX passengers/y

7. Direct and indirect state indicators for biodiversity

By Svante Hultengren, with supplements by Knut Per Hasund

The developed indicators that are presented in Table 4 to Table 30 above is an effort to make operational a wide set of considerations of many kinds. This chapter gives a part of the biodiversity background, and discusses direct and indirect biodiversity indicators in relation to criteria for their practical use.

The main idea of using indicators is to make the policy more efficient: alarming situations can be discovered, prioritisation becomes easier and cheaper, etc. By the use of a small number of easily measured indicators, biodiversity values of wide areas can be traced easily and cost efficiently.

Two major types of biodiversity indicators occur:

- species based, “direct” indicators, and
- structure based, “indirect” indicators.

The principle of species based indicators is to find some suitable species that reflect biological values in a wider sense. Structure indicators measure physical phenomena in the landscape that are correlated with the biodiversity values of interest. Both types are discussed in the following text.

7.1 Species are direct indicators for biodiversity

Indicator species are supposed to occur along with several rare or red-listed species or specific management types. Some indicator species are so dependent on a precise type of ecosystem management that they will disappear only a few years after the cessation of the appropriate management.

The Swedish, nation-wide inventory of grasslands (Naturvårdsverket 1987, 1997) was mainly based on identification of indicator species, both ”positive” and ”negative” indicators. Negative impacts was indicated by for example dandelions *Taraxacum spp*., Cow Parsley *Anthriscus sylvestris* and nettle *Urtica dioica*, which are all favoured by abundant soil nitrogen from fertilizers and/or due to lack of sufficient management. Others features, such as specific types of vegetation and species, indicate positive features in terms of biodiversity. These indicators show the influence of management in the habitats. Some of these indicators respond quickly, other slowly, to changes in the management or environmental conditions.

In the first column of Table 32, a number of species are listed, which are suggested to be strong indicators of high conservation values in various segments of the agricultural landscape. This set of species was selected based on ideas similar to those of Cederberg (2001).

7.2 Physical elements as indirect indicators

Another way of using indicators indirectly is to identify elements strongly associated with the presence of biological values in terms of vegetation types or species. In Swedish forestry, such a method has been frequently used to map biological qualities. The number of dead trees, old trees, tree species composition and dead trees on the ground were counted and then assigned points (Drakenberg & Lindhe 1999). The number of points suggests the level of conservation value. A similar kind of measures has also been used in the agricultural landscape in order to prioritise agri-environmental payments in relation to the number of trees in alleys, length of stone fences, area of meadows, etc.

Habitat condition indicators, such as grazing or mowing intensity, the condition of stone walls, etc. are quite useful in this context. They are likely to be strong indicators of biological diversity. Table 31 shows an overview of the chief orders of plants and animals and their habitats in the agricultural landscape.

7.3 Advantages and disadvantages of the indicator types

The main difference between the indicator-systems described above is that systems based on indicator species is a direct, qualitative system where the demanded qualities are identified and verified together, while in the case of object indicators the relationship with biodiversity values is statistical and indirect.

In the former type of system, a high indicator estimate implies that a certain species definitely occur. The disadvantage with this kind of system is that it is time-consuming and therefore more expensive. It also requires skilful and well-educated personnel to execute the inventories and it puts high demands on the indicator value of the chosen species. Temporal variability in the possibility to identify certain organisms complicates the use of these species as indicators. Many vascular plant species, for example, may be reliably identified only during restricted parts of the growing season, and that many fungi have a very strong year-to-year variability in the occurrence of fruit bodies.

Indirect indicators are more easily quantified, also by less skilled personnel. By counting the number of indirect indicators it is possible to make a fair estimate of the conservation values of an area. A disadvantage is that this kind of indicators may fail to show the qualities of an area accurately, since the number of indicator objects (quantity) does not necessarily stand in direct relation to the values in terms of rare or endangered species etc (quality). There is thus at least a theoretical risk that indirect indicators may lead to a low valuation of areas with high species qualities, and vice versa.

Concerning measurability, the experience from the LiM-project is that:

- The cultural-historical nature types were well defined and easy to examine and classify both from CIR aerial photographs and in the field.
- The vegetation types were more difficult to delimit. There seems to be a gap in knowledge regarding the classification of semi-natural grasslands in temperate climate, and further research is needed.
- The selected vascular plant species were found to be good indicators of ancient meadows and pastures as well as management type. Certain species are used to identify continued long-term management and also different succession phases when management ceases.
- The method with combination of interpretation in CIR aerial photographs and fieldwork, has been very quick, efficient and reliable. The aerial photos allows a systematic survey, with total cover, identification and selection of among other things vegetation types, cultural-historical nature types and cultural traces, with potential high value. The field documentation gives of the values by identification of indicator plant species. Areas with disturbances could thus easily be excluded from an early phase in the survey.
- The combination of field work with aerial photo interpretation is the key to good results. Without detailed plant-ecological field work the best photo-interpretation will mostly not be good enough.

(Ihse & Lindahl 2000)

A combination of a limited number of easily identified, good indicator species (species level), together with simple but strong vegetation type indicators (vegetation level) and well defined indicator objects and structures (structural level, object level) are here suggested to be a favourable compromise between different indicator strategies. Also, landscape level indicators, such as calcareous soils or the topography, may improve the system. A set of indicators on the five different levels is likely to provide a cost-efficient tool for setting priorities of economic support for conservation measures in the agricultural landscape. Table 32 presents a number of candidates of such indicators on five different levels, their relations to criteria and relative importance.

Table 31. Chief plant and animal orders and their most important habitats in the agricultural landscape.
The table also shows indirect indicators (object or structural indicators). The bottom line shows the total score as an indication of the estimated, accumulated value for biodiversity.

	alleys	pasture	unpaved roads	pollards	limerich soil	unpainted buildings	solitary oaks	stone fences	wooden fences	meadows	rocky outcrops	open ditches	shore meadows
mammals	•	•	•	••	•	•	•	••	•	•	•	••	••
Birds	•	•	•	••	•	•	••	••	•	•	•	••	••
insects	••	••	••	••	••	•	•••	•	•	••	••	••	••
Vasc. plants	•	•••	•	•	•••	•	•	•	•	•••	••	••	••
lichens	•••	•	•	•••	••	••	•••	••	••	•	•••	•	•
mosses	••	••	•	••	•••	•	••	••	•	•	•••	•	•
Fungi	••	•••	•	••	•••	•	••	•	•	••	••	•	•
Acc. value	12	13	8	12	15	8	15	11	8	11	14	11	11

7.3.1 Biodiversity indicators assessed by criteria

Table 32 below shows a system of developed biodiversity indicators. They are divided into five levels: the species, the vegetation, the object, the structural and the landscape levels. These indicators should not be considered as alternatives to the indicators of Table 4 - Table 30 above, but rather as a way to describe the same indicator foundations, detailed in other aspects. Important criteria for designing a certain indicator have been: *relevance, sensitivity/responsiveness, measurability, monitoring costs & efficiency*, *analytical soundness*, *conceptual clarity* and *simplicity*. These criteria have been given scores from (*) to (***) depending on the estimated strength of each criterion. (*) denotes “good”, (**) “very good” and (***) “excellent”. A summation of the values has been made resulting in the suggested ”indicator usefulness”. Dark red colour represents the best indicators. The second column shows the unit for each indicator, while the third shows the identification level. *Field* means that field investigation is essential, while *A.ph* means analysis by aerial photographs.

An example of the interaction between the different levels in the hierarchy of indicators: Suppose that we find a hay meadow (structural level), which contains *Scorzonera* vegetation (vegetation level), which in turn holds the rare species *Gentianella amarella* (species level). This piece of meadow has a higher value than a hay meadow, which may look similar at a glance, but does not contain the valuable elements at the species or vegetation level. Similarly, the object level can be valuated based on species and/or vegetation values. The species level always shows the most direct conservation values.

The suggestions made in Table 32 should be interpreted as very preliminary. It is a selection of indicators based on information found in the literature (e.g. Arvidssson & Thor 1999, Hallingbäck 1998, Larsson 1997, Aronsson 1999) as well as information obtained from experts in the field. Table 32 is going to be revised and supplemented with SMS values for each of the indicators.

Table 32. Assessment of state indicators for biodiversity

	Organism group	Maesur-able unit	Identifica-tion level	Relevance	Sensitivity /respon-siveness	Measur-ability	Monitor-ing costs	Analyt. Sound-ness	Conceptu al clarity	Simplicity	Indicator usefulness*	Important habitat
SPECIES LEVEL												
Amphibians	VER	Number (n)	field	**	**	**	*	***	***	*		Ponds
Arnica montana	VAS	cover (m2)	field	***	**	**	**	**	***	**		Moving, grazing
Charadrius hiaticula (Ringed Plover)	VER	Number (n)	field	**	**	**	**	**	***	**		Graz.mov. shore veg.
Cliostomum corrugatum	LIC	Number (n)	field	***	**	***	**	***	***	**		Solitary oaks
Cyphelium inquinans	LIC	Number (n)	field	***	***	***	**	***	***	***		Sunlit wood, bark
Cyphelium tigillare	LIC	Number (n)	field	**	***	***	**	***	***	***		Sunlit wood
Fistulia hepatica	FUN	Number (n)	field	**	*	**	*	**	***	**		Old oaks
Gentianella spp.	VAS	Number (n)	field	***	***	*	**	***	***	**		Calc., mowing, grazing
Gnorimus spp.	INS	Number (n)	field	**	**	**	**	**	***	*		Old oaks
Gyalecta ulmi	LIC	Number (n)	field	***	**	***	**	***	***	***		Pollards
Hygrocybe spp.	FUN	Number (n)	field	***	***	*	*	**	***	*		moving, grazing
Leptogium corniculatum	LIC	Number (n)	field	***	**	***	**	***	***	**		Rock outcrops
Lobaria pulmonaria	LIC	Number (n)	field	**	**	***	**	**	***	***		Old broadleafs
Motacilla flava (Yellow Wagtail)	VER	Number (n)	field	***	***	**	**	***	***	**		Graz.mov. shore veg.
Opegrapha illecebrosa	LIC	Number (n)	field	***	**	***	**	**	***	**		Old oaks

Continued

Table continued

	Organism group	Maesurable unit	Identifica-tion level	Relevance	Sensitivity/responsiveness	Measur-ability	Monitoring costs	Analyt. soundness	Conceptual clarity	Simplicity		Important habitat
Orchids (Dactylorhiza, Orchis spp.)	VAS	Number (n)	field	***	**	**	**	***	***	***		Moving, grazing
Osmoderma eremita	INS	Number (n)	field	***	**	***	**	***	***	**		Old oaks, pollards
Pedicularis sylvatica	VAS	Number (n)	field	***	***	**	**	***	***	***		Moving, grazing
Small rodents and lizards	VER	Number (n)	field	**	**	*	*	**	***	*		stone walls, fences
Squamarina and Psora spp.	LIC	Number (n)	field	**	**	**	**	**	**	**		Calc. grazed soils
Tringa totanus (Redshank)	VER	Number (n)	field	***	***	**	**	***	***	**		Graz.mov. shore veg.
Vanellus vanellus (Lapwing)	VER	Number (n)	field	**	***	***	**	***	***	**		Arable fields
VEGETATION LEVEL												**Important organisms**
Agrostis vegetation (grazed)		cover (ha)	field	***	**	***	**	***	***	**		Vascular plants, fungi, insects
Dry meadow vegetation (grazed)		cover (ha)	A.Ph/f	***	**	***	**	***	***	**		Vascular plants, insects
Fen vegetation (grazed)		cover (ha)	field	***	***	**	**	**	**	***		Vascular plants, insects
Heath vegetation		cover (ha)	A.Ph/f	***	**	***	***	**	**	***		Insects, birds
Lake shore vegetation (grazed)		cover (ha)	A.Ph	***	**	***	***	***	***	***		Birds, insects
Nardus vegetation		cover (ha)	field	***	**	***	**	***	***	**		Vascular plants, fungi
Scorzonera vegetation		cover (ha)	field	***	**	***	**	***	***	**		Vascular plants, fungi
Sea shore vegetation (grazed)		cover (ha)	A.Ph	***	**	***	***	***	***	***		Birds, insects

Table continued

	Maesur-able unit	Identifica-tion level	Relevance	Sensitivity /respon-siveness	Measur-ability	Monitor-ing costs	Analytical sound-ness	Concep-tual clarity	Simplicity	Indicator usefulness	Important habitat
OBJECT LEVEL											**Important organisms**
Alley trees	Number (n)	A.Ph	***	**	***	***	***	***	***		lichens, insects, fungi, mosses
Alleys	Length (m)	A.Ph	***	**	***	***	***	***	***		lichens, insects, fungi, mosses
Blooming and fruitbearing bushes	Number (n)	field	**	*	***	***	***	**	*		insects
Exposed rock outcrops	Number (n)	A.Ph	***	**	***	***	***	**	**		lichens, insects, fungi, mosses
Islands in arable fields	Cover (ha)	A.Ph/f	***	**	***	***	***	**	***		vertebrates, insects, vasc. plants
Old oaks	Number (n)	A.Ph	***	*	***	***	***	***	***		lichens, insects, fungi, mosses
Open ditches	Length (m)	A.Ph	***	**	***	***	***	***	***		vascular plants, insects
Pollarded trees	Number (n)	A.Ph	***	**	***	***	***	***	***		lichens, insects, fungi, mosses
Pools and ponds	Number (n)	A.Ph	***	*	**	***	**	**	***		vertebrates, insects
Solitary trees	Number (n)	A.Ph	***	**	***	***	***	***	***		lichens, insects, fungi, mosses
Stone fencens	Length (m)	A.Ph	***	**	***	***	***	***	***		lichens, vertebrates
Unpainted buidnings	Number (n)	field	***	*	***	***	***	***	**		lichens
Unpaved roads	Length (m)	A.Ph	**	**	***	***	***	**	**		insects, vascular plants
Wooden fences	Length (m)	field	***	**	***	***	***	***	***		lichens

Continued

Table continued

	Maesur-able unit	Identifica-tion level	Relevance	Sensitivity /respons-iveness	Measur-ability	Monitor-ing costs	Analytical sound-ness	Concep-tual clarity	Simplicity	Indicator usefulness	Important habitat
STRUCTURAL LEVEL											**Important organisms**
Cultivated pastures or meadows (grazing, fodder)	Cover (ha)	A.Ph/f.	***	***	***	**	***	***	**		vascular plants, insects, fungi
Forest edges	Length (km)	A.Ph/f.	**	***	***	***	**	**	*		insects, vascular plants etc.
Grazed or mowed shore pastures	Cover (ha)	A.Ph	***	***	***	***	***	***	***		birds, vascular plants, insects
Meandering streams	Length (km)	A.Ph	**	**	***	***	*	**	***		evertebrates, insects
Natural meadows (active mowing)	Cover (ha)	A.Ph/f.	***	***	***	**	***	***	**		vascular plants, insects, fungi
Natural pastures (non fertilized)	Cover (ha)	A.Ph/f.	***	***	***	**	***	***	**		vascular plants, insects, fungi
Small arable fields (traditional)	Cover (ha)	A.Ph	***	***	***	***	***	***	**		vascular plants
LANDSCAPE LEVEL											**Important organisms**
Calcaerous soil or bedrock	Pres./abs.	Geomap	**		***	**	**	*	**		vascular plants, mosses, fungi
Topography	Rel. height (m)	Map/GIS	**		***	***	*	*	**		most organisms

* Legend of column “Indicator usefulness: Red colour represents the best indicators
** Scores of indicator assessments: (*) denotes “good”, (**) “very good” and (***) “excellent”

8. Measurement methodology

The attributes of all agricultural fields, linear elements and other selected objects in the study areas have been measured by a combination of GIS-data, air-photo interpretations and field surveys. As much as possible was measured by using existing GIS-databases and air-photo estimation since it for several attributes gives higher accuracy and – where feasible – is less costly.

8.1 Description of GIS and air-photo measurement methodology

There are four main sources of data for the estimation of the indicators of the agricultural landscape:

- GIS-data bases
- Remote sensing (air-photo surveys)
- Field surveys by the authorities
- Farmers' self-reporting

If the methodology of this project should be applied in a national scale, a decisive matter would be the costs of conducting it well. There is no reason for spending costly time on measuring variables that could be obtained from already existing databases. Fortunately, quite some information of relevance is available in Sweden, which would make a possible application less cumbersome.

In order to investigate the usefulness of such GIS-databases, and to save time for the air-photo estimations, digitalized maps of the study areas[8] were bought from National Land Survey of Sweden. Exact measures of areas, length of linear objects, land use, location of historic relics and farm centres, etc. could be obtained by using these databases.

Buying these GIS-bases saved several days of air-photo measurements. The savings for a national scale would be most considerable

Swedish Board of Agriculture generously provided their GIS-database on agricultural land blocks for the study areas without cost. It has information about block boundaries, land use (maintenance) and crops, which was used for the project.

An experienced sub-contractor have been carrying out the air-photo analyses and combining the results with the GIS-databases to provide indicator data and spatial presentations (see further chapter 11).

The air-photo measurements covered all objects. All indicators were measured, and a wide set of the factors that determine the respective indicator values, although not all factors. Among the factors that were estimated are grassland type, maintenance status, the occurrence of trees and bushes, and the type of forest edge. An evaluation of the

[8] Name of databases: "Gröna kartans vektordatabas", parts of 6FSV and 10HNO.

feasibility of air-photo estimation for each variable is presented in a separate report, which also includes transaction cost estimates for the methodology.

8.2 Description of the field measurement methodology

The indicators have been estimated by visual field inspection by specially educated experts. It was carried out at one occasion for each land parcel, following the indicator criteria of chapter 5.2 above. Point elements, forest edges and other linear elements could mostly be inspected from distance, if necessary by binoculars, while permanent grasslands always were investigated by walking across them. Field survey schemes were developed in advance to render the inspections effective.

The inspectors also took accounts of the time used for monitoring each land parcel and each indicator. The reliability of the indicator estimates was noted: whether the indicator was difficult to assess in the field and how confident the indicator estimate was. It has the aim of assessing and revising the design of the indicators and AEPs.

All field inspections were carried out after the GIS and air photo analyses were performed. Besides checking supplementary criteria, the field inspections could so use the maps produced and control the validity of the air photo analyses.

9. Measurement of actual indicator values and interpretation of results

9.1 The agri-environmental situation in Selaö study area

The situation for biodiversity and the landscape qualities of agricultural land in Selaö study area is neither very good, nor catastrophic. In many respects it is, as expected, quite typical of the general situation in The Plain Districts in Svealand. The more critical problems concern the amount of grasslands and the general quality of forest edges. A few, semi-natural grasslands with high qualities do not compensate for large areas that are reclaimed into arable fields, abandoned or in poor status. All biodiversity and landscape indicator estimates are presented in Table 33 below.

Table 33. Estimates of Landscape indicators in Selaö Study area. 2002

AREA PERMANENT GRASSLANDS	L1	ha:	93	ha/km^2:	3.1
QUALITATIVE AREA GRASSLANDS	L2	qha:	449	ha/km^2:	15.0
QUALITATIVE AREA NON-SHORE GRASSLANDS	L2b	qha:	405	ha/km^2:	13.6
DRY LINEAR FIELD ELEMENTS	L3	qm:	56719	qm/km^2:	1897
DRY POINT FIELD ELEMENTS	L4	qN°:	549	qN°/ km^2:	18.4
WET LINEAR FIELD ELEMENTS	L5	qm:	109206	qm/ km^2:	3653
WET POINT FIELD ELEMENTS	L6	qN°:	1.0	qN°/ km^2:	0.03
QUALITATIVE FOREST EDGES	L7	qm:	218820	qm/ km^2:	7319
BIORICH TREES	L8	qN°:	565	qN°/ km^2:	18.9
HISTORIC RELICS	L9	qN°:	116	qN°/ km^2:	3.9
CONFIRMATION SPECIES BIRDS*	L10				-
CONFIRMATION SPECIES VASCULAR PLANTS	L11	qN°:	225	qN°/ km^2:	7.5
CONFIRMATION SPECIES bryophytes and lichens*	L12				-
CONFIRMATION SPECIES INVERTEBRATES*	L13				-

* Theoretical indicator, outside the AEMBAC-project owing to its resource constraints

9.1.1 Area permanent grasslands

The indicator L1 for "area of permanent grasslands" is estimated to 3.1 ha per km^2 of land in the study area. This reflects an impact that entirely is a positive externality of agriculture, and which consequently is above any abandoned or natural state. Still, it is a relatively low figure, considering politically stated goals of biodiversity preservation and welfare economic estimates of the public demand for landscape amenities. In a historic perspective covering the last centuries, it is a very low figure. See chapter 10.3 for a further evaluation against EMR.

The indicator is supposed to reflect values and functions concerning the maintenance of fauna and flora populations or meadow and pasture biotopes, the preservation of historic landscape structure, aesthetic qualities, fertile land, etc. (see Table 4). All cultivated or semi-natural grasslands that are maintained by grazing or mowing are included.

Behind the indicator estimate are 93.1 hectares in total, distributed on 166 objects. Many of these are obviously quite small. Only 12 objects are larger than 2 hectares, although smaller grasslands can be adjacent to each other. For many species, a few, larger objects is more favourable than many, small objects, since they need a minimum size of grassland to get a viable population. For other species, it is more important to have many objects not too far from each other, so that there may be a communication between the sub-populations of the objects.

In total 130 ha are still classified as agricultural land and grassland. Additional areas are grasslands, but not registered as agricultural land anymore. It implies that there above the 93 hectares that are managed at present exists a potential of at least 50 ha that could be restored at relatively low costs. There are also significant, former grasslands that now are classified as forest, since the tree canopy covers > 70% of the surface. Many of these have been abandoned and spontaneously afforested, still retaining some grassland glades or grassland species. The registered 16 ha of forest grazing have been more open, at least during some historical periods. Several of these objects are of considerable value, although far from compensating the low figure of 93 ha open grasslands.

Nil meadows exist anymore in the study area. It implies that the maintained permanent grassland area is identical to the area of pastures.

Noteworthy is that a substantial part of the pastures in the study area are maintained by horse grazing, without which they in most cases probably would be abandoned. A possible explanation *may* be the stud centre at a castle giving effects in the surrounding area. Particular for the study area is also a large deer production estate, where flocks graze in large pens of fields, pastures and woods.

The indicator is considered as a major biodiversity and landscape indicator. It is transparent, has high reliability, and can be monitored at low costs. It is less informative than indicator L2, which also takes account of qualitative aspects. For a more elaborated evaluation of the indicator, see report of wp7.

9.1.2 Qualitative area grasslands

The indicator L2 for "qualitative area grasslands" is estimated to 15.0 qha per km^2 of land in the study area. It demonstrates that the situation for the permanent grasslands and appurtenant values is unsatisfactory but not destituted. The fairly low figure is partly explained by the relatively small area of grasslands (discussed in 9.1.1 above) and partly by the poor status of many objects.

The indicator aims at constituting a comprehensive measure for all values ascribed to the permanent grasslands, reflecting the quantity of meadows and pastures as well as their qualities. By multiplying the area for each object with factors expressing its qualitative attributes, a measure in qha, "qualitative hectares", is obtained. Qualitative characters of the respective objects are thus weighted into the indicator according to the principles of Table 5, Table 19 and Table 20. An object that, for instance, is 1 ha will have the same amount of qha, qualitative hectares, as another object of 2 ha that has just half as large qualitative weights.

The purpose of the indicator[9] is to give an overall measure for the values and functions concerning maintenance of bird, invertebrate and vascular plant populations with their genetic resources that are related to the permanent grasslands. Other, central purposes are to indicate their provision of aesthetic and other recreational qualities, or the maintenance of landscape character, relevant in cultural and historic contexts.

Given the weights of Table 20, “type” of grassland is the most influential, qualitative factor. Its average value for Selaö study area is 2.8. Since semi-natural grasslands are decidedly more valuable than cultivated grasslands, especially for biodiversity and scenic values, they should be correspondingly weighted up to express this difference so that the payments could be efficiently allocated. Accordingly, a significant difference in value could be distinguished by a variable that is easily monitored by air-photo or field surveys.

The frequency of trees and bushes in the grassland is another factor with multiple influences on biodiversity, cultural and social qualities of the objects. Varying from -0.75 to 0.5, the variable may have a significant impact on the indicator of – and payment to – an object. The average value for the factor is 0.19. Negative factor weights are based on estimates of invading brushwood, which may reduce the values of the grasslands significantly. Out of the 93 ha that are maintained, about 5.5 ha grassland have >50 % of their surface covered by trees and bushes. About 21 ha are covered by more than 25%, while only 5.5 ha are of mainly open character, having less than 10% of trees and bushes.

Besides these two structural factors that represent a wide spectrum of values, specific factors to further distinguish biodiversity, cultural historic respective other social qualities may influence the object’s indicator value. The biodiversity factor is the more powerful among these, adding in average 1.36 to the indicator values. As stipulated in Table 20, it comprises variables for maintenance, flora confirmation species and bushes diversity. Variables for bird and invertebrate confirmation species, as well as for tree diversity, are recommended for an applied system, but not surveyed within the project.

The variable for intensity of maintenance expresses whether the grazing or mowing leaves a layer of organic litter or keeps the grass sword down. More animals grazing a longer time will increase the factor. It is considered a major factor for the field layer flora, but is certainly also affecting aesthetic and other non-biodiversity values. Indirectly, it may give an early indication whether the object will be successively overgrown. Less than half of the maintained area is well maintained.

Another biodiversity factor component, vascular plant confirmation species, is developed to further distinguish between the botanically good and the most valuable objects. Having four classes: 0, 1 – 3, 4 – 6, and > 6 species that indicate generally high flora values, farmers are rewarded for a long continuity of good maintenance and given further step-by-step incentives to improve the object’s biodiversity status. Fully 60 of

[9] See Table 5 above for a complete list of the indicator’s purposes.

the permanent grassland objects carried confirmation species. Out of the 93 ha maintained grassland, just 41 ha were registered for having any of the confirmation species. There are another 13 ha permanent grasslands in the study area with some of these species, but that are not maintained anymore, demonstrating the time lags and that some plants may sustain for a shorter or longer period.

Bushes diversity reflects biodiversity values in general and some invertebrate values in particular, but is not given high weight. An area of 47 ha is classified for higher bushes diversity. *Prunus spinosa* and *Rosa sp.* are the most common among the valued bushes.

The cultural historic factor adds paltry 0.03 in general to the indicator values. Note that this excludes the value of linear and point elements that may be in the pastures, but merely express the cultural values of the area *per se* above those covered by the structural factors. There are no pollards in the area. Underlying the estimate is solely the upgrading of pastures close to farm or farm village centres.

The factor for other cultural and social values is estimated to zero, since there are no pastures that are extra important for recreation or scenery because of vicinity to population centres or large traffic roads.

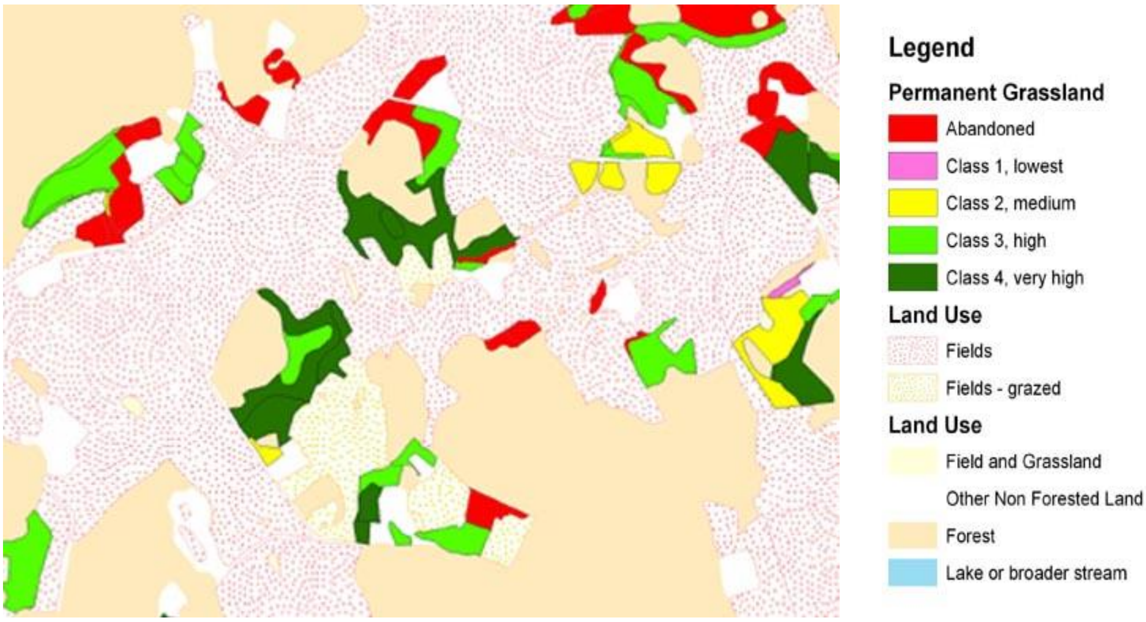


Figure 3. Permanent grasslands as estimated by indicators*. Excerpt over central part of Selaö study area. Year 2002
Area of excerpt c. 1.5 X 2 km

Summing up, the average permanent grassland indicator estimate for Selaö study area is 4.45 (maintained grasslands only). One small object is the most highly ranked, with an indicator value of 9.95. This can be compared with a theoretical maximum indicator value of 16.4 (plus additional scores from possible pollards). Ten pasture objects together covering 12 ha are "high value grasslands" with indicator estimates ≥ 8.5.

The indicator is considered to be a major biodiversity and landscape indicator. It has high policy relevance. Involving several components, it has less simplicity than indicators who do not cover as many qualitative dimensions. Its informative and pedagogic values should be high, considering that it gives a comprehensive measure for the grassland situation. That demands that the components of the indicator could be presented separately to explain the underlying reasons for the situation – a demand which is satisfied. The monitoring costs are higher than for the other indicators, but still fairly small compared to the proposed AEP:s. For a more elaborated evaluation of the indicator, see report of wp7.

9.1.3 Qualitative area non-shore grasslands

The indicator L2b for "qualitative area of non-shore grasslands" is estimated to 13.6 qha per km^2 of land in the study area. As for the situation of grasslands in general (indicator L2), the situation is barely satisfying for achieving stated goals. Most of the comments in chapter 9.1.2 also apply to the non-shore grasslands alone.

The purpose of developing and estimating an indicator for non-shore grasslands specifically is to detect a possible serious decline of dry pastures and meadows before becoming too critical. Permanent grasslands along the coast or the lakeshores may occupy large areas relative the dry grasslands. Since wet and dry wetlands not are perfect substitutes, for example providing different habitats for plants and birds, drastic changes in the acreage of dry pastures could be concealed if wet pastures clearly dominated, giving just a little impact on their joint indicator value.

This is not the case in Selaö study area, where only 6.5 ha of lake shore grasslands are still maintained. Surrounded on two sides by lake Mälaren, the low figure for the study area is partly explained by physical geographical conditions (long shores stretches along moraine soils unfeasible for agriculture) and the fact that most of the shore wetlands have been abandoned. For the study area, the scarcity of wet grasslands is actually more pronounced.

Existing shore grasslands are distributed on a couple of small and one larger pastures on sedimentary clay soils. The potential for increasing the shore pasture area is large.

9.1.4 Dry linear field elements

The indicator L3 for "Dry linear field elements" is estimated to 1,897 qm per km^2 of land in the study area. The amount of dry, linear elements is thus relatively low, in a historic, national and – not the least – ecological perspective, although there certainly are other agricultural districts much worse off. It is probably not very realistic to significantly increase the length of linear elements within the fields, but the situation could be somewhat improved by better maintenance of the still remaining elements.

Linear field elements are important for biodiversity, especially in highly cultivated areas, but also in mixed regions such as Selaön. Their functions of habitats, refugees or – in particular – ecological corridors are more or less vital for many species of birds, mammals, reptiles, vascular plants, bryophytes and lichens. Elements such as alleys, stone-walls and old field roads are ascribed cultural historic values. All of them are striking landscape features, adding to landscape scenery and recreational access, see further chapters 2.1 - 2.4.

The indicator is simply calculated by multiplying the estimated length of the linear elements in the area with quality factors, and then dividing the product-sum by total land area. A first variable (factor) is to distinguish between types of elements, where, for instance, stone-walls in general are considered as more valuable than plain headlands. Element width is another variable, since an eight meters wide vegetation strip is a better refugee than just half a meter wide one. Trees and bushes, as well as maintenance are other variables that determine the indicator, see Table 7, Table 21 and Table 22.

There are in total 8,550 m of dry, linear elements within or along agricultural land in the area. Almost half of it are mere headlands. Field roads is the other major type, with a total length of 3,300 m. There are alleys and stone-walls in the area, but just a few, in total extending 220 m respective 430 m. The wood fences have nearly disappeared, as just 210 m remain.

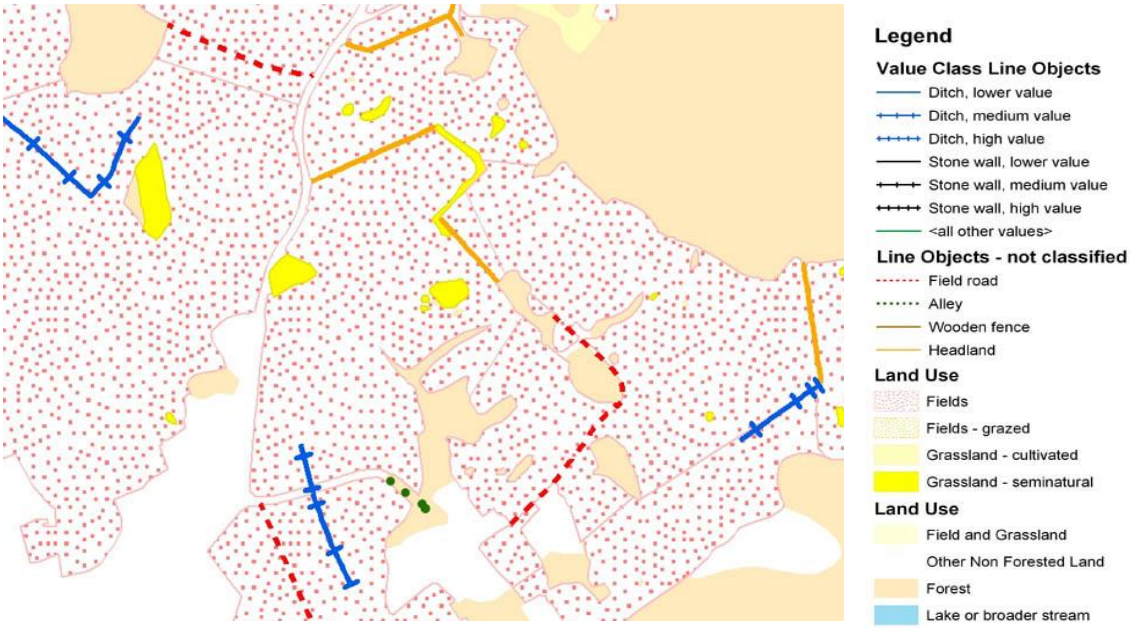


Figure 4. Linear elements as estimated by indicators*. Excerpt over central part of Selaö study area. Year 2002
Area of excerpt c. 1 X 1.5 km

What concerns quality variables, a disquieting measurement is that 1,300 m (including wet linear elements) are invaded by brushwood. If these trees and bushes in early succession stages grow up, the functions and the values of the elements will change drastically. Two thirds of all linear elements are in spite of this still open, having less than 10% of their length covered by trees or bushes. However, more brushwood may appear and more confirmation species may disappear, since remarkably little, 50 m, of the elements were well maintained. A positive factor is that only 700 m of all 17,400 m linear elements have vegetation strips narrower than 2 m.

The weighted average of the dry, linear element indicator is 6.63 for the objects. Much of the value above 1 is owing to the fact that field roads, alleys and stone-walls are weighted up relative mere headlands (indicator weight = 1). If there are a few, but not too many, trees or bushes along the element, it normally adds to its biodiversity value – and accordingly to its indicator estimate. Element width also contributes some to increasing the objects' indicator values, but other quality variables add little in the study area.

The indicator is fairly easy and cheap to measure by GIS and air-photo surveys of length, width, type and extent of trees or bushes. Maintenance, bushes diversity and confirmation species have to monitored by field surveys or self-reporting, and are thus relatively more expensive to include. Considering the specific importance of the linear elements for biodiversity and other landscape values, the indicator is judged as appropriate for policy use (see further the wp7-report for an assessment of the indicator.)

9.1.5 Dry point field elements

The "Dry point field element"-indicator, L4, for Selaö study area is in the survey year 2002 estimated to 18.4 qN°/km^2 of total land area, where qN° signifies "qualitative number". It corresponds to 71.9 qN°/km^2 arable land. This measure of the density of "qualitative" point elements on agricultural land is determined by given, physical geographic conditions, historic activities and present land use. An estimate of this magnitude is not bad, thanks to the many islets of rock or moraine within the fields, but could be higher if the elements had been maintained better. There are other regions with significantly more point elements, naturally or from a history leaving plenty of cairns. Some fairly large bands of sedimentary clay soils from former sea beds do not have any natural field elements, reducing the average for the study area.

Point elements within the fields are important habitats or refugees for many species in cultivated areas, they are parts of the traditional landscape scenery, or carry cultural historic qualities. The indicator aims at reflecting all the values of public good character coming from these field elements (see further Table 8). To calculate the indicator, the number of point elements is multiplied by quality factors for respective type, size, management status, the occurrence of confirmation species, and vicinity to main roads (see Table 25 and Table 26).

What underlying the estimate are 160 field islets and 25 flat rocks. Note that biorich trees and historic relics, who also are point elements, are measured by separate indicators. Of the field islets, 67 are semi-natural grasslands and 63 deciduous groves. Flat rocks are valuable for especially bryophytes and lichens, and possibly also for increasing the landscape heterogeneity. Only flat rocks in arable land are included in the indicator, since rocks in grasslands do not differ much from those where agriculture is abandoned. Hence, pasture rocks are not positive externalities of agriculture.

The maintenance of the field islets is in general neglected. Consequently, this quality factor is only 0.06 in average. Just a couple of field islets were observed having any confirmation species of vascular plants, adding hardly anything to the biodiversity quality factor. There may be some more, however, since not all field islets could be surveyed for botany. A factor for cover of trees and bushes increases the indicator value significantly, because there are just a few field islets completely covered by conifers.

Deciduous groves and grassland islets, or mixed grass and tree islets, are valued higher. The generally low quality of existing objects gives an indicator value of 3.33 in average for the dry point field islets.

The indicator is important for regions having a lot of arable land, but should be considered as supplementary to the other field element indicators. Except for confirmation species, monitoring it is not costly, but such measures could be added after the general survey as self-reported supplements.

9.1.6 Wet linear field elements

The "Wet linear field element"-indicator, L5, get the value 3,650 qm/km^2 for Selaö study area. The situation is thus better in general than what concerns the dry lines through the cultivated fields, not the least ecologically (although they are of course not directly comparable). Relatively large areas of fields that have little inclination explain why there are still some ditches in the landscape.

Surrounded by vegetation strips on each side, ditches and brooks have almost all the functions and values as the dry linear elements (see 9.1.4 above). Some scenic, historic and access characters are different, however, and accordingly these values. In addition to the services of the terrestrial strips, wet elements also have the aquatic functions and values. Batrachians, some bird and plant species are among those promoted by these aquatic environments. (see further Table 9, Table 21, Table 22)

Underlying the indicator estimate are 8,840 m of ditches. There are no brooks at all. Both large and small ditches are represented. The variable for width of the vegetation strip adds in average by a factor of 2 to the indicator, since almost all have a double-zone wider than 2 m to the cultivated soil. There is hardly any maintenance of the grass and herb layer, so, consequently, this variable does not add to the indicator estimate. Trees and bushes increase the value of the ditches in some cases, while decreasing it where there is a lot of invasive brushwood.

The weighted average of the wet linear objects' indicator values is 12.4. This relatively high value is much owing to the fact that ditches *per se* are valuable by bringing aquatic environments, and could be increased if they were maintained better.

It is an indicator that can be monitored at fairly low costs by air-photo surveys. Judged as highly relevant for biodiversity as well as some social functions, it should serve well for agri-environmental payment systems.

9.1.7 Wet point field elements

With an estimate of just 0.033 qN°/km^2 for the "Wet point field element"-indicator, L6, the Selaö study area is destitute of this kind of important objects. The alarming situation can to some extent be explained by natural conditions, but draining and filling of ponds and minor wetlands in the 19th and 20th centuries are usually the main causes.

Wet point elements in the fields are extremely important habitats for many batrachian, reptile, bird and invertebrate species, especially if they are sun-exposed. Ponds, but even minor wetlands, can be valuable also for cultural historic and landscape scenic reasons, see further Table 8.

Just one small pond has been registered in the study area. It is man-made, recently so, dug out in a pasture to supply the cattle with water.

This indicator should be considered as supplementary to the other field element indicators, especially to L5 for some biodiversity values. The reason for having a separate indicator for wet point elements and not including them in an overall point element indicator is that they are important for partly different species. There could be a risk that unsatisfactory conditions concerning the wet habitats could be masked by a joint indicator for all point elements.

Indicator L6 is easy and cheap to monitor in its present design. The objects and all their quality variables can quickly be detected by air-photo surveys. Actually, there are only two variables for the ponds, size and sun-exposed/shadow. The advantage of adding more quality variables should be considered.

9.1.8 Qualitative forest edges

The indicator L7 for "Qualitative forest edges" is estimated to 7,300 qm per km^2 of land in the study area. It is a fairly good figure, but could be significantly higher if the edges between agricultural land and the forest were managed better. The still relatively good situation can be explained by the physical geographic conditions of fertile sedimentary clay soils in the depressions mixed with non-cultivable moraine soils on other land, which naturally gives many forest edges. Afforestation of small fields and field bays between woods show that the forest edges were longer just a few decades ago.

The edges between forest and agricultural land can be very important for biodiversity, scenery and access for outdoor life, see chapter 2.1.3.

A few variables are used to estimate the qualities of the forest edges. *Edge depth* is surveyed from air-photos, distinguishing between edges that are more or less a wall of trees and edges that are open, having a zone of grass and herbs of 10 m or more. *Edge type* is estimated by the field surveys. It indicates whether the edge is a tree wall or it is stratified, with a mix of tall trees, small trees and bushes. Another variable distinguishes between *deciduous* and conifer edges. The *maintenance* variable indicates whether the grass along the edge is cut or there has been an accumulation of organic litter. The *confirmation species* of vascular plants, finally, have not been surveyed, but are supposed to be reported by farmers who can point out such species. See Table 11, Table 21 and Table 22 for more information about the objectives of the indicator and how it is calculated.

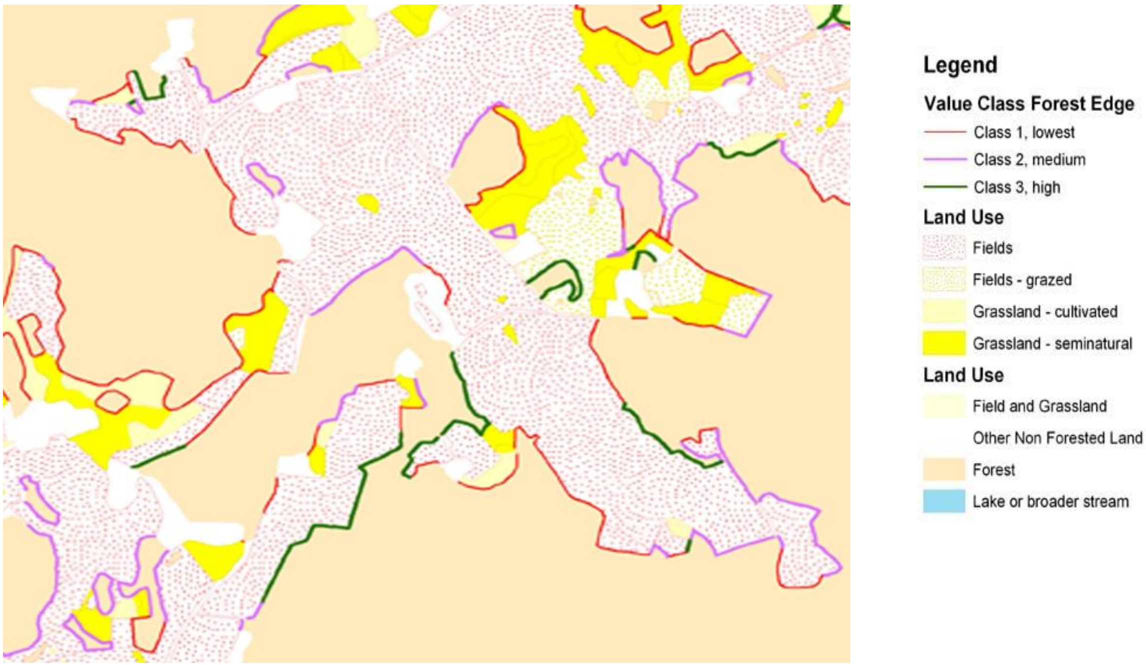


Figure 5. Forest edges as estimated by indicators. Excerpt over central part of Selaö study area. Year 2002
Area of excerpt c. 1.75 X 2 km

There are in total 98 000 m forest edges in the study area. As the total qualitative length is 219 000 qm, the weighted average for the indicator at the object level is 2.23. Most of the value above 1 is due to the factor for deciduous trees. They are considered more valuable, partly for biodiversity reasons, and extend over 60 000 m. On the other hand, only 25 000 m of the forest edges are open or stratified. This reduces the biodiversity, scenic and recreational values of the area's forest edges substantially. Here is a potential for enhancing the landscape services by relatively small efforts.

L7, the forest edge indicator, is in many respects overlapping with the indicators for the field elements, especially dry linear elements, as concerns biodiversity functions and access. Since some functions are more or less different, the forest edge indicator should be considered as a supplementary but separate indicator.

The indicator is considered as highly relevant for a set of biodiversity values or functions, for aesthetic values and landscape heterogeneity. The length can be estimated automatically by GIS-procedures. Some of its qualitative factors can also be estimated at low costs, such as edge depth and the deciduous/conifer-character. To monitor maintenance and confirmation species in a full, national scale will, however, be demanding. A system of self-reporting with random inspection is recommended instead.

9.1.9 Biorich trees

The situation for the biorich trees is quite good in the study area, as indicated by an estimate of 19 qN^{o}/km^{2} of total land area for Landscape indicator L8. Its corresponding figure is 65 if expressed in qN^{o} per km^{2} of agricultural land. The satisfactory situation is due mainly to the many preserved, large oak trees in the area. A further, significant improvement would be achieved if it were cleared around more of them. Their biodiversity values would then increase, as they got more sun-exposed.

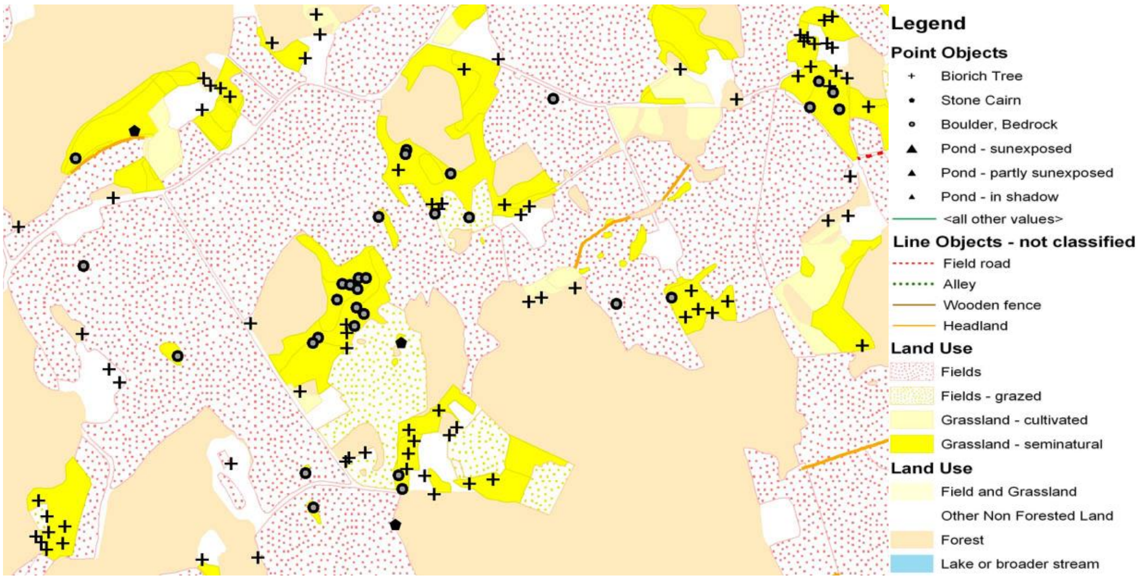


Figure 6. Biorich trees and (other) point elements as estimated by indicators. Excerpt over central part of Selaö study area. Year 2002
Area of excerpt c. 1.5 X 2 km

The indicator is estimated by first counting the number of trees with large canopies through air-photo surveys. An indicator value for each of these is calculated by multiplying with a factor for tree species, where oaks and old aspens are among those with highest biodiversity qualities. Variables for hollow trees, coarseness and sun-exposure add to the indicator value, since these reflect important biodiversity qualities. (See Table 12, Table 27 and Table 28.)

Old, hollow oaks and other large, deciduous trees are particularly "biorich trees", and the indicator is designed to reflect the values ascribed to these qualities. The main concern of the indicator is thus biodiversity. Many of these trees that are classified as biorich may also contribute to the landscape's aesthetic and identity forming values, see chapters 0, 2.2 and Table 12.

The indicator is more or less independent of the other indicators. By reflecting other qualities it gives little over-lapping. Certainly, arable fields and pastures that carry – and are the prerequisites for – the biorich trees will indirectly become more valuable according to how these trees are allocated.

To monitor the number of trees with large canopies and sun-exposure from air-photos is little time consuming and not costly. Identifying hollow trees, tree species and trees larger than 1 m in chest-high is, on the other hand, more time demanding considering the large amount of biorich trees in some regions. A system of self-reporting with random inspections would be an alternative to field surveys for these variables.

9.1.10 Historic relics

The indicator L9 for "historic relics" is estimated in the study area to 13.2 qNº/km^2 of agricultural land, or 3.9 qNº/km^2 of total land area. It tells that the study area is relatively poor in such elements, although its prehistoric grave fields contribute appreciably to improve the situation. Note, however, that in addition to, for example, grave fields and cultivation cairns that are measured by this indicator, come the cultural historic values of stone-walls, ditches, meadows, fields and other objects that are expressed through the previous indicators. The low figure is because there are not many historic relics in the area, and only in some few cases because of neglected maintenance.

The indicator is calculated by multiplying the number of historic relics with respective objects' quality factors for type, maintenance and visibility (see Table 13, Table 29 and Table 30). The objects are identified from a GIS-database and by the field surveys.

The main aim of designing such an indicator for historic relics, separate from the indicators for other acreage, linear or point objects, is to highlight these elements of specific, cultural historic interest. Some of them certainly also have other values as well, aesthetic and even for biodiversity.

Underlying the indicator estimate are 7 ancient grave fields, 2 ruin house foundations, 1 church and 16 cultivation cairns. The major contribution (80%) to the indicator comes from the grave fields and their large historic values. Stone cairns are the second most important type in terms of indicator impact. The cairns are traces from historic cultivation, clearing the fields from stones. Note that not all cairns may have been registered in the survey, so that the indicator is likely to underestimate the real situation. Fields surrounding churches are more valuable than fields in general, from cultural, historic and scenic perspectives, and hence the church in the study area is included in the indicator. There are no rune stones and no pollards in the study area part of Selaö.

The indicator is judged as highly relevant for some types of cultural historic qualities of agricultural districts, but should be considered as supplementary to the indicators for fields, grasslands, linear and point elements. Since it is forbidden to remove this kind of historic relics, the main aim of the indicator is to allocate resources to fields and pastures having historic relics – and hence increase the chance that they will be maintained. Another aim is to provide incentives for management of the relics. The pedagogic and cost-efficiency criteria are well satisfied for the indicator.

9.1.11 Confirmation species vascular plants

A specific indicator is developed for confirmation species of vascular plants, L11, which is estimated to 7.5 qNº/km^2 of land in the study area. Such a few registered confirmation species give cause for concern. The number of high quality objects has to be increased by maintaining larger areas and increasing the floristic qualities of existing objects if the situation should not be further aggravated.

The indicator is measured by counting each of the 34 confirmation species that are observed on an object. The accumulated number of confirmation species over all agricultural land, Σ(observed number/object), is then divided by land area (see Table 15). All permanent pastures, meadows, linear and point elements are included in the objects that are surveyed.

By supplementing the structural indicators L1 – L9, the main aim of the indicator *at the landscape level* is to serve as a security control device for the botanical situation in an area. There could otherwise be some risk that poor botanic conditions are more or less masked if other quality variables were good. Confirmation species of vascular plants are also included as a quality variable into the indicators for grasslands and field objects. At *the object level*, the confirmation species are used to further distinguish between very high quality objects and more ordinary ones that maybe do not have the same continuity of good maintenance, in order to allocate resources efficiently and provide incentives for better and durable maintenance. A good botanical status normally implies good conditions also for insects and other interests. Some species are considered as historically interesting by revealing old cultivation systems.

There are in total less than 250 registrations of confirmation species in the study area. These vascular plants were found on 62 objects, which probably is a smaller underestimation, since not all field islets, forest edges or other linear elements could be surveyed. The area of pastures that is the habitat for more than four confirmation species is alarmingly small, just 20 ha in the study area. Only 12 ha of these top-grasslands are still maintained. It implies that they are traces from former mowing or grazing; that it is just a matter of time before they will disappear on these objects if not re-maintained.

The indicator is relatively time demanding and thus costly to measure. A system of self-reporting could be less resource demanding. There are also some possibilities to use existing flora survey data-bases. The indicator supplements the structural indicators[10] that measure the conditions for biodiversity by actually monitoring the presence of some informative species. Alternative designs of the indicator are evaluated in a later work-package. A major alternative has similar survey costs, is less simple but more relevant. It appears to be necessary having some indicator based on the presence of species.

9.1.12 Confirmation species for other organisms

Indicators based on confirmation species of birds, bryophytes and lichens, respective invertebrates are developed and suggested for the AEP-system. They are, however, not estimated within the project because of the project's resource constraints.

9.2 The agri-environmental situation in Vetlanda study area

Vetlanda study area is in many respects in a fairly good state as concerns biodiversity and other landscape qualities of agricultural land. The more critical problems concern

[10] At the object level, the confirmation species operate as a *variable* adding a top-quality dimension.

the amount and the general quality of some field elements. Ponds and small wetlands are especially scarce resources. The relative richness of grasslands, forest edges and other farmland elements probably still make the area to one of the higher valued in Sweden, although not among the very most valuable. All biodiversity and landscape indicator estimates are presented in Table 34 below, but note that it has not been possible to measure all objects by the field surveys. Possible errors should be minor at the landscape level.

Table 34. Estimates of Landscape Indicators in Vetlanda Study area. 2002

AREA PERMANENT GRASSLANDS	L1	ha:	412	ha/km^2:	5,6
QUALITATIVE AREA GRASSLANDS	L2	qha:	2,060	ha/km^2:	28.2
QUALITATIVE AREA NON-SHORE GRASSLANDS	L2b	qha:	1,940	ha/km^2:	26.5
DRY LINEAR FIELD ELEMENTS	L3	qm:	641,205	qm/km^2:	8,784
DRY POINT FIELD ELEMENTS	L4	qN°:	905	qN°/ km^2:	12.4
WET LINEAR FIELD ELEMENTS	L5	qm:	262,789	qm/ km^2:	3,600
WET POINT FIELD ELEMENTS	L6	qN°:	34,0	qN°/ km^2:	0.466
QUALITATIVE FOREST EDGES	L7	qm:	462,079	qm/ km^2:	6,330
BIORICH TREES	L8	qN°:	2,318	qN°/ km^2:	31.8
HISTORIC RELICS	L9	qN°:	509	qN°/ km^2:	7.0
CONFIRMATION SPECIES BIRDS*	L10		-		-
CONFIRMATION SPECIES VASCULAR PLANTS	L11	qN°:	-	qN°/ km^2:	-
CONFIRMATION SPECIES bryophytes and lichens*	L12		-		-
CONFIRMATION SPECIES INVERTEBRATES*	L13		-		-

* Theoretical indicator, outside the AEMBAC-project owing to its resource constraints

9.2.1 Area permanent grasslands

There are 5.6 ha of permanent pastures and meadows per km^2 of land in the study area, as expressed by indicator L1. It reveals a fairly good situation, considering that agricultural land is scattered in forests on moraine soils. Much of the present forests were more or less intensively grazed or mowed in the past, so there has been decline despite that the situation is good compared to many other areas.

The aim of the indicator is to reflect values and functions concerning the maintenance of fauna and flora populations or meadow and pasture biotopes, the preservation of historic landscape structure, aesthetic qualities, fertile land, etc. (see Table 4). All cultivated or semi-natural grasslands that are permanently maintained by grazing or mowing are included, but hence not any leys on arable land.

Behind the indicator estimate are 2 maintained meadows, 215 cultivated pastures and 301 semi-natural pastures, having 412 hectares in total. Many of these are obviously quite small. Less than 50 objects are larger than 2 ha and 7 objects are larger than 5 ha, although several grasslands can be adjacent to each other, together making larger habitats. The acreage of meadows is 2.8 ha, of cultivated pastures 145 ha, and of semi-natural pastures 265 ha.

A lot of previous grasslands have been abandoned, not the least extensively used grazing lands that now are afforested as the pasturing is concentrated to fenced parcels. Of particular interest are former meadows along the Emå river. Just a little of them are maintained as grasslands, although the transformation to wood is far from finished everywhere.

The indicator is considered as a major biodiversity and landscape indicator. It is transparent, has high reliability, and can be monitored at low costs. It is less informative than indicator L2, which also takes account of qualitative aspects. For a more elaborated evaluation of the indicator, see the wp7-report.

9.2.2 Qualitative area grasslands

Vetlanda study area is relatively well endowed with permanent pastures and meadows in a national and European perspective, although lower than past levels. The indicator L2 that express the qualitative area of permanent grasslands is estimated to 28.2 qha per km^2 of land in the study area.

It demonstrates that the situation for the permanent grasslands and appurtenant values is not bad but could be better. A reason for the fairly low figure is that the study area is situated in a forest region where agriculture covers just a fraction of the land today. Physical geographic conditions combined with modern technology hence explain why the pasture areas are limited. Considering these, given conditions, the continued husbandry in more fertile parts of the area maintains a few grasslands with high biodiversity and landscape qualities plus quite some pastures of less high qualities.

The indicator aims to be a comprehensive measure for all values ascribed to the permanent grasslands. Hence, its measure "qualitative hectares", qha, that should reflect the quantity of meadows and pastures as well as their qualities. (See further Table 5, Table 19 and Table 20.)

The purpose of the indicator[11] is to give an overall measure for the values and functions concerning maintenance of bird, invertebrate and vascular plant populations with their genetic resources that are related to the permanent grasslands. Other, central purposes are to indicate their provision of aesthetic and other recreational qualities, or the maintenance of landscape character, relevant in cultural and historic contexts.

[11] See Table 5 above for a complete list of the indicator's purposes.

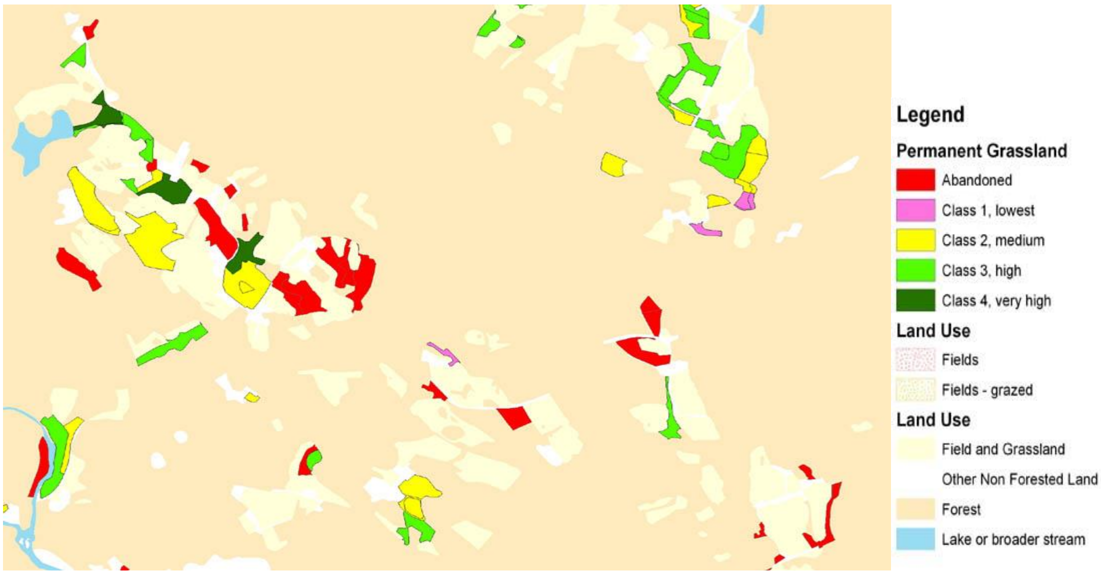


Figure 7. Permanent grasslands as estimated by indicators*. North-central segment of Vetlanda study area. Year 2002
Area of excerpt c. 2.5 X 3.5 km

“Type” of grassland is the qualitative factor that turns out to be the most influential, given the weights in Table 20 who express the importance of respective parameter. Its average value for Vetlanda study area is 2.8. Since semi-natural grasslands are decidedly more valuable than cultivated grasslands, especially for biodiversity and scenic values, they should be correspondingly weighted up to express this difference so that the payments could be efficiently allocated. There are two highly valued meadows in the study area, but their impact at the landscape level is little because of their small acreage.

The frequency of trees and bushes in the grassland is another factor with multiple influences on biodiversity, cultural and social qualities of the objects. The estimated average for the factor is 0.20. Out of the 412 ha of grasslands that are maintained, about 24 ha are quite wooded, having more than 50 % of their surface covered by the canopies of trees and bushes. Fully 100 ha are covered by more than 25%, while only 17 ha are of mainly open character, having less than 10% of trees and bushes.

The biodiversity factor is the more powerful among the non-structural factors. It adds in average 1.45 to the indicator values. Variables for maintenance, flora confirmation species and bushes diversity determine the factor (see Table 20). The variable for intensity of maintenance expresses whether the grazing or mowing leaves a layer of organic litter or keeps the grass sword down. It is considered as important for the field layer flora, but is certainly also affecting other landscape values. Only one third of the pasture area still in use is well maintained. Vascular plant confirmation species is another biodiversity factor component that is developed to further distinguish the biologically very richest pastures and to give farmers further step-by-step incentives to improve the object’s status. Just 50 percent of the permanent grassland objects carried confirmation species. A few, 5%, of the pastures are top objects in the sense that they have six or more confirmation species.

The cultural historic factor adds merely 0.02 in average to the indicator values. There are a few pollards in the area that add to the cultural historic values of the permanent grasslands. Some pastures are also given extra value points for contributing to the historic environments around a farm or village. The figure does, however, not include the value of linear and point elements that may be in the pastures, which are covered by the structural factors.

The factor for other cultural and social values is as little influential, estimated to 0.02. An appreciation of the indicator has anyway been motivated for some pastures by a factor considering that they are seen from a main road with many travellers passing by.

Summing up, the average permanent grassland indicator estimate for Vetlanda study area is 4.48 (maintained grasslands only). The two meadows are the most highly ranked.

The indicator is considered to be a major biodiversity and landscape indicator. It has high policy relevance. Involving several components, it has less simplicity than indicators who do not cover as many qualitative dimensions. Its informative and pedagogic values should be high, considering that it gives a comprehensive measure for the grassland situation. Pedagogy and policy directive power demands that the components of the indicator could be presented separately to explain the underlying reasons for the situation – a demand which is satisfied. The monitoring costs are higher than for the other indicators, but still fairly small compared to the proposed AEP:s. For a more elaborated evaluation of the indicator, see the report for WP7.

9.2.3 Qualitative area non-shore grasslands

The indicator L2b for “qualitative area of non-shore grasslands” is estimated to 26.5 qha per km^2 of land in the study area. It implies that the situation is in accordance with what is required but not very good, as for the situation of grasslands in general (indicator L2). Most of the comments in chapter 9.2.2 also apply to the non-shore grasslands alone.

The purpose of an indicator for non-shore grasslands specifically is to detect a possible serious decline of dry pastures and meadows before becoming too critical. A considerable decrease in the acreage of dry pastures could be concealed if wet pastures clearly dominated, giving just a little impact on their joint indicator value. Biodiversity and cultural goals would be at risk, since wet and dry wetlands not are perfect substitutes.

This is not the case in Vetlanda study area, where only 21 ha (corresponding to 97 qha) of wet grasslands are still maintained, mainly along the Emå river. Pastures on dry land dominate in the study area, occupying 390 ha in total.

9.2.4 Dry linear field elements

The indicator L3 for “Dry linear field elements” is estimated to 8,800 qm per km^2 of land in the study area. The supply of dry, linear elements is thus quite good. It is the great length of all stone walls, wooden fences, field roads and headlands that is the main reason for the positive situation. However, many of them are poorly maintained, so if the quality factors were improved the situation and the indicator could rise significantly.

Linear field elements are important for biodiversity, even if they are less crucial in forest regions than in highly cultivated areas. Elements such as stone-walls, wooden fences and old field roads are ascribed cultural historic values. All of them are striking landscape features, adding to landscape scenery and recreational access; see further chapters 2.1 - 2.4.

The indicator is simply calculated by multiplying the estimated length of the linear elements in the area with quality factors, and then dividing the product-sum by total land area. A first variable (factor) is to distinguish between types of elements, where, for instance, stone-walls in general are considered as more valuable than plain head-lands. Element width, trees and bushes, as well as maintenance are other variables that determine the indicator, see Table 7, Table 21 and Table 22.

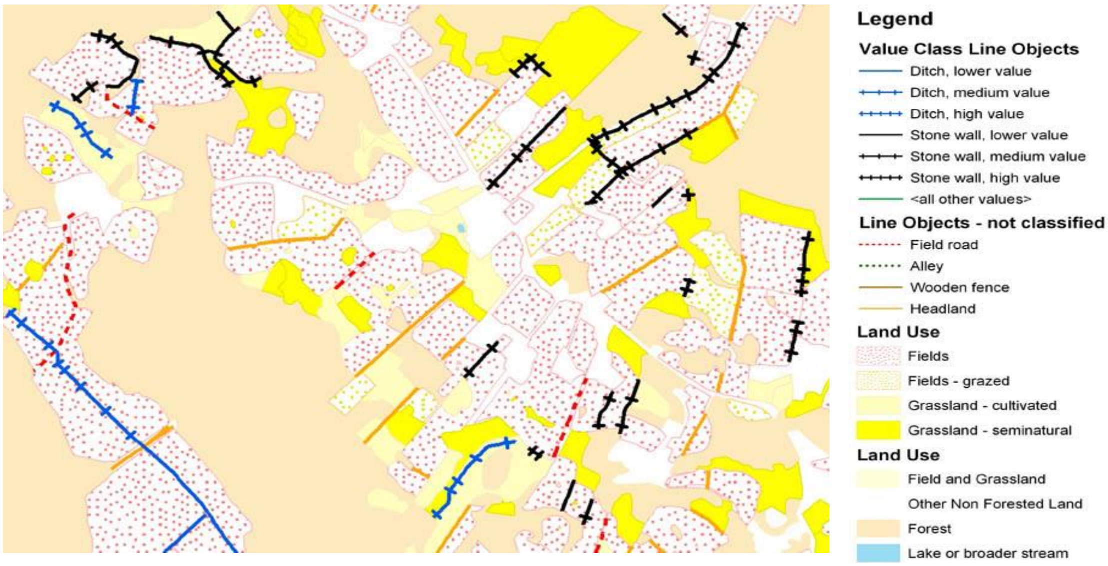


Figure 8. Linear elements as estimated by indicators*. Excerpt over south-central part of Vetlanda study area. Year 2002. **Area of excerpt c. 1,5 X 2 km**

There are in total 85,000 m of dry, linear elements within or along agricultural land in the area. In addition to that are all the forest edges, see 9.2.8 below, which also are kinds of dry, linear elements. Stone-walls contribute decisively by their characters and a total length of 44,700 m. However, many of them are not well maintained. As much as 11,000 m stone-walls get an indicator estimate ≤ 4. Wooden fences of traditional type are also important landscape features in the study area. Most of them are concentrated to some farms where the farmer has been interested in conserving them. Headlands are by 22,700 m the second most frequent linear element, although many of them are less valuable per meter than the other types. Field roads is another major type of element amply represented in the study area, with a total length of 3,300 m. There is also a considerable amount of alleys in the area, in total 725 m, which are highly valued per meter.

Quality variables supplement the structural ones. A disquieting quality factor measure is that 46,000 m or 42% of the linear elements (including wet elements) are invaded by brushwood. If these trees and bushes in early succession stages grow up, the functions and the values of the elements will change drastically. One fourth of all linear elements are in spite of this still open, having less than 10% of their length covered by trees or bushes. A positive factor is that 87 % of all linear elements have vegetation strips wider than 2 m.

The average indicator estimate is 7.52 for the dry, linear elements, if weighting for difference in length. Most of the value above 1 is owing to the fact that stone-walls, wooden fences, field roads and alleys are weighted up relative mere headlands (indicator weight = 1). Element width also contributes some to increasing the objects' indicator values, but other quality variables add little in the study area. This is because much of the biodiversity, cultural and social values are covered by the structural factors, but also because confirmation species are supposed to be reported by the farmers and not monitored by field surveys.

The indicator is fairly easy and cheap to measure by GIS and air-photo surveys of length, width, type and extent of trees or bushes. Maintenance, bushes diversity and confirmation species have to monitored by field surveys or self-reporting, and are thus relatively more expensive to include. Considering the specific importance of the linear elements for biodiversity and other landscape values, the indicator is judged as appropriate for policy use (see further the wp7-report for an assessment of the indicator).

9.2.5 Dry point field elements

The "Dry point field element"-indicator, L4, for Vetlanda study area is estimated to 12.4 qN° per km^2 of total land area, where qN° signifies "qualitative number". It corresponds to 89 qN° per km^2 of arable land. The fields in the area are thus fairly amply equipped with flat rocks, boulders and uncultivated islets of various qualities. Also in this case, the large extent of forest reduces the estimate if measured per km^2 of total land area. The richness in numbers of field elements is in general not followed up by high qualities.

Point elements within the fields are important habitats or refugees for many species in cultivated areas, they are parts of the traditional landscape scenery, or carry cultural historic qualities. The indicator aims at reflecting all the values of public good character coming from these field elements (see further Table 8). To calculate the indicator, the number of point elements is multiplied by quality factors for respective type, size, management status, the occurrence of confirmation species, and vicinity to main roads (see Table 25 and Table 26).

The landscape indicator estimate derives from 362 field islets and 319 flat rocks or boulders. Note that biorich trees and historic relics, who also are point elements, are measured by separate indicators. Of the field islets, 89 are semi-natural grasslands and 103 deciduous groves, which are the two more valuable types. Flat rocks are valuable for especially bryophytes and lichens, and possibly also for increasing the landscape heterogeneity.

There are just a very few field islets that are maintained by grazing or mowing. The maintenance quality factor for the indicator is accordingly almost negligible in average. If a maintenance variable were implemented for the payment schemes, it could certainly become larger by giving incentives to the farmers. A factor for cover of trees and bushes increases the indicator value significantly, because there are just a few field islets completely covered by conifers. Deciduous groves and grassland islets, or mixed grass and tree islets, are valued higher. The generally low quality of existing objects gives an indicator value of 3.11 in average for the dry point field islets. Just 14 field islets are large enough or have high qualities enough to merit an object indicator value higher than 5.

The indicator is important for regions having a lot of arable land, but should be considered as supplementary to the other field element indicators. Except for confirmation species, monitoring it is not costly, but such measures could be added after the general survey as self-reported supplements.

9.2.6 Wet linear field elements

The “Wet linear field element”-indicator, L5, get the value 3,600 qm/km^2 for Vetlanda study area. Although their presence vary much within the area, the situation in general is thus neither good, nor bad. Considering that parts of the agricultural areas are hilly, demanding less drainage, and that there is a lot of forest, it may be difficult to achieve more open land ditches, although it would be desirable from an ecological point of view.

Surrounded by vegetation strips on each side, ditches and brooks have almost all the functions and values as the dry linear elements (see 9.1.4 above). Some scenic, historic and access characters are different, however, and accordingly these values. In addition to the services of the terrestrial strips, wet elements also have the aquatic functions and values. Batrachians, some bird and plant species are among those promoted by these aquatic environments. (see further Table 9, Table 21, Table 22)

Underlying the indicator estimate are 24,600 m of ditches. No brooks at all cross agricultural land. The variable for width of the vegetation strip adds in average by a factor of 2 to the indicator, since almost all have a double-zone wider than 2 m to the cultivated soil. There is hardly any maintenance of the grass and herb layer, so, consequently, this variable does not add to the indicator estimate.

The weighted average of the wet linear objects’ indicator values is 10.7. This relatively high value is much owing to the fact that ditches *per se* are valuable by bringing aquatic environments, and could be increased if they were maintained better. About 13,000 m ditches are low ranked, with indicator estimates ≤ 10. There are 5,010 m highly valued ditches, with indicator estimates > 13.

It is an indicator whose main variables can be monitored at low costs by air-photo surveys. Judged as highly relevant for biodiversity as well as some social functions, it should serve well for agri-environmental payment systems.

9.2.7 Wet point field elements

Vetlanda study area has alarmingly few wet point field elements preserved. Indicator L6 is estimated to paltry 0.47 qN°/km^2. Other areas may have even less, but the situation is nevertheless unsatisfactory considering the goals of historical and ecological perspectives.

Wet point elements in the fields are extremely important habitats for many batrachian, reptile, bird and invertebrate species, especially if they are sun-exposed. Ponds, but even minor wetlands, can be valuable also for cultural historic and landscape scenic reasons, see further Table 8.

Eight ponds have been registered in the study area. Positive with respect to biodiversity is that six of them are sun-exposed and another one partly so. No minor wetlands contribute to the indicator.

The indicator should be considered as supplementary to the other field element indicators, especially to L5 for some biodiversity values. It is easy and cheap to monitor in its present design. The objects and all their quality variables can quickly be detected by air-photo surveys. Actually, there are only two variables for the ponds, size and sun-exposed/shadow. The advantage of adding more quality variables should be considered.

9.2.8 Qualitative forest edges

The indicator L7 for "Qualitative forest edges" is estimated to 6,300 qm per km^2 of land in the study area. That good figure is mainly because of the mosaic character of the landscape, where heterogeneous physical geographical conditions combined with cultivation in the past wherever it was possible give many borders between agricultural and forest land. The situation could improve significantly more if the forest edges were managed better.

The edges between forest and agricultural land can be very important for biodiversity, scenery and access for outdoor life, see chapter 2.1.3.

A few variables are used to estimate the qualities of the forest edges. *Edge depth* is surveyed from air-photos, distinguishing between edges that are more or less a wall of trees and edges that are open, having a zone of grass and herbs of 10 m or more. *Edge type* is estimated by the field surveys. It indicates whether the edge is a tree wall or it is stratified, with a mix of tall trees, small trees and bushes. Another variable distinguishes between *deciduous* and conifer edges. The *maintenance* variable indicates whether the grass along the edge is cut or grazed, or if there has been an accumulation of organic litter. The *confirmation species* of vascular plants, finally, have not been surveyed, but are supposed to be reported by farmers who can point out such species. See Table 11, Table 21 and Table 22 for more information about the objectives of the indicator and how it is calculated.

There are in total 277 000 m forest edges in the study area. As the total qualitative length is 462 000 qm, the weighted average for the indicator at the object level is 1.67. Poor forest edges, whose indicator estimate is 1, extend to 105,000 m in total. The total length of high quality forest edges, indicator value ≥ 2, is mere 19,700 m. Most of the obtained values above 1 are due to the factor for deciduous trees. They are considered more valuable, partly for biodiversity reasons, and extend over 160,000 m. On the other hand, mere 11 000 m of the forest edges are open or stratified. This scarcity reduces the biodiversity, scenic and recreational values of the area's forest edges substantially. Here is a potential for enhancing the landscape services by relatively small efforts.

L7, the forest edge indicator, is in many respects overlapping with the indicators for the field elements, for example what concerns biodiversity functions and access. Since some functions are more or less different, the forest edge indicator should be considered as a supplementary but separate indicator.

The indicator is considered as highly relevant for a set of biodiversity values or functions, for aesthetic values and landscape heterogeneity. The length can be estimated automatically by GIS-procedures. Some of its qualitative factors can also be estimated at low costs, such as edge depth and the deciduous/conifer-character. To monitor maintenance and confirmation species in a full, national scale will, however, be demanding. A system of self-reporting with random inspection is recommended instead.

9.2.9 Biorich trees

The situation for the biorich trees is good in the study area. Landscape indicator L8 for biorich trees is estimated of 51 qN^o per km^2 of total land area. If instead expressed in qN^o per km^2 of agricultural land is the corresponding indicator value 255.

The indicator is estimated by first counting the number of trees with large canopies through air-photo surveys. An indicator value for each of these is calculated by multiplying with a factor for tree species, where oak and lime-trees are among those with highest biodiversity qualities. Variables for hollow trees, coarseness and sun-exposure add to the indicator value, since these reflect important biodiversity qualities. (See Table 12, Table 27 and Table 28.) Note that it has not been possible to do field surveys in all the study area, so these variables are accordingly not fully taken account of in the study. The indicator estimate is thus a minimum value, most certainly a little underestimated.

Old, hollow oaks and other large, deciduous trees are particularly "biorich" trees, and the indicator is designed to reflect the values ascribed to these qualities. The main concern of the indicator is thus biodiversity. Many of these trees that are classified as biorich may also contribute to the landscape's aesthetic and identity forming values, see chapters 0, 2.2 and Table 12.

There are in total 2,280 biorich trees identified that underlie the estimate. Most of them are oaks.

The indicator is more or less independent of the other indicators. By reflecting other qualities it gives little over-lapping. To monitor the number of trees with large canopies and sun-exposure from air-photos is little time consuming and not costly. Identifying hollow trees, tree species and trees larger than 1.5 m in chest-high is, on the other hand, more time demanding considering the large amount of biorich trees in some regions. A system of self-reporting with random inspections would be an alternative to field surveys for these variables.

9.2.10 Historic relics

The indicator L9 for "historic relics" is estimated to 35 qNº/km^2 of agricultural land in the study area. If instead measuring the indicator relative total land area, the estimate would become 7.0 qNº/km^2, but that is not recommended considering that the forest and wetland areas would influence the indicator estimate improperly. The indicator estimate tells that the area is relatively rich in historic elements. Note also that in addition to, for example, grave fields and cultivation cairns that are measured by this indicator, come the cultural historic values of stone-walls, ditches, meadows, fields and other objects that are expressed through the previous indicators. The positive situation is mainly owing to the large number of stone cairns from past cultivation in the area, and only to some extent from good maintenance.

The indicator is calculated by multiplying the number of historic relics with respective objects' quality factors for type, maintenance and visibility (see Table 13, Table 29 and Table 30). The objects are identified from a GIS-database and by the field surveys.

The main aim of designing such an indicator for historic relics, separate from the indicators for other acreage, linear or point objects, is to highlight these elements of specific, cultural historic interest. Some of them certainly also have other values as well, aesthetic and even for biodiversity.

Underlying the indicator estimate are 10 ancient grave fields or rune stones, 2 ruin house foundations, 18 field barns or other old farmland buildings, and 169 cultivation cairns. The major contribution (50%) to the indicator value comes from the stone cairns. Note that not all cairns may have been registered in the survey, so that the indicator is likely to underestimate the real situation. Field barns and other old farmland buildings are the second most important type in terms of indicator impact (30%).

The indicator is judged as highly relevant for some types of cultural historic qualities of agricultural districts, but should be considered as supplementary to the indicators for fields, grasslands, linear and point elements. Since it is forbidden to remove this kind of historic relics, the main aim of the indicator is to allocate resources to fields and pastures having historic relics – and hence increase the chance that they will be maintained. Another aim is to provide incentives for management of the relics. The pedagogic and cost-efficiency criteria are well satisfied for the indicator.

9.2.11 Confirmation species

Indicators based on confirmation species of vascular plants, birds, bryophytes and lichens, respective invertebrates are developed and suggested for the AEP-system. They are, however, not or only fragmentary estimated within the project because of the project's resource constraints.

10. Methodology for analyses and calculating EMR

10.1 Indicator species

by Svante Hultengren & Andreas Malmqvist, Naturcentrum AB, 2002.

10.1.1 Birds

Birds are often are easy to recognize both by vision and sound and they are also quite easy to count. They also respond to changes in the environment. These are factors that make birds useful as indicator spices. One problem with the use of birds as indicators is that they are rather easily affected by bad weather situations, both during breeding, migration and at their winter quarters. Compared to other organisms birds often have a good dispersal capabilities (Edenhamn et. al. 1999) and may accidentally occupy areas with lower biodiversity. The birds described below are presented as indicator species for habitats with high biodiversity and where many threatened organisms often occur.

Many birds in the agricultural landscape have decreased rapidly in numbers during the last century and some of our most threatened bird species are found here (Gärdenfors 2000). The change in land use from a traditional small scaled system to the more intensive and large scaled we see today is often pointed out as the main cause for many species decline (Andersson 1988). The vast drainage of wet areas for improved crop yield during the last 150 years led to a considerable decrease in wet meadows and related important habitats. This change has led to small and fragmented suitable habitats for many species (Alexandersson & Eriksson 1988). An investigation in Älvsborgs län (Eriksson 1981) show that an inland wet meadow area in Southern Sweden should exceed 15 ha to contain the characteristic bird fauna.

Wet and well-managed meadows are a habitat of great importance for many birds as well as for many other organisms. The southern sub-species of Dunlin *C. a. schinzii* and the Black-tailed Godwit *Limosa limosa* are two rare species breeding at well-managed wet meadows and pastures along the coastline in southern Sweden. The populations have continuously declined during the 20th century due to loss of suitable habitats and the breeding population in Sweden is for both species estimated somewhere between 250 and 350 pairs (Svensson 1999). Restoration of wet meadows has shown that a combination of mowing and grazing is a favourable management for the Black-talied Godwit (Hellström & Berg 2001). This management is also favourable for many other organisms like vascular plants and insekts. These waders´ strong preferance for short vegetation and at least the Black-tailed Godwit´s preference for big areas make them probably very good indicator species for well-managed and valuable wet meadows and pastures.

Redshank *Tringa totanus* and Lapwing *Vanellus vanellus* also occur in the same habitat but they can use more different habitats than the Dunlin and the Black-tailed Godwit. They are most common along the coastline but both the redshank and especially the Lapwing still breed at many inland locations (Svensson 1999). The southern sub-species of Yellow wagtail *Motacilla flava flava* is another bird that breeds in the same habitats. Like the other species the Yellow Wagtail has decreased in numbers probably due to decreasing areas with well-managed meadows (Andersson 1988). In the same way as the Dunlin and the Black-tailed Godwit these birds habitat preferences can make them useful as indicators of valuable habitats rich in rare organisms but at a lower level.

In more arid habitats abandoned meadows and pastures has led to a gradual invasion by scrub and later on higher bushes and trees. Many of the species in an open and well managed meadow or pasture are adapted to the low vegetation and the warm soil and ground due to intensive sunexposure. These habitats are often very rich in insects and many insecteating birds in this habitat are therefore negatively affected when meadows and pastures are abandoned (Svensson 1999). Birds that are dependent on groundliving insects probably indicate areas with high diversity of both plants and animals adapted in an open and well-managed agricultural landscape.

Wheatear *Oenanthe oenanthe*, Red-backed Shrike *Lanius collurio* and Starling *Sturnus vulgaris* are all insectseating birds that have been negatively effected by the change in agricultural landuse (Svensson 1999). They are all characteristic birds for open areas with short grass and in that way dependent on grazing or mowing. Often is grazing preffered because of all insects associated with the cattel. The Wheatear is more or less restricted to habitats with low plant layer as they often pray upon ground living insects. An other requirement is heaps of stones or stone walls were they nest (Carlsson & Morena 1988). The Red-backed Shrike is probably not that dependent on very short grass as they often strikes their prey in the air (Olsson 1995). Except the diversity connected to open areas the Starling also indicate hollow trees where they nest. Old hollow trees often contain a specialized and fauna of insects

Wryneck *Jynx torquilla* and Stock Dove *Columba oenas* are two another birds in the agricultural landscape that has decreased rapidly in numbers (Svensson 1999). They nest in holes in old trees and both species can be found in old forests but they seem to prefer hollow trees close to well-managed pastures. The wryneck feed on small groundliving ants dependent on a very short grass, often in pastures. The large number of abandoned pastures is supposed to be the major cause of the Wryneck´s decreas (Axelsson et. al. 1997). Stockdove and Wryneck can be used as indicators of open – semi open agricultural landscape with a good supply of hollow trees. The Wryneck does also indicate well-managed pastures.

10.1.2 Vascular plants

Many vascular plants are dependent on mowing or grazing for their survival (Ekstam & Forshed 1996). All of the vascular plants propsed as indicator species are connected to well-managed pastures and meadows and will disappear soon if the habitat is left in an abandoned state (Ekstam & Forshed 1992).

10.1.3 Insects

Several insects are probably very good indicators of well-managed agricultural landscape rich in biodiversity. They often thrive under hot condition and may therefore decrease in numbers if an managed area i abandoned with shading bushes and trees as a result. Most av the insects in the agricultural ladscape probably have a low disperal rate which make the valuable habitats easy to point out. One disadvantage with insects as indicatorspecies is that they can be hard to identify without expert knowledge. The species suggested as indicators are therefore few and often easy to recognize.

The Hermite *Osmoderma eremita* is a large beetle that live inside old and hollow trees, often oaks, in the agricultural landscape. It is a rare species and like many other organisms dependent on old oaks it has decreased in numbers. Many old oaks were cut down in southern Sweden during the 19th century (Eliasson & Nilsson) and this affected probably many oak-living organisms in a negative way. The Hermite is sensitive to habitat fragmentation and can be used to indicate area that are and have been less fragmented (Ranius 2001). It's dispersal rate is also low (Ranius & Hedin 2001) which improve its ability as an indicator species. Other rare insects living in old has also been shown to be negatively affected by fragmentation (Ranius 2001).

Several ground-living beetles are restricted to open and thereby often warm areas (Ljungberg 1999). In wet and well-managed areas the rare but easily recognized beetles *Chlaenius nigricornis* and *Panagaeus crux-major* can be found. They are dependen on low grass vegetation, mowed or grazed, close to water. Both species has decreased rapidly in numbers as grazing and mowing along shores is very rare today (Ljungberg 1994,1995). They indicate valuable and rare beetle communities dependent on well-managed shore vegetation (Ljunberg pers. comm.). Well-managed shores is also a valuable habitat for many other organisms.

In more arid areas some butterflies and beetles can be used as indicators of well-managed and open pastures and meadows. The Silver spotted Skipper *Hesperia comma* and the breeds in open chalk grassland and has the Sheep´s-festuce Festuca ovina as it´s sole foodplant. The butterfly has declined rapidly during the 20th century and is now a rare and red-listed species in Sweden (Gärdefors 2000). The Silver spotted Skipper is restricted to arid areas and often lay its eggs on foodplant gowing in the warmest position (Millenium atlas). In Great Britain has many of its habitats been lost due to agricultural improvement and cessation of grazing (Millen) and the same is probably true for Swedish populations.

Members af the genus *Zygaena* are all easily recognized butterflies living on dry grassland. All except one species are on the red-list for Sweden (Gärdenfors 2000). They occur on flower-rich medows and pastures in the small scaled agricultuiral landscape and are probably useful as indicators

Many dung beetles have declined rapidly (Ljungberg 1999). All members of the genus *Ontophagus* are red-listed and occur mainly on hot and sandy pastures i southern Sweden (Ljungberg 1999). They are dependent on an intensive grazing with very short grass preferably on sandy soil. Dung beetles bury pieces of dung underground where the lay their eggs. A to thick grass layer makes it hard for the beetles to dig (Ljungberg 1999) and may prevent a proper development of the larvae due to lower soil temperature. These dung beetles is supposed to occure in areas that often contain high biodiversity. A disadvantage with the use of these beetles as indicator species is their supposed good dispersal rate (Ljunberg pers. comm.).

10.1.4 Lichens and mosses

Those two groups of organisms have often been used as biological indicators in many different investigations in forest environment, but not so often in the agricultural landscape. Lichens and mosses are, however, often favoured by mechanical disturbances of soil in combination with grazing or mowing. Lichens are also common on rocky outcrops in the agricultural landscape. Pollared trees, old oaks and other types of trees (biorich trees) also contain a large number of common as well as redlisted species.

10.2 About EMR

by Svante Hultengren & Andreas Malmqvist, Naturcentrum AB

Ecological minimum requirement (EMR) is a value connected to a structure, object or species and their relation to biodiversity in a well-managed agricultural landscape. A high EMR indicate high relation to biodiversity and these objects and species are negatively affected when the habitats are left in an abandoned state. There is a lack of research on the interactions between habitat and species that can work as indicators of high biodiversity in an agricultural habitat. Most research points out good indicators within different organism groups, for example vascular plants that indicates valuable flora communities in a natural pastures, but the connection between organisms groups have to be done from a best professional judgement (BPJ) as long as we lack research results.

All proposed indicators are negatively affected at an abandoned state but in different degrees. Agricultural habitats that has been left in an abandoned state are lacking or inhabited by very few of the presented indicator objects and species. There is however a big difference between the objects and the species relation to biodiversity. Many of the species disappears long before the objects. At an abandoned state objects like ”Old trees” can still be found but most of the biodiversity connected to the trees in an open environment has disappeared. The total EMR-value for a habitat left in an abandoned state is very low and lack at least species with the highest EMR. This level equals the EMR 0- level.

Above the EMR 0-level each habitat gets en EMR-value depending on the type of habitat, the habitat’s area, included indicator-objects and indicator-species. The EMR-value connected to the habitat-type is low and based on quantity while the EMR-values connected to objects and species are based on both quality and quantity. Some objects and species can be found in several habitats but they are thought to maintain their indicator ability everywhere in the agricultural landscape. But as mentioned above there is a difference between objects and species.

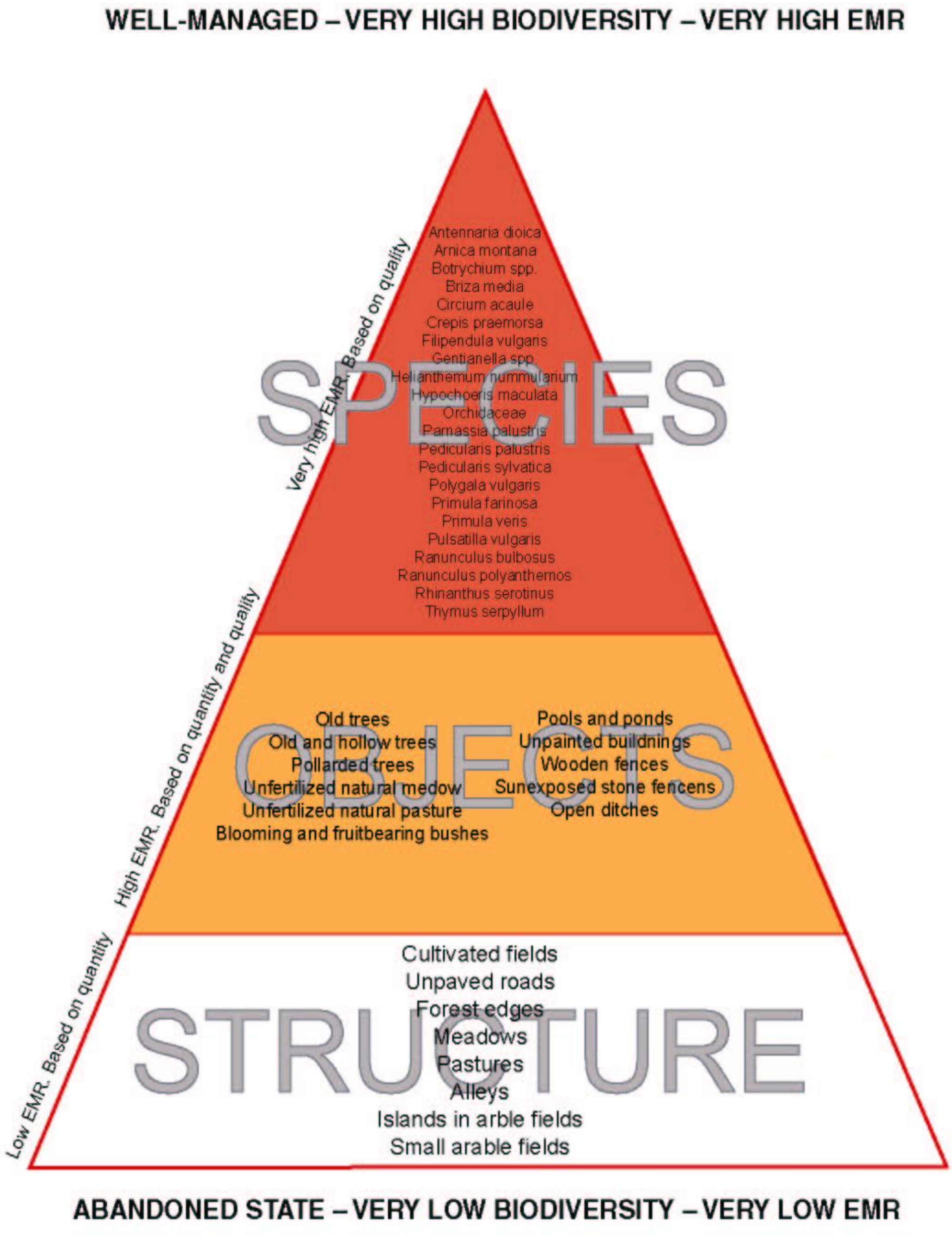


Figure 9. The pyramid of biodiversity demands

10.3 Settlement of tiers

by Knut Per Hasund

10.3.1 Tiers for the object level

The attempt to settle tiers – or rather scales – for the object indicators that are developed in this study is founded on *the abandoned state as reference level*. The "abandoned state-situation" that is used as benchmark with tier = 0 refers to a (simulated) average, mature state of the land. Acknowledging that there is no such static, climax state, an estimated average situation of the mature state of abandoned land is used as the reference level. Using merely the average, mature state as reference implies that the environmental qualities of intermediate states are not considered when a field is going from the managed to the abandoned state. The intermediate states may have qualities that in some respects have higher or lower valued environmental qualities than the managed and the abandoned states. It would certainly be possible to consider temporal effects, but that is not done here to not make the analyses more complicated.

There are two main motives for using the abandoned state as reference level in a study on agri-environmental payments for Sweden. One motive concerns realism and pedagogic. A realistic scenario for much of agricultural land in Sweden is that production may cease and the area will be afforested. Besides being a realistic and "natural" reference point, it is lucid to compare different land uses and management regimes against a zero level of no management at all. Some land uses and management regimes may give indicator estimates above tier = 0, other below. The relative values for the alternatives may be compared once there is a scale.

The reason for not choosing "The natural state" for the reference level with tier = 0 is partly that this is not a realistic alternative for assessment of present and future alternatives. Agricultural land is by definition non-virgin. The influence is more or less irreversible, although the abandoned state in many cases by time may get close to the natural state.

The other motive has a welfare theoretic foundation. The abandoned state is the given reference level for assessing the externalities of agriculture. By definition, an externality exists if there is an impact on an argument in somebody's utility function without a corresponding compensation. Hence, the abandoned state is what would exist spontaneously (given the historic situation), while any activity may cause environmental effects that are externalities. Settling tier = 0 for the abandoned state will give a direct correlation for estimating the externalities that shall serve as the basis for designing the agri-environmental measures.

10.3.2 Tiers for the landscape level

The purpose of using EMR and settling tiers is to get benchmarks against which to compare whether the actual, environmental situation is good or could involve risks of a non-sustainable development. Below EMR there is a danger that the environmental function will not be performed at the level of the study area. Assessments of the environmental status at the landscape level should thus be easier to conduct and communicate if using EMR for reference. The EMR-tiers hence consist of a normative, political component, and a scientific, factual component of which level society can accept as a minimum standard and what conditions that are necessary to achieve it.

It means that an EMR-tier = 0 corresponds to the value that respective indicator would take if the environmental status of the area would perform at minimum required level. If, for example, a hypothetical indicator I_h has an EMR-tier at 14, then an estimated $I_h = 14$ would correspond to an environmental status = 0, while $I_h = 11$ might correspond to –1 and $I_h = 19$ to +1.

Table 35 below presents a first attempt to establish tiers for assessing the environmental status of a landscape by using the developed indicators. The indicators are explored in chapter 6.

Table 35. Preliminary tiers for environmental status at the landscape level related to EMR concerning the defined biodiversity functions[1)].

N°	Landscape indicator name	-2	-1	0	+1	+2	Measure*
L1	Area permanent grasslands (PG)	L1≤3		3<L1<5	5<L1<10	L1≥10	Ha_{PG}/km^2
L2a	Qualitative area of grasslands	L2a≤20		20<L2a<30	30<L2<50	L2a≥50	qHa_{PG} /km^2
L2b	Area non-shore grasslands (CG)	L2b≤15		15<L2b<25	25<L<40	L2b≥40	qHa_{CG} /km^2
L3	Dry, linear field elements (DLFE)	L3<1500		1500<L3< 2500	L3≥2500		qm/km^2
L4	Dry, point field elements (DPFE)	L4≤3	3<L4≤5	5<L4<15	15<L4<30	L4≥30	qN°/km^2
L5	Wet, linear field elements (WLFE)	L5≤3000		3000<L5< 5000	L5≥5000		qm/km^2
L6	Wet, point field elements (WPFE)	L6≤3	3<L6≤5	5<L6<10	10<L6<20	L6≥20	qN°/km^2
L7	Forest edges (FE)	L7≤3000		3000<L7< 6000	L7≥6000		qm/km^2
L8	Biorich trees (BT)	L8≤2	2<L8<5	5<L8<10	10≤L8<15	L8≥15	$qN°_{BT}$ /km^2
L9	Historic relics(HR)	–		–	–		$qN°_{HR}$ /km^2**
L10	Confirm. species of birds (CSB)	..	..	..	..	..	qN°/km^2
L11	Confirm. species vascular plants	L11≤5	5<L11≤10	10<L11<20	20<L11≤ 40	L11>40	qN°/km^2
L12	Confirm. species of bryophytes + lichens	..	..	..	..	..	qN°/km^2

1) See **Fel! Hittar inte referenskälla.**.

* km^2: per km^2 of total land area in the study area

** km^2: per km^2 of agricultural land area (arable fields + permanent grasslands) in the study area

Table 36. Preliminary tiers for EMR concerning the defined historic and socio-cultural landscape functions[1)].

Nº	Landscape indicator name	-2	-1	0	+1	+2	Measure*
L1	Area permanent grasslands (PG)	L1≤5		5<L1<7	7<L1<10	L1≥10	Ha_{PG}/km^2
L2a	Qualitative area of grasslands	L2a≤10		10<L2a<20	20<L2<40	L2a≥40	qHa_{PG}/km^2
L2b	Area non-shore grasslands (CG)	L2b≤10		10<L2b<20	20<L<40	L2b≥40	qHa_{CG}/km^2
L3	Dry, linear field elements (DLFE)	L3<2000		2000<L3< 3000	L3≥3000		qm/km^2
L4	Dry, point field elements (DPFE)	L4≤3	L4≤5	5<L4<15	15<L4<30	L4≥30	$qN°/km^2$
L5	Wet, linear field elements (WLFE)	L5≤2000		2000<L5< 4000	L5≥4000		qm/km^2
L6	Wet, point field elements (WPFE)	L6≤2	L6≤4	4<L6<8	8<L6<20	L6≥20	$qN°/km^2$
L7	Forest edges (FE)	L7≤3000		3000<L7< 6000	L7≥6000		qm/km^2
L8	Biorich trees (BT)	L8≤1	1<L8<2	2<L8<5	5≤L8<10	L8≥10	$qN°_{BT}/km^2$
L9	Historic relics(HR)	L9≤2.5		2.5<L9<5	L9≥5		$qN°_{HR}/km^2$**
L10	Confirm. species of birds (CSB)	–	–	–	–	–	qN^o/km^2
L11	Confirm. species vascular plants	–	–	–	–	–	qN^o/km^2
L12	Confirm. species of bryophytes + lichens	–	–	–	–	–	qN^o/km^2

1) See **Fel! Hittar inte referenskälla.** and **Fel! Hittar inte referenskälla.**.

* km^2: per km^2 of total land area in the study area

** km^2: per km^2 of agricultural land area (arable fields + permanent grasslands) in the study area

10.4 Methodology for establishing EMR-tiers

The first step involves choosing which reference level to apply. The abandoned state turned out as the relevant level for determining the external, environmental effects and hence as basis for the agri-environmental payments. The reasons are stated in chapter 10.3 and given the approach of the Swedish study. However, at the landscape level, the indicators serve partly other objectives, including the role of detecting if the situation is complying with the social demands of a satisfying and sustainable development. Tiers for what experts judge as bad and good situations are hence developed at *the landscape level*. The tiers are based on scientific assessments of factual relations, given the stated goals and demands of society for the environment. A set of Environmental Minimum Requirements, EMRs, are supplemented by tentative tiers to distinguish between grades of beneficial or unsatisfactory states. Please consider that all tiers are preliminary and open for revision, not to be understood as definite truths.

Another crucial, phase is to settle the most appropriate measure of the indicator and its tiers. For the purpose of this study, qualitative measures per area of total land area appeared as the more appropriate choice. Stating the indicators and their tiers in this kind of measure has implications, not only for how the situation may be communicated, but also for how different problems are revealed. The choice of qualitative measures is motivated by the heterogeneity of the physical objects in the landscape, and that the environmental services are highly dependent of the character of these, different qualities. Simply using quantitative measures of the objects would be too coarse an information, not giving sufficient precision. A crucial question is whether to relate the aggregated figures against total land area, total agricultural land area, or some other entity. Any choice will influence how the problems are exposed in relative terms across regions[12]. Measures *per total land area* (/km^2) are established as the reference base here, since the possibilities for many species to communicate between sub-populations and survive are spatially determined. Some cultural and social values are also more related to total area than to what is actually cultivated or grazed at present. This is, however, a scientific question that is still open, and the choice may be revised.

Next step is to estimate which value of respective indicator that would correspond to the EMR. These estimates are stated as EMR-tiers = 0. Consequently, estimated indicator values higher than these values would get positive signs, since all indicators measure positive qualities. The fourth step involves establishing tiers for differentiating between a positive (negative) and very positive (negative) state, in order to develop a better warning system. These tiers are by nature characterized by quite subjective components, and should be understood as such. A +1-value should still be interpreted as a scientifically based assessment signifying a state better than the EMR-state. Analogously, A +2-value should be interpreted as a favourable state with good margins to a critical level. Note that +1-values refer to the EMR-state, and that the situation still could be critical from a society point of view, if demanding more than just the minimum requirements. Negative values signify states that are worse or seriously worse than the EMR-state with respect to the indicator.

The methodology involves a process of establishing, revising and confirming the values of the tiers. This process has two parts. One part of the task has been to interpret former policy decisions, where the demands of society are explicitly or implicitly expressed. Stated goals and objectives, policy instrument designs, resource allocations and case decisions in policy implementation reveal what and how much society values various environmental goods and services. Among the sources are e.g. Naturvårdsverket 1987a, Naturvårdsverket 1987b, Naturvårdsverket 1997, Ministry of Agriculture 1999, SJVFS 1995:133 and Swedish Board of Agriculture 2002. The task also involves studying surveys on how people value landscape amenities and landscape elements. Environmental valuation studies serve the aim of settling a normative basis for the tiers, as a foundation for the scientific problem to determine and operationalize the goals into physical terms.

[12] If, for instance, using “total land area” as the base, problems in regions with relatively much agricultural land will be less pronounced than if instead using “total agricultural land area” as the base.

The other part of the process has been to establish physical tiers. A series of seminars, meetings and telephone interviews has been carried out with members of the project's reference group of experts. Its outcome is a median value to be established as the preliminary Best Professional Judgement (BPJ) for respective tier. The reference group consists of fully 30 persons that have been involved at varying degrees. Included are some of the country's most eminent experts in various branches of biology, cultural history, landscape architecture and geography.

11. GIS-monitoring and spatial presentation

11.1 Methodology of GIS and air-photo surveys

Existing GIS-databases were analysed in combination with air-photo surveys; see chapter 8.1 for a brief introduction of the applied methodology. To combine the databases into one, relevant GIS-database, consistent and free from discrepancies, turned out to be a fairly demanding work. As this task now has been successfully completed and there is a programme developed for conducting it, a corresponding GIS-database for all of Sweden could be produced almost by “press-a-button”-simplicity.

Infrared photos from 1996 in scale 1:30 000 have been used for the air-photo surveys. Unfortunately, there are not yet more recent photos available over the study areas. There are, however, discussions on whether all Sweden should be monitored annually by such air-photos.

The data collection and interpretation were carried out as direct digitalising in an analytical stereo-plotter. All data processing and interpretations were done in the programme ArcInfo 8.2, mainly by using AMLs. Every measure performed within the AMLs are documented. It should be possible to easily adopt them for application in a national scale.

11.2 Result-maps of Selaö study area

Data from GIS-databases, air photo surveys and field surveys have been compiled and analysed to evaluate the environmental situation in the agricultural landscapes of Selaö and Vetlanda study areas. The indicators that are developed to reflect the biodiversity and other landscape functions and values have been estimated for each landscape object within the representing object categories. Each arable field, each stone cairn etc. accordingly get an indicator value that is supposed to represent its landscape values. Supplementary to the texts and tables of previous chapters come below some maps on land use and indicator values that should illustrate the biodiversity, cultural and social landscape situation of the two agricultural areas.

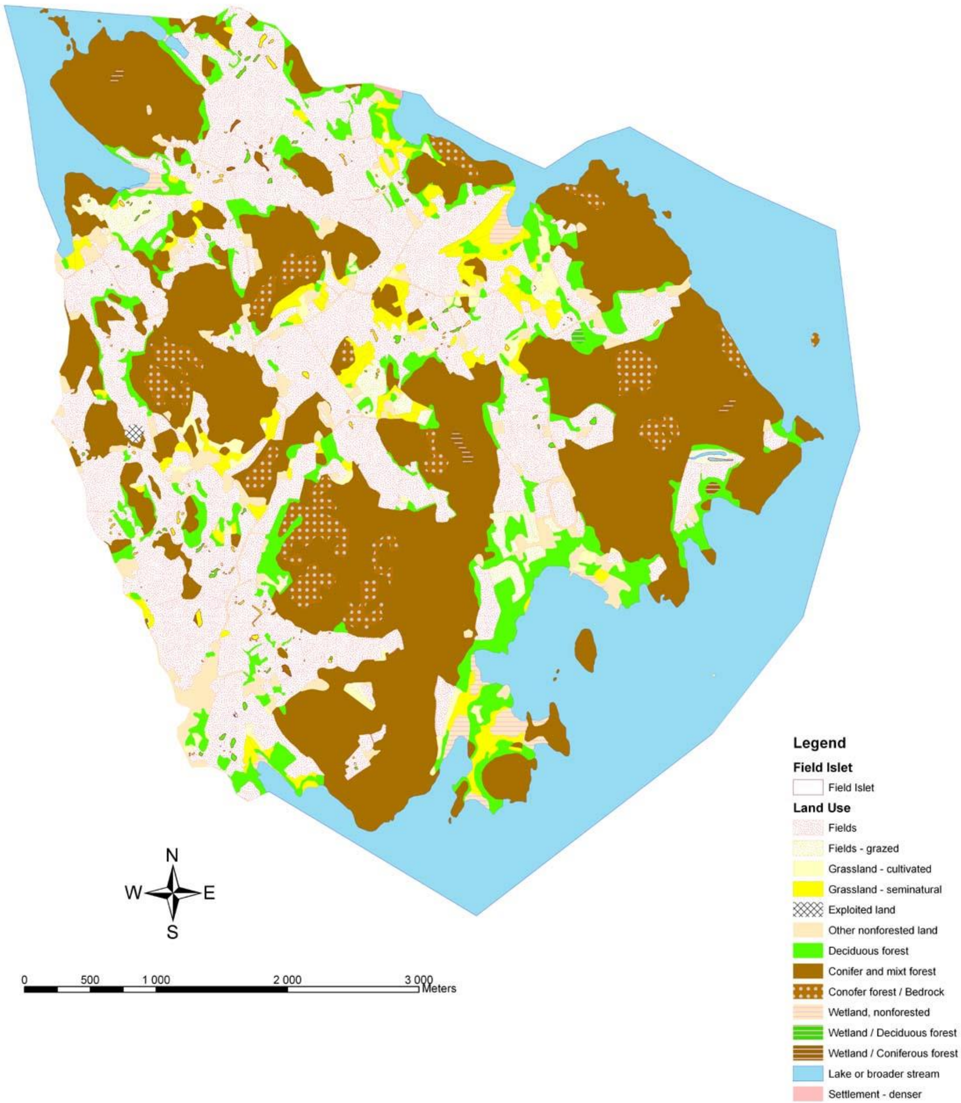


Figure 10. Land use in Selaö study area. Year 2002

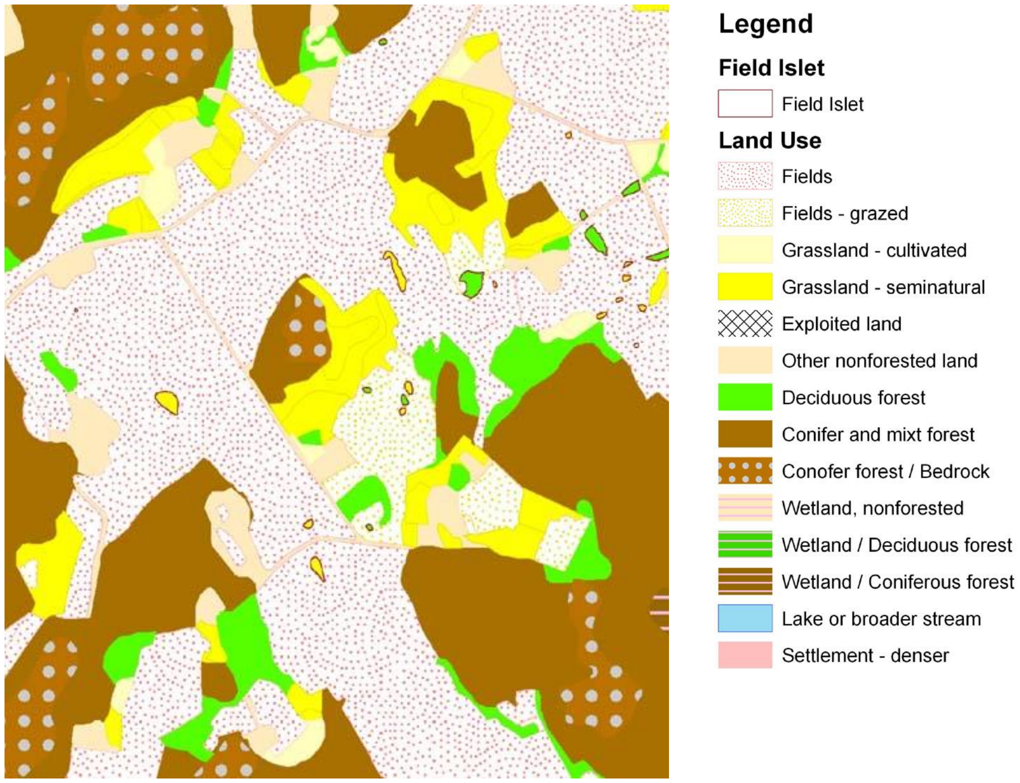


Figure 11. Land use in Selaö study area. Excerpt of central part. Year 2002
Area c. 2 X 2 km.

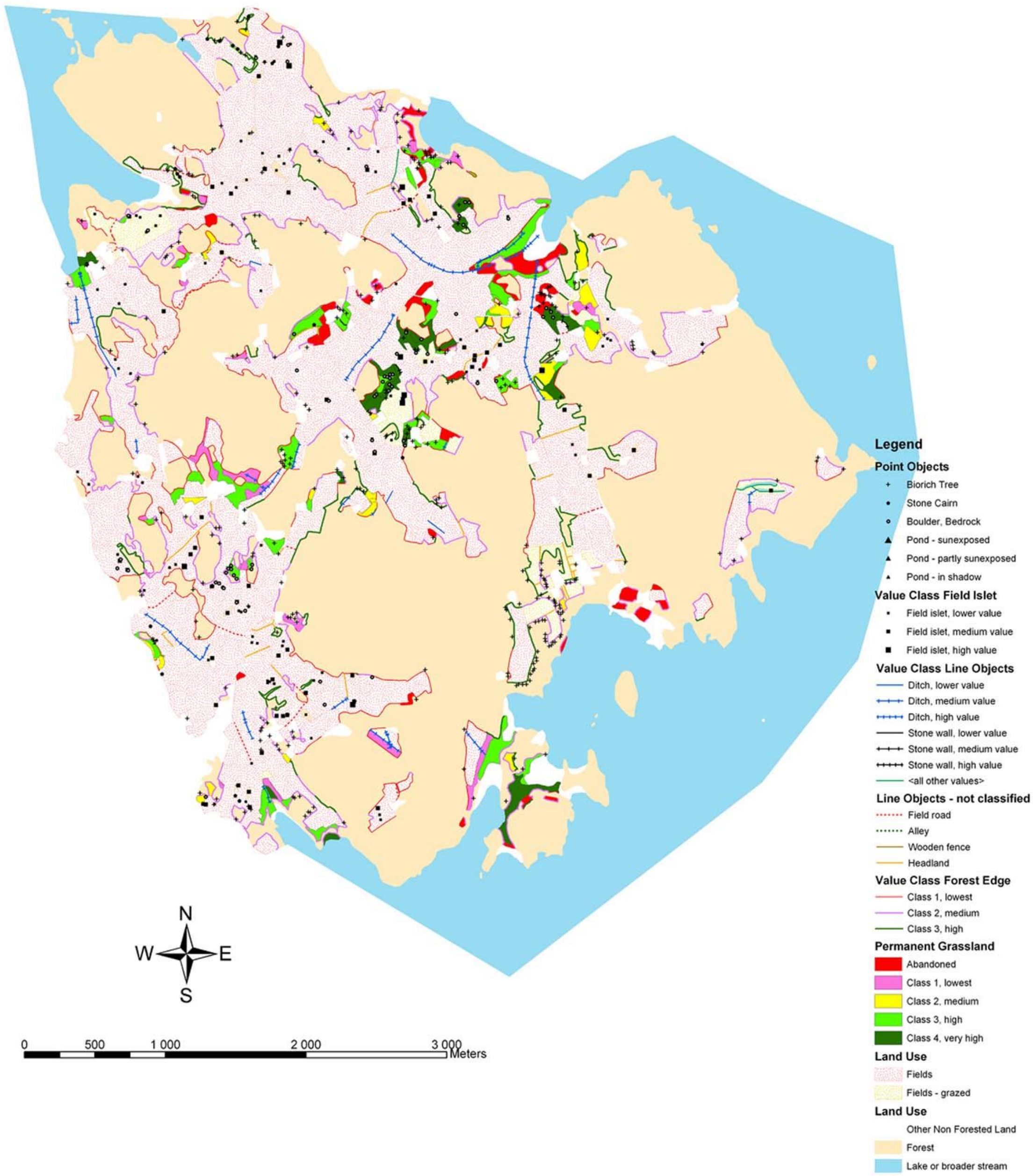


Figure 12. Environmental qualities of Selaö landscape objects as estimated by indicators. Year 2002

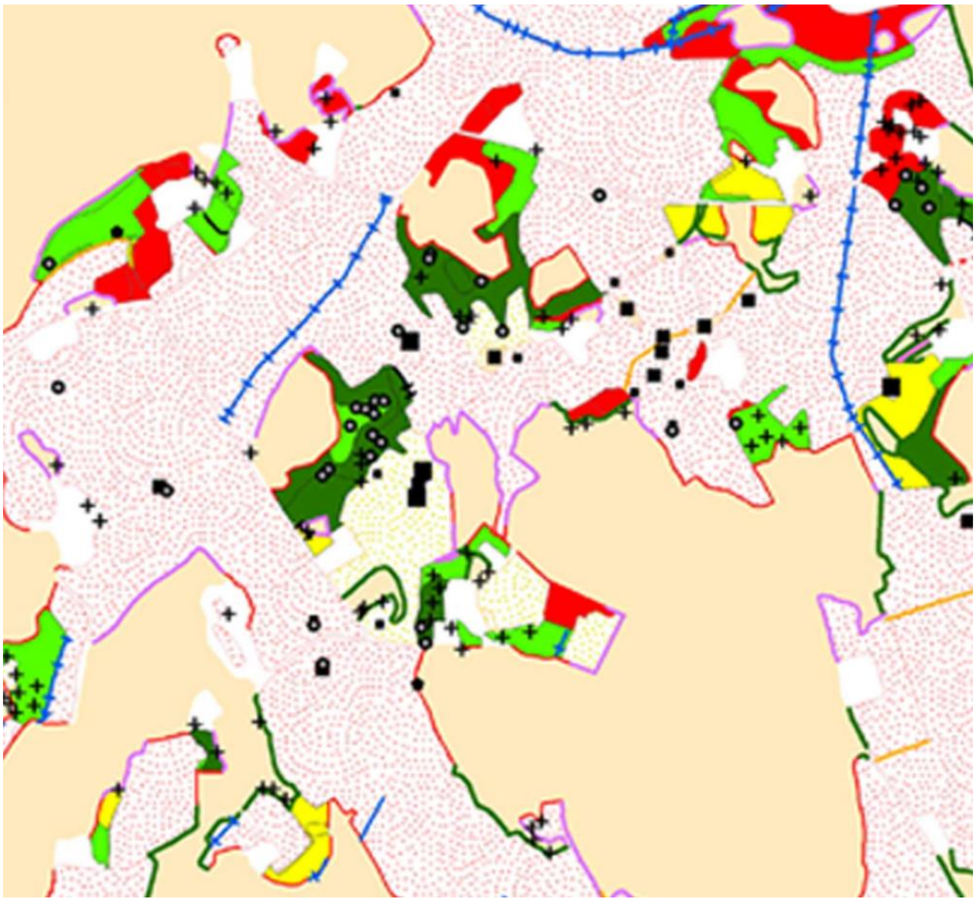


Figure 13. Environmental qualities of Selaö landscape objects as estimated by indicators*. Excerpt over central part of study area. Year 2002
Size of excerpt c. 2 X 2 km
* For legend see
Figure 12

11.3 Result maps of Vetlanda study area

Figure 14. Land use in Vetlanda study area. Year 2002
(Following page)

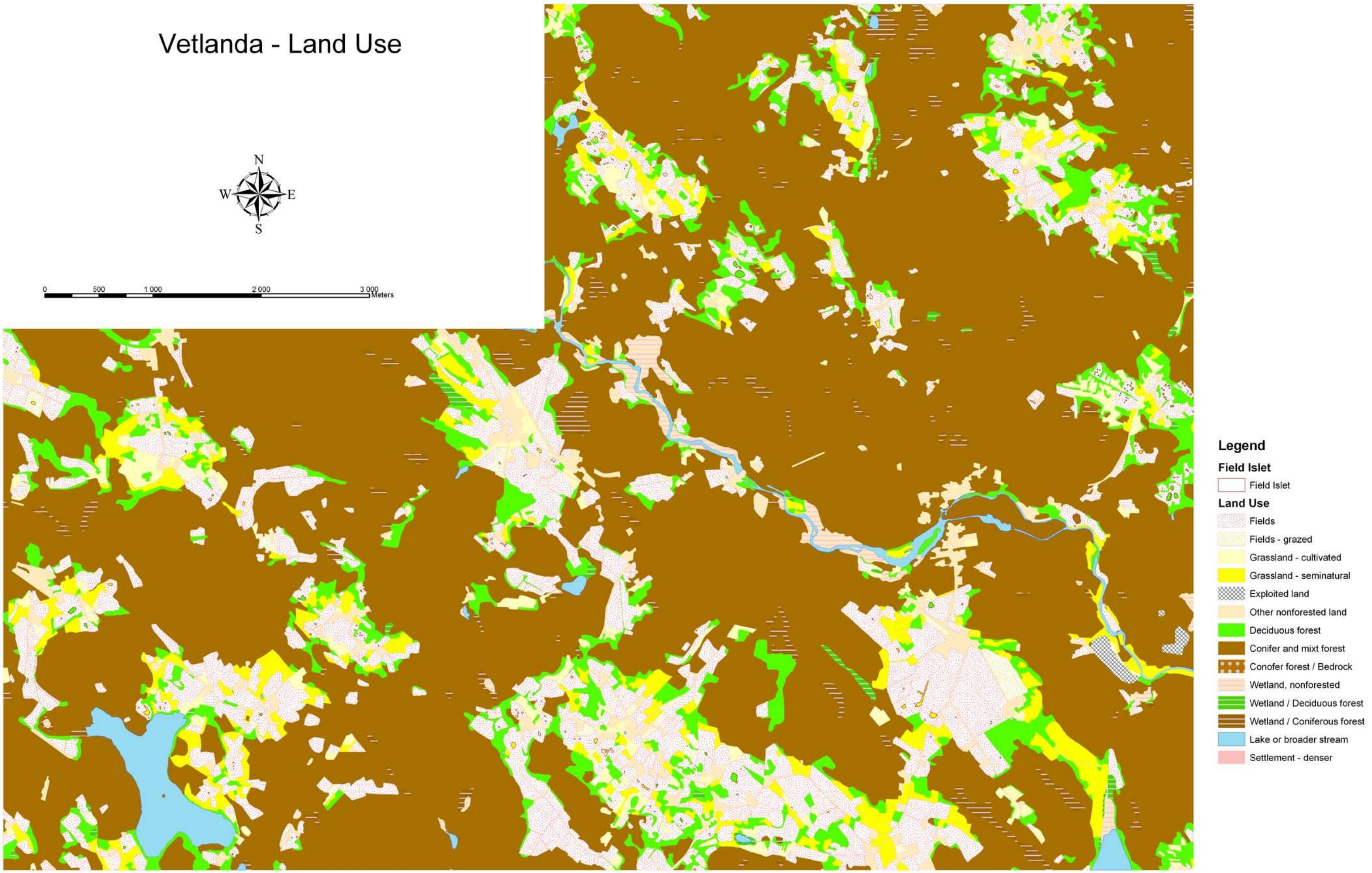

Vetlanda - Land Use
N
W
E
S
0
500
1 000
2 000
3 000
Meters
Legend
Field Islet
Field Islet
Land Use
Fields
Fields - grazed
Grassland - cultivated
Grassland - seminatural
Exploited land
Other nonforested land
Deciduous forest
Conifer and mixt forest
Conofer forest / Bedrock
Wetland, nonforested
Wetland / Deciduous forest
Wetland / Coniferous forest
Lake or broader stream
Settlement - denser

Figure 15. . Environmental qualities of Vetlanda landscape objects as estimated by indicators. Year 2002

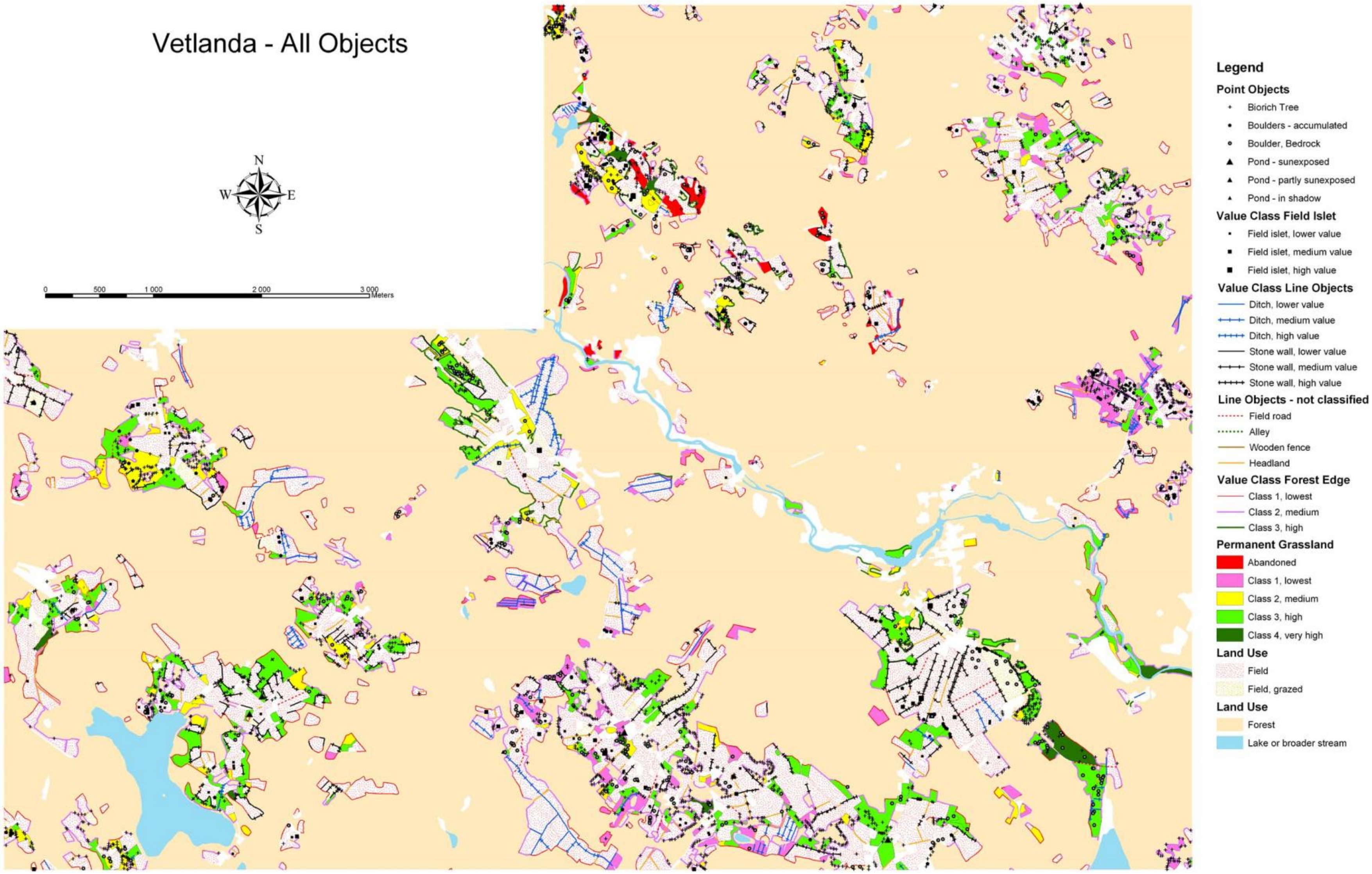


Figure 16. Environmental qualities of Vetlanda landscape objects as estimated by indicators*. Excerpt over north-central part of study area. Year 2002
* For legend see Figure 15

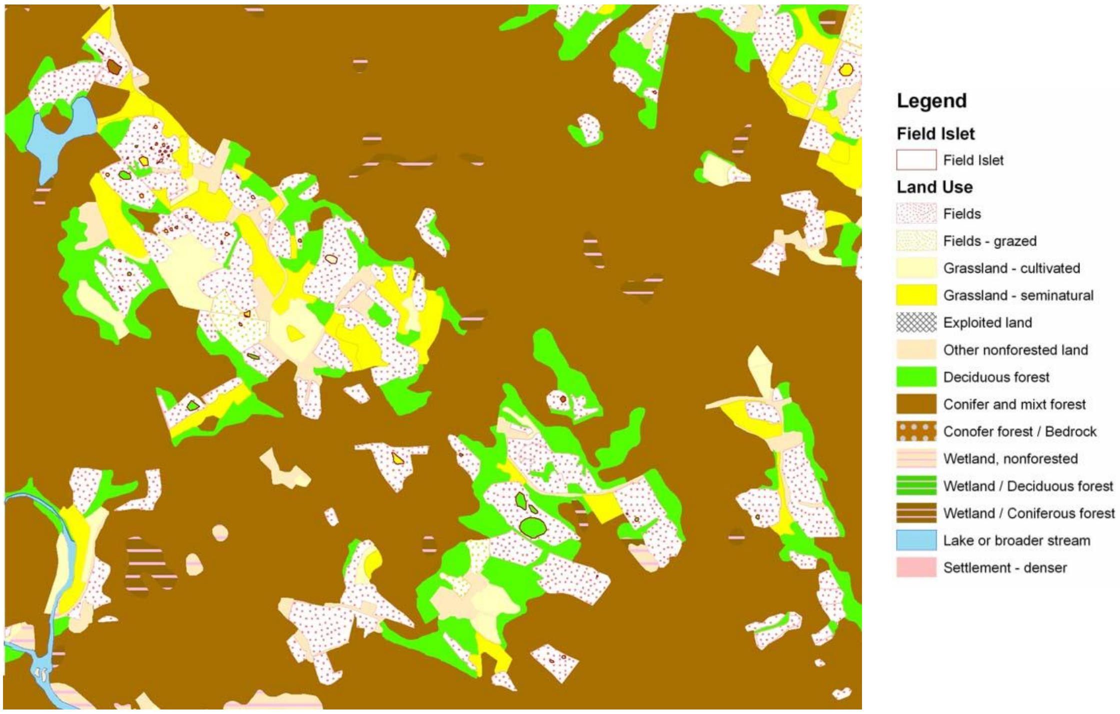


Figure 17. Land use in Vetlanda study area. Excerpt of north-central part. Year 2002.
Area c. 2 X 2 km

References

Abler, David. A Synthesis of Country Reports on Jointness between Comodity and Non-Commodity Outputs in OECD Agriculture. Workshop on Multifunctionality. 7-2-2001. Paris, OECD, Organisation for Economic Co-operation and Development. Directorate for Food, Agriculture and Fisheries. 7-2-0010. (GENERIC)
Ref Type: Conference Proceeding

Agger, J., Brandt, J., Byrnak, E., Jensen, S.M. & Ursin, M., 1986. Udviklingen i agerlandets småbiotoper i Östdanmark. Biotopgruppen. *Roskilde Universitetscenter, Forskningsrapport* no. 48, 541 pp (In Danish)

Agger, P. & Brandt, J., 1988. Dynamics of small biotopes in Danish agricultural landscapes. *Landscape Ecology* vol. 1 no. 4, 227-240.

Andersson, S. 1988: *Fåglar i odlingslandskapet. Om det äldre och det moderna jordbrukets inverkan på fågellivet*. Sveriges Ornitologiska Förening, Stockholm 1988.

Andersson, S. Småjordbrukets rationalisering 1945-1985. 1988. I: Andersson, S. (ed.). Fåglar i jordbrukslandskapet, *Vår Fågelvärld* suppl. 12:35-44

Appelquist, T. & Svedlund, L. 1998: *Insekter i odlingslandskapet*. Jordbruksverket, Jönköping.

Aronsson, M., 1980. Markanvändning och kulturlandskapsutveckling i södra skogsbygden. In: Resting, A., (ed.), *Människan, kulturlandskapet och framtiden*. KVHAA, konferens 4, 12-14 februari 1979, Stockholm, 221-232 (In Swedish).

Aronsson, M. (red.) 1999. *Rödlistade kärlväxter i Sverige I & II*. ArtDatabanken, SLU.

Arrow KJ, Debreu G. Existence of an Equilibrium for a Competitive Economy. Econometrica 1954;22:265-290.

Arvidsson, L. & Thor, G. (red) 1999: *Rödlistade lavar i Sverige 1999*. ArtDatabanken, Uppsala.

Asher, J. 2001. The Millennium Atlas of Butterflies in Britain and Ireland. Oxford University Press. 2001.

Austad, I. & Skogen, A., 1990: Restoration of deciduous woodland in western Norway formerly used for fodder production: effects on tree canopy and field layer. Vegetation 88:1-20.

Austad, I., Skogen, A., Hauge, L., Helle, T. & Timberlid, A., 1991. Human-influenced vegetation types and landscape elements in the cultural landscape of inner Sogn, Western Norway. *Norsk Geografisk Tidsskrift* vol. 45, 35-58.

Axelsson, C., Nömm, M., Carlsson, H. & Carlsson, L. 1997. Projekt göktyta *Jynx torquilla*: biotopval och häckningsframgång. *Ornis Svecica* 7:35-36.

Bengtsson-Lindsjö, S., Ihse, M. & Olsson, G., 1991. Changes in landscape pattern and grassland plant species diversity in the Ystad area during the 20th century. In: Berglund, B.E., (ed.), The cultural landscape during 6000 years in southern Sweden - the Ystad project. *Ecological Bulletins* no. 41, 388-396.

Bergendorff, C. & Emanuelsson, U., 1990. History and traces of lopping for wood and fodder in Scania, southern Sweden. University of Lund, 64, pp.

Bergendorff, C. & Emanuelsson, U., 1996. History and traces of coppicing and pollarding in Scania, south Sweden. In: Slotte, H. & Göransson, H., (eds.). *Lövtäkt och* *stubbskottsbruk. Människans förändring av landskapet – boskapsskötsel och åkerbruk med hjälp av skog*. Kungliga Skogs- och Lantbruksakademien. Stockholm, 235-304.

Braat, Leon. 1991. The predictive meaning of sustainability indicators". In: In search of Indicators of Sustainable Development", eds: Harmen Verbruggen & Onno Kuik, Kluwer Academic Publishers, Dordrecht.

Brandt, J. & Agger, P., (eds.), 1984. *Methodologies in landscape ecological research and planning*. Proceedings of the First International Seminar of the International Association of Landscape Ecology, Roskilde October 15-19, 1984.

Brandt, J., Holmes, E. & Larsen, D., 1994. Monitoring 'small biotopes'. In: Klijn, F., (ed.), Ecosystem classification for environmental management. *Ecology & environment* vol. 2. Kluwer Academic Publishers, Dortrecht, 251-274.

Brandtzæg, B.A. 1998. System for Tilstandsovervakning og resultatkontroll i jordbrukets kulturlandskap: Beskrivelse og vurdering av definierte indikatorer. Rapport nr. 13/99, Telemarksforskning, Bø.

Bunce, R.G.H. & Hallam, C.J., 1993. The ecological significance of linear features in agricultural landscapes in Britain. In: Bunce, R.G.H., Ryszkowski, L. & Paoletti, M.G., (eds.), *Landscape ecology and agroecosystems* i C.J., Howard, D.C. & Hallam, C.J., 1994. The current status of field margins in the UK. In: Boatman, N., (ed.), Field margins: Integrating agriculture and conservation. *British Crop Protection Council Monograph* No. 58. Great Britain, 13-20.

Carlsson, A. & Morena, J. 1988. Stenskvätta Oenanthe oenanthe L. 1988. I: Andersson, S. (ed.). Fåglar i jordbrukslandskapet, *Vår Fågelvärld* suppl. 12:293-298.

Cederberg, B. 2001: *Skogsbrukets effekter på rödlistade arter*. ArtDatabanken rapporterar 4. ArtDatabanken, SLU, Uppsala.

Commission of the European Communities DG XI, DG XII & Eurostat. 1996. "Environmental Indicators and Green Accounting", Brussels.

Commission of the European Communities, 1997?, "Environmental Pressure Indices Handbook"

Costanza, Robert; Wainger, Lisa & Bockstael, Nancy. 1995. "Integrated Ecological Economic Modelling: Theoretical Issues and Practical Applications", in: Integrating Economic and Ecological Indicators, eds: Shogren & Milon, Praeger Publishers, Westport.

de Groot R, Wilson MA, Boumans MJ. A. Typology for the Description, Classification and Valuation of Ecosystem Functions, Goods and Services. Ecological Economics 2001;

Drake, L., 1992. The non–market values of the Swedish agricultural landscape. European Review of Agricultural Economics, 19, 351–364.

Drakenberg, B. & Lindhe, A. 1999: Indirekt naturvärdesbedömning på beståndsnivå – en praktikt tillämpbar metod. *Skog & Forskning 2/99*: 60–66.

Edenhamn, P., Ekendahl, A., Lönn, M. & Pamilo, P. 1999. *Spridningsförmåga hos svenska växter och djur*. SNV Rapport 4964. Naturvårdsverkets förlag. Stockholm.

Ekstam, U., Aronsson, M. and Forshed, N., 1988. Ängar. Skötsel av naturtyper. LT/Swedish Environmental Protection Agency Publisher, Stockholm.

Ekstam, U. & Forshed, N., 1992. Om hävden upphör. Kärlväxter som indikatorarter i ängs- och hagmarker. *Swedish Environmental Protection Agency's Series, Skötsel av naturtyper*, 135 pp (In Swedish).

Ekstam, U. & Forshed, N. 1996. Äldre fodermarker. Betydelsen av hävdregimen i det förgångna, Målstyrning, Mätning och uppföljning. Naturvårdsverkets förlag. Värnamo.Ljungberg, H. 1999. Skalbaggar och andra insekter på sandstäppslokaler i östra Skåne. Länsstyrelsen i Skåne län. Malmö.

Eliasson, P. & Nilsson, S.G. 1999. Rättat efter Skogarnes aftagande – en miljöhistorisk undersökning av den svenska eken under 1700- och 1800-talen. *Bebyggelsehistorisk Tidskrift* 37: 33-64.

Elfström, J. 1991. Landskapsbilsdanalys-Landskapets visuella identitet med exempel från Nyköpings kommun. Stad & Land nr 97/1991, Movium/institutionen för landskapsplanering. SLU.

Ellenberg, H. 1979: Zeigerwerte der Gefässpflanzen Mitteleuropas. Zweite verbesserte und erweidete Auflage. Scripta Geobotanica 9, Göttingen.

Emanuelsson, U. & Johansson, C.E., (eds.) 1987. Biotoper i det nordiska kulturlandskapet. *Naturvårdsverket Rapport* no. 3556 (In Swedish, Norwegian and Danish).

Emanuelsson U. Landmärken och vågrörelser i kulturlandskapet - dynamiken i det svenska landskapets utveckling. In: Hasund KP, ed. Landskapet: restprodukt eller medvetet skapat? Stockholm: KSLA, Kungl. Skogs- och Lantbruksakademien [Royal Academy of Agriculture and Forestry], 2001:19-33.

Ericson, L., Hansson, L., Larsson, T. & Rasmusson, G., 1988. The importance of residual biotopes for fauna and flora. In: Schreiber, K.-F., (ed.), *Connectivity in landscape ecology*. Proceedings of the 2nd International Seminar of the International Association for Landscape Ecology, Münster 1988. Münstersche Geographische Arbeiten no. 29, Snöningh, 105-106.

Eriksson, M. O. G. 1981. Betydelsen av betade fuktängars areal och inbördes avstånd för häckfågelfaunan. *Vår Fågelvärld* 40:185-192.

Eriksson, O., Ehrlén, J., Telenius, A. & Fröborg, H., 1995. Dynamik och abundans hos fältskiktsarter i lunden på Tullganrsnäs, Södermanland. [Dynamics and abundance of field layer plants in a deciduous wood at Tullgarn, province of Södermanland.]. *Svensk Botanisk. Tidskrift* 89:91-107 (In Swedish).

Flodin, L.-Å., Hirsimäki, H. & Norén, L.-G. 1995. Samhäckande vadare på strandängar i sydvästra Sverige. Predationskydd eller habitatval? *Ornis Svecica* 5:23-30.

Flyckt, G. 1999. Gulärlans Motacilla f. flava häckningsbiologi i strandängsmiljö i nordöstra Skåne. *Ornis Svecica* 9:217-233.

Fry, G.L.A., 1994. The role of field margins in the landscape. In: Boatman, N., (ed.), Field margins: Integrating agriculture and conservation. *British Crop Protection Council Monograph* no. 58. Warwick, England, 31-40.

Gilbert, A.J. & Feenstra, J. F. 1994. "A Sustainable Indicator for the Dutch Environmental Theme ´Diffusion´: Cadmium Accumulation in Soil", Ecological Economics 9, 253 – 265.

Glimskär, A. & Svensson, R., 1990. Vegetationsförändringar vid gödsling och ändrad hävd. *Institutionen för ekologi och miljövård, Sveriges lantbruksuniversitet, rapport* 38. Uppsala, 31 pp (In Swedish).

Gouzee, Nadine. 1996. " Indicators of Sustainable Development", Working Paper 1-96, Federal Planning Bureau, Ministry for Foreign Affairs, Brussels.

Grime, J.P., 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. The American Naturalist, Vol. 111, pp. 1169-1194.

Grime, J.P., 1979. Plant strategies and vegetation processes. Wiley, Chichester.

Grime, J. P., Hodgson, J. G. & Hunt, R. 1988: Comparative Plant Ecology. A functional approach to common British species. London.

Gustavsson, Roland & Ingelög, Torleif. 1994. "Det nya landskapet". Skogsstyrelsen. Jönköping.

Gustafsson, L., Jonsson, B.-G. & Kruys, N. 1999: Förekomst av sällsynta växter i produktionsskogen. *Skog & Forskning 2/99*: 21 – 25.

Gärdenfors, U. (red) 2000. *Rödlistade arter i Sverige 2000*. ArtDatabanken, Uppsala.

Hallingbäck, T. (red.) 1998. *Rödlistade mossor i Sverige*. ArtDatabanken, SLU.

Hansen, A. J. & di Castri, F., (eds.), 1992. *Landscape boundaries consequences for biotic diversity and ecological flows*. Ecological Studies 92, Springer Verlag, 452 pp.

Hansson, M., 1991. Skötsel av naturliga fodermarker: Resultat av femtonåriga fältexperiment i Syd- och Mellansverige. *Institutionen för ekologi och miljövård, Sveriges lant-bruksuniversitet, rapport* 45. Uppsala, 124 pp (In Swedish).

Hasund, K. P., 1998, Valuable Landscapes and Reliable Estimates. In: Dabbert, S., Dubgaard, A., Slangen, L., Whitby, M. (Eds.), The Economics of Landscape and Wildlife Conservation, Wallingford, New York: CAB International, 65–83.

Hasund, Knut Per. 1999a. "Developing an Indictor Methodology". In: Schramek, J., D. Biehl, H. Buller, G. Wilson (eds.) (1999): Implementation and effectiveness of agri-environmental schemes established under Regulation 2078/92. Final Consolidated Report of the EU-project N° FAIR1 CT95 - 274, Volume I. Frankfurt/Main.

Hasund, Knut Per. 1999b. WP 3 Report. In: AEMBAC: Implementation and effectiveness of agri-environmental schemes established under Regulation 2078/92. Work Progress Report of the EU-project N° FAIR1 CT95 - 274.

Holmberg, J. & Karlsson, S. 1992. "On Designing Socio-Ecological Indicators", In: Society and Environment: A Swedish Research Perspective, eds: Svedin, U. & Hägerhill Aniansson, B., Kluwer Academic Publishers, Dortrecht.

Hutchinson, W. George. 1996. "Evaluation Methods to Measure and Monitor Change in Environmental Benefits from Agriculture", OECD seminar on environmental benefits from a sustainable agriculture: issues and policies, COM/AGR/CA/ENV/EPOC(96)107, Paris.

Holstein F. The Values of the Agricultural Landscape: a Discussion on Value-related Terms in Natural and Social Sciences and the Implications for the Contingent Valuation Method. In: Dabbert S, Dubgaard A, Slangen L, Whitby M, eds. The Economics of Landscape and Wildlife Conservation. Wallingford, New York: CAB International, 1998:37-52.

Hæggström, C.A., 1992. Wooded meadows and the use of deciduous trees for fodder, fuel, carpentry and building purposes. *Protoindustries et histoire des forêts*. Toulouse: GDR ISARD-CNRS (Les Cahiers de l'ISARD, no. 3), 151-162.

Hutchinson, W. George. 1996. “Evaluation Methods to Measure and Monitor Chan
Hutchinson, W. George. 1996. “Evaluation Methods to Measure and Monitor Change in Environmental Benefits from Agriculture”, OECD seminar on environmental benefits from a sustainable agriculture: issues and policies, COM/AGR/CA/ENV/EPOC(96)107, Paris.

Ihse, M. & Blom, G. 2000: A Swedish countryside survey for monitoring of landscape features, biodiversity and cultural heritage - the LiM-project. In Mander, Ü. & Jongman R.G.H., (eds.): Consequences of Land-use Changes - Wit Press, Southampton and Boston, series Advances in Ecology, pp 39-74.

Ihse, M. & Lindahl, C. 2000: A holistic model for landscape ecology in practice. The Swedish survey of ancient meadows and pastures. - Landscape and Urban Planning, 50:59-84.

Ihse, M. and Norderhaug, A., 1996. Biological values of the Nordic cultural landscape – different perspectives. International Journal of Heritage 1 (3), pp. 156–170.

Ihse, M., 1993. *Flygbildstolkning för landskapövervakning med inriktning mot biologisk mångfald*. Environmental Protection Agency, 60 pp (In Swedish).

Ihse, M., 1994. Kulturlandskapets ekologiska värden och dess förändring. *Svensk Geografisk Årsbok*, vol. 70, 70-81 (In Swedish).

Ihse, M., 1995a. Swedish agricultural landscapes – patterns and changes during the last 50 years, studied by aerial photos. In: Landscape and Urban Planning, vol. 41, no 1–3, pp. 11–36.

Ihse, M., 1995b. Landscape ecological mapping and evaluation of small biotopes in the Swedish agricultural landscape by visual remote sensing - a pilot study. In: Delbaere, E. & Gulinck, H., (eds.), *Remote sensing in landscape ecological mapping*. Proceedings from the European Collaborative Programme Workshop held in Leuven 17-19 March 1994, 91-99.

Ihse, M., 1996. Behovet av landskapsinformation för natur- och miljövård. *Kartbladet* 1996:2, 32-44.

Ingelög, T., Thor, G., Hallingbäck, T., Andersson, R. & Aronsson, M., (eds.), 1993. *Floravård i jordbrukslandskapet. Skyddsvärda växter.* Databanken för hotade arter, Lund, Sverige, 560 pp (In Swedish).

Ingelög, T. 1988. Floraläget i Sverige. *Svensk Botanisk Tidskrift* vol. 82, 376-375 (In Swedish).

Jennersten, O., Loman, J., Rape Møller, A., Robertson, J. & Widén, B., 1993. Conservation biology in agricultural habitat islands. In: Hansson, L., (ed.), *Ecological principles of nature conservation*. Elsevier Applied Science, London, 394-424.

Jesinghaus, Jochen. 1998. “A European System of Environmental Pressure Indices. Introduction to the political and theoretical background”. At: European Commission. DG34, Eurostat, Environment Statistics. Luxenbourg.

Kalkhoven, J.T.R., 1993. Survival of populations and the scale of the fragmented agricultural landscape. In: Bunce, R.G.H., Ryszkowski, L. & Paoletti, M.G., (eds.), *Landscape ecology and agroecosystems*. Lewis Publishers, Ann Arbor, 83-90.

Kienast, F., 1993. Analysis of historic landscape pattern with a Geographical Information System - a methodological outline. *Landscape Ecology* vol. 8 no. 2, 103-118.

Klijn, F. & Udo de Haes, A., 1994. A hierarchical approach to ecosystems and its implications for ecological land classification. *Landscape Ecology* vol. 9, no. 2, 89-104.

Landres, Peter B. 1990. “Ecological Indicators: Panacea or Liability?”, In: Ecological Indicators Volume 2, eds: Daniel McKenzie, D. Eric Hyatt & V. Janet McDonald, Elsevier Applied Science, London & New York.

Larsson, K.-H. (red.) 1997. *Rödlistade svampar i Sverige*. ArtDatabanken, SLU.

Liverman, Diana M.; Hanson Mark E.; Brown,Becky J. & Merideth, Robert W. 1988. “Global Sustainability: Toward Measurement”. *Environmental Management*, Vol. 12, No. 2, pp. 133 – 143.

Lynch, K. 1960. Image of the City. Camebridge, MA: MIT Press.

Mattson, R. Jordbrukets utveckling i Sverige. 344. 1985. Uppsala, SLU, Sveriges lantbruks-universitet [Swedish University of Agricultural Sciences]. Aktuellt från lantbruks-universitetet.

Merriam, G., 1984. Connectivity: A fundamental ecological characteristic of landscape pattern. In: Brandt, J. & Agger, P., (eds.), *Methodologies in landscape ecological research and planning*. Proceedings of the First International Seminar of the International Association of Landscape Ecology, Roskilde October 15-19 1984, 5-15.

Ministry of Agriculture. 1999. ”Jordbruk och miljönytta”. Stockholm, Miljöprogram-utredningen, Jordbruksdepartementet. Statens offentliga utredningar, SOU 1999:78.

Naturvårdsverket 1987a: *Inventering av ängs- och hagmarker – handbok.* Naturvårdsverket informerar. Naturvårdsverket. Stockholm.

Naturvårdsverket. 1987b. Inventering av ängs- och hagmarker i Sverige. Handbok. 1987. Stockholm, Naturvårdsverket förlag. Naturvårdsverket informerar.

Naturvårdsverket 1997: *Ängs- och hagmarker i Sverige*. Naturvårdsverket Rapport 4819. Naturvårdsverket. Stockholm.

Nilsson, S.G., Arup, U., Baranowski, R & Ekman, S., 1994: Trödbundna lavar och skalbaggar i ålderdomliga kulturlandskap. [Tree-dependent lichens and beetles in old-fashioned agricultural landscapes]. *Svensk Botanisk Tidskrift.*. Lund, 88:1-12 (In Swedish).

Nilsson, Jim & Bergström, Sören. 1995. “Indicators for the Assessment of Ecological and Economic Consequences of Municipal Policies for Resource Use”, *Ecological Economics* 14, 175 – 184.

Nitare, J. & Norén, M. 1992: Nyckelbiotoper kartläggs i nytt projekt vid Skogsstyrelsen. *Svensk Bot. Tidskr. 86*: 219 – 226.

Nitare, J. 2000: *Signalarter – Mossor, lavar och svampar*. Skogsstyrelsen.

Norderhaug, A., Ihse, M. and Pedersen, O., 2000. Biotope patterns and abundance of meadow plant species in a Norwegian rural landscape. Landscape Ecology -in press.

Norderhaug, A., 1996. Hay meadows: biodiversity and conservation (doctoral thesis) Report series from Department of Botany, Gothenburg University.

Noss, R.f., 1990: Indicators for Monitoring Biodiversity. A hierarchical approach. Conservation Biology, volume 4 no. 4 pp 355-364.

OECD, Organisation for Economic Co-operation and Development. 1994. “Environmental Indicators. OECD Core Set”, Paris.

OECD, Organisation for Economic Co-operation and Development. 1997. “Environmental Indicators for Agriculture”, Paris.

Opdam, P., 1991. Metapopulation theory and habitat fragmentation: a review of holarctic breeding bird studies. *Landscape Ecology* vol. 5 no. 2, 93-106.

Opschoor, Hans & Reijnders, Lucas. 1991. “Towards sustainable development indicators”. In: In search of Indicators of Sustainable Development”, eds: Harmen Verbruggen & Onno Kuik, Kluwer Academic Publishers, Dordrecht.

Pattersson, B. D. 1987: The principle of nested subsets and its impact for biological conservation. *Conservation Biology 1*: 323 –334.

Peco, Begoña; Malo, Juan E.; Oñate, Juan J. & Sumpsi, José, “Agri-environmental Indicators in Extensive Land Use Systems in the Iberian Peninsula: some theoretical and practical problems”, in: Agriculture and Environment in Europe: The Role of Indicators in Agricultural Policy Development, eds: Brouwer, F. & Crabtree, R., CAB International, Wallingford (forthcoming).

Pettersson R. 2001. Synliga och osynliga händer - övergripande analys av landskapets förändringar. In: Hasund, Knut Per, ed. Landskapet: restprodukt eller medvetet skapat? Stockholm: KSLA, Kungl. Skogs- och Lantbruksakademien [Royal Academy of Agriculture and Forestry], 2001:75-83.

Quantitative Methods in Landscape Ecology. The Analysis and Interpretation of Landscape Heterogeneity. 1991. Eds: Monica G. Turner & Robert H. Gardner. Ecological Studies 82. Springer-Verlag. New York, Berlin.

Rackham, O., 1989: The history of the conutryside. London, 394 pp.

Rapaport, E and Snickar, F. 1999. GIS based road location analysis in Sweden: A case study to minimize environmental damage, building costs and travel time. In: J J. Stillwell, S. Geertman, and S. Openshaw (Eds.) Geographical Informaiton and Planning. Springer-Verlag. Berlin. Germany.

Reams, Margaret A.; Coffee, Stephen R.; Machen, Angela R. & Poche, Kevin J., 1990, “Use of Environmental Indicators in Evaluating Effectiveness of State Environmental Programs”, In: Ecological Indicators Volume 2, eds: Daniel McKenzie, D. Eric Hyatt & V. Janet McDonald, Elsevier Applied Science, London & New York.

Reid, Walter V.; McNeely, Jeffrey A.; Tunstall, Daniel B.; Bryant, Dirk B. & Winograd, Manuel. 1993. “Biodiversity Indicators”, Report, World Resources Institute, New York.

Rizell, Malin & Gustavsson, Roland. 1998. “Att anlägga skogsbryn”. Stad & Land, nr 160:1998.

SBA, Swedish Board of Agriculture. 1998. LiM-projektets slutrapport. Naturvårdsverket, Jordbruksverket, Riksantikvarieämbetet [Swedish Environmental Protection Agency, Swedish Board of Agriculture, Swedish Board of National Antiquities. Report. Stockholm, Jönköping.

SJVFS 1995:133. Swedish Board of Agriculture. Statens jordbruksverks författningssamling. Förordning om miljöstöd utfärdad den 7 september 1995. Jönköping.

Samuelson PA. The Pure Theory of Public Expenditure. The Review of Economic Statistics 1954;36:387-389.

Saunders, D.A. & Hobbs, R.J., (eds.), 1991. *Nature conservation 2: The role of corridors*. Surrey, Beatty & Sons.

Schreiber, K.-F., (ed.), 1988. *Connectivity in landscape ecology*. Proceedings of the 2nd International Seminar of the International Association for Landscape Ecology, Münster 1987. Münstersche Geographische Arbeiten no. 29, Snöningh, 255 pp.

Shogren, Jason F. & Milon, J. Walter. 1995. "Epilogue", In: Integrating Economic and Ecological Indicators, eds: Shogren & Milon, Praeger Publishers, Westport.

Sjöbäck, M., 1966. Hur såg landskapet ut och hur fungerade växtligheten under forntiden och medeltiden. In: Nihlén, J., (ed.), *Landskapsvård*. LT's förlag, 223-245 (In Swedish).

Sjögren-Gulve, P. 1999: Indikatormetodik för biologisk mångfald. *Skog & Forskning 2/99*: 18 – 20.

Skånes, H., 1996. Landscape change and grassland dynamics - Retrospective studies based on aerial photographs and old cadastral maps during 200 years in south Sweden. *The Department of Physical Geography Stockholm University. Dissertation series, no 8,* papers I-IV.

Slotte, H., 2000: Lövtäkt i Sverige och på Åland. Metoder och påverkan på landskapet. Acta Universitatis Agriculturae Sueciae, Agraria 236. (In Swedish).

Sporrong, U., 1993, By. In: *Encyclopaedia Suesica,* 1993. vol. 3. Bokförlaget Bra Böcker, Belgium,467-470 (In Swedish).

SBA, Swedish Board of Agriculture. 2002. ”Metodhandledning. Inventering av värdefulla Ängs och Betesmarker”. Jönköping.

Svensson, R., 1988. Floravård i jordbrukslandskapet. *Svensk Botanisk Tidskrift* vol. 82, 458-465 (In Swedish).

Sveriges Skogsvårdsförbund. 1999: Indikatorer på biologisk mångfald i odlingslandskapet. *Skog & Forskning – Kunskaper och idéer i skogsbruket. 2/99.*

Tansley, A.G., 1935. The use and abuse of vegetational concepts and terms. *Ecology* vol. 16, 284-307.

Tollin, C. 1998. Värdebeskrivning av kustområdet i Halland-Landskapshistorisk innehåll. Länsstyrelsen i Halland län.

Troll, C., 1968. Landschaftsökologie. In: Tüxen R., (ed.), *Plantzesoziologie und Landschaftsökologie.* Bereichte das Internalen Symposiums der Internationalen Vereinigung für Vegetationskunde, Stolzenau/Weser 1963. The Hague, 1-21 (In German).

Turner, R. K., van den Bergh, J.C. J. M., Söderqvist, T., Barendregt, A., van der Straaten, J., Maltby, E. & van Ierland, E.C. 2000. 'Ecological-economic analysis of wetlands: scientific integration for management and policy'. *Ecological Economics*, Volume 35, Issue 1, October 2000, Pages 7-23

Udo de Haes, H.A. & Klijn, F., 1994. Environmental policy and ecosystem classification. In: Klijn, F., (ed.), Ecosystem classification for environmental management. *Ecology & Environment* vol. 2. Kluwer Academic Publishers, Dortrecht, 1-22.

UNEP, 1995. *Global biodiversity assessment*. Summary for policy-makers. Cambridge University Press, 46 pp.

Unnerbäck, A. 1995. *Kulturhistoriskt värde?.* Kulturmiljövård, 1-2: Svenska hus

Walpole, S.C. & Sinden, J.A. 1997. "BCA and GIS: integration of economic and ecological indicators to aid land management decisions". *Ecological Economics* 23, 45 – 57.

Verbruggen, Harmen & Kuik, Onno. 1991. "Indicators of sustainable development: an overview". In: In search of Indicators of Sustainable Development", eds: Harmen Verbruggen & Onno Kuik, Kluwer Academic Publishers, Dordrecht.

Wyatt, B.K., Greatorex-Davies, J.N., Hill, M.O., Parr, T.W., Bunce, R.G.H. & Fuller, R.M., 1994. Comparison of land cover definitions. *Institute of Terrestrial Ecology, Department of the Environment, Countryside 1990 series* vol. 3, 72 pp.

Zonneveld, I.S., 1989. The land unit - a fundamental concept in landscape ecology and its applications. *Landscape Ecology* vol. 3 no. 2, 67-86.

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Appendix 1. Concepts, terminology and definitions

By Knut Per Hasund, Svante Hultengren and Helle Skånes

Agri-environmental measures (AEMs) include all policy measures directed toward the environmental problems of agriculture. The concept does not refer to policy measures with other main goals or objectives, such as tax legislation or general agricultural price regulations, even if such policy measures would have significant environmental effects. AEMs can be:

- Command and control regulations of quantities or technology (pesticide ban, manure handling restrictions, mandatory land planning, etc.)
- incentive instruments (taxes, payments, subsidies, price regulations, etc.)
- education and information, and
- research and development.

Agri-environmental payments (AEPs) are payments from the public sector to farmers or agricultural landowners as a reward for providing positive environmental goods or services. The AEPs constitute a sub-category of AEMs. Within the European Union, the AEPs are handled by EC Regulation 1257/1999.

Agro-ecosystem functioning is the interaction of ecological characteristics, structure and processes, determining the agro-ecosystem's ability to provide goods and services. (Turner *et al*., 2000)

Agro-ecosystem use refers to all direct and indirect utilization of agro-ecosystem goods and services. (Turner *et al*., 2000)

Biodiversity: "variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Convention on Biological Diversity)

Biorich trees are trees providing particularly good conditions for a spectrum of other species. The function may be in terms of feed (e.g. berries for birds), growth substrate (e.g. old bark for lichens), shelter, hibernation (e.g. bats, insects) or nesting. In southern Sweden (Götaland, Svealand), the definition includes oaks (*Querqus robur*), ash (*Fraxinus excelcior*), tilia (*Tilia cordata*), elm (*Ulmus glabra*), beech (*Fagus silvatica*), aspen (*Populus tremula*), mountain ash (*Sorbus aucuparia*) and Swedish whitebeam (*Sorbus media*). with a sun-exposed trunk[13], and wider than 3,14 m in trunk girth (≈ 1 m diameter) or all trees with significant cavities or hollows.

Biotope means by definition the location of a biotic community, i.e. the living part of an eco-system (Haber 1994). It commonly focuses on the homogeneous living space required for a particular set of plant and animal species as defined from the outside, without specifying the abiotic factors or cultural aspects. Biotope is often used with a similar meaning as *ecotope* (Forman 1995). Haber (1994) argues that the use of the two terms is confusing and states that biotope derives from community ecology and ecotope comes from landscape ecology. The con-fusion is evident since UNEP (1995) defines biotope as a small area with uniform biological conditions explicitly including the abiotic factors.

[13] Sun-exposed trees are trees with no other tree or object closer than its own height.

Early succession trees or bushes: trees or bushes ≤ 30 y old.

Ecosystem: functional unit consisting of all the living organisms (plants, animals, and microbes) in a given area, and all the non-living physical and chemical factors of their environment, linked together through nutrient cycling and energy flow. An ecosystem can be of any size -- a log, pond, field, forest or the earth's biosphere -- but it always functions as a whole unit. Ecosystems are commonly described according to the major type o vegetation, for example, forest ecosystem or range ecosystem.

Ecotone is defined as a zone of transition between adjacent ecological systems. They have a set of characteristics uniquely defined by space and time scales, and by the strength of the interactions between the adjacent ecological systems. An ecotone can vary both in spatial and time scale as well as in ecological function and origin. The concept is central to landscape ecology and is discussed in detail in Hansen & di Castri (1992). Other terms frequently used as synonyms are *boundary*, *edge* and *transition zone*.

Ecotope is generally regarded as the smallest ecological land unit relevant in landscape ecology, with relative homogeneity regarding vegetation structure (Udo de Haes & Klijn 1994, Forman 1995). It was first defined by Tansley (1935) and Troll (1968). Depending on hierarchical level and the weight given within the landscape ecological approach, ecotope can mean either a landscape or simply a landscape element.

Environmental functions are defined as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly" (De Groot, Functions of Nature, 1992)

Grassland is the highest hierarchical level of all land cover types which are currently influenced by, or still show evidence of, grazing or mowing (Skånes 1996, paper II). They are characterised and mostly dominated by light-demanding herbaceous vegetation.

Habitat is the part of an ecosystem where a species lives and reproduces (UNEP 1995). It is also defined as the space used by an organism together with other organisms with which it co-exists, and the landscape and climatic elements that affect it. Often the habitat comprises different biotopes that can be used in different seasons or in different life-history stages.

Land parcel stands for the smallest administrative unit of acreage, that is, each separate field, forest, etc. as delimited by the Agricultural Register and on the Economic Maps. The land parcels serve as the base for the field (object) indicators and the agri-environmental payments.

Landscape element is referred to as each of the relatively homogeneous units or spatial elements recognised in a mosaic on any scale (Forman 1995). A landscape element can be anything from a single tree, or patches of plants, to a mosaic of elements of a higher order of magnitude. The term is therefore neutral and needs to be explained if used with a specific definition.

Land unit is a fundamental concept in landscape ecology. It stands for an ecologically homogeneous tract of land at the scale level being considered (Zonneveld 1989). Biotic as well as abiotic aspects and relationships are included in the concept as it is applied in a holistic approach to landscape study including. It is frequently used as a synonym of *ecotope*. This definition has roots back to the geographer von Humboldt, during the 19th century, who defined the landscape as the total character of a patch of the Earth (Zonneveld 1989).

Land use type and *land cover type* are often used as synonyms, but per definition they are not the same (Wyatt *et al.* 1994). Land use is the management regime in terms of socio-economic practices such as grazing, mowing, forestry and tillage of arable land, and is therefore difficult to map. Land cover is the result of the natural site conditions and present and past land use. The land cover is often represented by vegetation cover types on different levels, depending on the degree of generalisation and the classification system used.

Small biotope is a frequently used term in Denmark and Sweden when referring to *small landscape elements* of agricultural or forest landscape in biological contexts. It was first described by Brandt & Agger (1984) as uncultivated areas that are permanently covered with vegetation (or water) and situated within agricultural areas. According to their definition, a small biotope must be smaller than 0.5 hectares and either larger than 10 m^2 or longer than 10 m with a width of more than 0.1 m. According to the Swedish Law of Biotope Protection, small biotopes are smaller than 0.5 hectare. Some categories are generally protected, such as alleys, micro ponds and field islets.

Small landscape elements in the agricultural landscape may be either linear or point features. Open ditches, stone walls, field roads, alleys and headlands are examples of linear elements, while field islets, solitary trees, ponds and cultivation cairns are among the point elements. In Swedish literature and legislation, the term “landskapselement” (landscape element) is used for simplicity, omitting other elements. In this study, the terms *landscape elements* or *field elements* are used. The concept refers to *small landscape elements* within or along fields, mainly as defined by the law SFS 2000:577, enclosure 5.

Structure, or pattern, is the spatial relationship among distinctive ecosystems or elements present in the landscape, both vertical and horizontal.

Value signifies the importance given to a phenomenon (objects, processes, actions, etc) according to a certain valuation criterion.

Appendix 2: GIS-Applications for the case study areas

By Knut Per Hasund, Tommy Löfgren & Barbara Neumann

1.1 Introduction and specific background

What was GIS used for?

The GIS (Geographical Information System) has been used mainly as a tool for estimating indicators reflecting the environmental qualities of agricultural land and its content of landscape elements. It has in this context also been used to identify the owners of fields, pastures and landscape elements that have environmental values and accordingly are eligible for grants. Thirdly, GIS has been used to present the indicator results and the agri-environmental payments on maps. These maps can be used in communication with farmers, or when illustrating the scientific approach, when analysing the environmental situation of an area, etc.

In AEMBAC, environmental indicators have been developed to reflect the total amount of environmental qualities of an area, that is, biodiversity, cultural heritage and other socio-cultural public goods. Higher environmental qualities are supposed to be reflected by a higher indicator estimate, which "automatically" should give a higher agri-environmental payment to that field, pasture or element. All in all seven indicators have been developed to cover the following types of objects: fields, permanent pastures, linear and point elements of various types. Each indicator is determined by its set of weighted variables expressing the environmental quality attributes of the element. With the aim of attaining measurability and minimizing arbitrariness, the variables are related to concrete, physical phenomena that are assessed as strongly correlated to the – metaphysical, intangible – values. The indicators are estimated with data from GIS-bases, air-photo surveys, field surveys, supplemented by farmer notifications.

General methodology for mapping the cultural landscape and its object indicators – Summary

A detailed mapping of the *Cultural Landscape*[14] was made in two test areas: Vetlanda (Småland) and Selaön (Sörmland, located in lake Mälaren). Interpretation of colour infrared images was digitised directly using an analytical stereoplotter. Base data used for the mapping were digital vectors of topographical maps ("Terrängkartan") and land use vectors of the Swedish Board of Agriculture. Both data sets were merged together.

Before mapping from this merged data set, defaults were constructed including land use, field impediments and forest edges. This initial data set and the defaults were controlled and edited when necessary.

Data mapped from the aerial photographs include

- Land use, maintenance, coverage of trees and bushes, tree species (deciduous or coniferous). Arable fields and permanent grasslands are treated as polygons. Deciduous woods adjoining agricultural land and three types of open forest edges were mapped to create the layer Forest Edge.
- Six types of Point Elements and nine types of Line Objects. As attributes for Line Objects, coverage of trees and bushes, tree species (deciduous or coniferous), maintenance and narrow grassy strips were mapped.

[14] "Cultural Landscape" was in this project defined to be fields and grassland with trees or bushes covering less than 70 percent of the ground, adjoining ground with other land use twenty meter from those (including "forest edge") and field islets smaller than 0.5 hectare.

Mapped data were then imported to ArcGIS (ArcInfo) for error checking, editing and GIS analyses. All data manipulation was made in ArcGIS (ArcInfo) using scripts. New map layers were constructed using GIS methods.

Polygons in defined distances to cultural objects in the topographical dataset converted into new map layers. The layer Visibility, for example, contains polygons visible from roads with more traffic. Field Impediments, Forest Edge, Point and Line Elements were then assigned to polygons if inside or at specified distance from polygon. The indicator value was thereafter calculated as a function of mapped data layers (including field data) for polygons in the cultural landscape and its structural elements. Indicator values of structural elements could then be summed on polygons using assignments. These indicator values can easily be used to calculate for example agri-environmental payments for separate objects, summed up on polygons or on farms.

The aim of this approach was to put forward a method for measuring environmental values as “Indicator Values”. An Indicator value should be set on all polygons in the cultural landscape and its structural elements (stone walls, head lands, biorich trees and others) based on their environmental qualities, such as type of vegetation, presence of invading brushwood, maintenance status, accessibility, or vicinity of cultural objects. The Indicator Value may be used to calculate agri-environmental payments to farmers.

Software and hardware equipment

Equipment used:

- analytical stereo-plotter (Topokart) with software for orientation of air images (Quasco)
- special software to produce digital vector data (SOSMAP)
- software for error checking and GIS-analysis (ArcGIS 8.x / ArcInfo Workstation).

Software [15]	**Extensions / Modules**	**Database systems**	**Computing systems**	**Printing hardware**
ArcView 3.2 PC Arc/Info 4.0 IDRISI ENVI MapInfo	Spatial Analyst	MS Access	Windows 98, Windows NT, Windows 2000 Unix	HP Plotter A0, Several Laser printers (black and white A4-A3), InkJet colour printers (A4)
ArcInfo 8.2	AML´s ArcInfo: UNION, DROPITEM			
ArcGIS		Kartex		
Quasco SOSMAP				Topokart (analytical plotter)
Equipment for stereographic interpretation: Zeiss Jena Interpretoscope, WILD Aviopret, Carto AP190 (analytical plotter with PC Arc/Info extension); WILD TSP1 for field work.				

Availability of base data

Table 37 gives an overview over the analogue and digital base data used, such as GIS databases and colour infrared aerial photographs (Table 38). Air-photos from the 1940s were

[15] ArcInfo, ArcView, ArcGIS: http://www.esri.com/software/index.html; IDRISI: http://www.clarklabs.org/; ENVI: http://www.rsinc.com/envi/index.asp

bought from SNLS to improve the interpretations of certain vegetation types, such as permanent grasslands or impediments of various kinds.

The "Terrängkartan" (=Gröna kartan) vectordatabase is produced by SNLS. It covers southern Sweden and coastal parts of northern Sweden[16]. Production line includes updating old version of the map, including updated data from larger scale (from The Real Property Map) , manual interpretation and digitalizing on screen in single image scanned panchromatic images and fieldwork.

The GIS-database ("Blockkartan") of the Swedish Board of Agriculture (SBA) consists of two parts: the polygon geometry where every polygon got its unique identity-number and data tables relating to those numbers[17]. The geometry is originally produced by SNLS from the Real Property Map and is updated yearly. Information in the tables about Land Use is yearly received from the farmers. Also Null-values in the table occur a certain year where no information was received.

Table 37: Data sources and base data used

Content / type	Title / Description	Data type analog/ digital	Digital data format grid / vector	Year / Date	Scale	Reference system
Land cover / land use Selaön	Terrängkartan (10H NO), vector database produced by SNLS (topographical map)	digital	V	Database build 1998, Field work 1997, air images 1996	Print scale 1:50 000	RT90 [18]
Land cover / land use Vetlanda	Terrängkartan (6F SV), . vector database produced by SNLS (topographical map)	Digital	V	Database build 1999, Field work 1998, air images 1997	Print scale 1: 50 000	RT90
Land cover / land use Selaön & Vetlanda	GIS-database of the Swedish Board of Agriculture (SBA)	Digital	V	2001	Print scale 1:10000	RT90
Land cover / land use – to derive Ground Control Points (GCP)	Gröna kartan (CD-ROM), Uppsala län and Södermanlands län (SNLS)	Digital	R	Distributed 2000	Print scale 1: 50 000	
Aerial photographs Selaön	Color Infrared	Analog		1996	1:30000	
	Panchromatic	Analog		1945	1:20000	
Aerial photographs Vetlanda	Color Infrared	Analog		1996	1:30000	
	Panchromatic	Analog		1951	1:20000	

[16] More information available at http://www.lantmateriet.se/ (press English, Your map, Terrängkartan) or at http://www.geolex.lm.se/ (just Swedish)

[17] Information source: http://www.sjv.se/net/SJV/Startsida/%c4mnesomr%e5den/St%f6d%2C+bidrag+&+mj%f6lkkvoter/Blockkartor

[18] RT 90 "National net" (National Reference System 1990) is a local geodetic datum based on the Swedish third national triangulation (1967-82), and is connected to the ellipsoid Bessel 1841. The corresponding plane coordinate system used for the Swedish topographic maps and

An official agricultural block is a continuous area of land. It should be relatively constant over the years. The block is delimited of, for example, roads, forest, settlements, ditches or lakes. Administrative borders of various kinds also delimit the blocks. Each agricultural block has a unique, official identity that is registered on the block map. A block can include one or more fields. A field can only belong to one block though. Several farmers may have fields within the same block. The block maps are produced in scale 1:10,000. They contain information from the Economic map supplemented by data about agriculture from previous years' applications of grants.

Table 38: Aerial photographs used

Område	Bildbeteckning	Type PANchrom / Color IinfraRed	Datum
Selaön	96I46-F Hg 1024: 14 - 17	CIR	19960723
Selaön	96I46-F Hh 1013: 15 - 17	CIR	19960723
Selaön	C45 41: 3 - 8	PAN	1945
Selaön	D45 43: 11 - 14	PAN	1945
Vetlanda	96I46-B Fc 1002: 45 - 48	CIR	19960819
Vetlanda	96I46-B Fd 1607: 45 - 49	CIR	19960726
Vetlanda	F51 71 9 - 12	PAN	1951
Vetlanda	F51 72 10 - 14	PAN	1951
Vetlanda	F51 74 9 - 14	PAN	1951

Mapping and digitizing of the curltural landscape from aerial photographs using an analytical stereoplotter (TOPOKART)

General methodology

An applied method for land use mapping from aerial photographs is the immediate digitising with an analytical plotter (TOPOKART). The plotter, originally an analogue stereo instrument, has been transformed with digital suppliers. The starting orientation (geo-referenciation) is conducted by a supporting programme (QUASCO) in a separate computer.

A "stereo-model" is the area where two adjoining aereal photographs overlap, normally by 60%. The interpretation of the air photos is carried out in this three dimensional model. The starting orientation of the stereo models is performed in four steps: before, internal, relative and absolute orientation. A model file is created at the absolute orientation by means of support points (see below). It expresses the transformation between the TOPOKART system of co-ordinates and the National Net. The model file invokes a '"lens file" that corrects for geometric characters of the lens that has been used for the actual air photos.

When digitising, co-ordinates of the National Net are transferred to a second computer running the mapping programme SOSMAP. Simultaneously, as areas are demarcated in the TOPOKART stereo model, the same objects are shown on the screen of the SOSMAP-computer. The results are thus not

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land use maps is denoted RT 90 2.5 gon V 0:-15 and is obtained by a Transverse Mercator (Gauss-Krüger) projection of the RT 90 latitudes and longitudes. (See further details at http://www.lm.se/geodesi/refsys/rt/rt_projections.htm) inserted in the stereo model, as for example in Zeiss Planicomp P3, but expressed on a separate screen. The programme MAPPLATE (a module within SOSMAP) allows to plot the digital base in each picture's central projection. This method is called "statistical in-reflection". It is possible to calculate the projection of the individual picture's projection from these model-files and lens files.

The "statistical in-reflection" significantly facilitates updating. It was used in this project to update the interpretation of old, small-scale air-photos with the interpretation of younger maps having a lager scale. Another programme module of SOSMAP allows to produce normal plot-files from the digital base in the National Net projection at an optional scale. This environment permits the interpretation of (older) black-and-white pictures as well as modern infra-red pictures. Results of the interpretation are provided directly as a digital data base.

Coordinates for natural support points, such as. junctions of roads or ditches, are derived from the digital grid version of the topographic map Kartex (Swedish National Land Survey "Lantmäteriet" SNLS). Altitude values are derived from lakes, established fix points or the altitude curves' crossing with roads etc. Deriving these points leads to the digitalisation of six numbered natural support points for each picture in Kartex. It produces a point-file that is used for the orientation of pictures. The positions of the points in the picture are marked on a plastic film applied to the air-photo. The number series is linked to a point file where the x,y and altitude positions are stated according to the National Net. The support points are necessary for getting map data according to the National Net directly from mapping in the analytical stereoplotter.

"In-orientation" of aerial photographs

The analytical stereoplotter Topokart is supported by two computers. On one computer runs the program Quasco for orientation of the air-photos, on the second one the program SOSMAP for the digitalisation. Topokart has four engines running the two carts for the pictures in x- and y-directions respectively. Sensors register the co-ordinates of the carts with the precision of 0.002 mm.

The two air-photos used to produce the stereo-model are put separately into the pair of carts where they are surveyed by a stereoscope instrument. The precision of the absolute orientation is 3 – 5 meters. The results of the orientation of the pictures written to a model file. It is possible to fix the position of a well defined object (such as a block of an arable field) with the precision of 0.2 – 1 m after conducting an absolute orientation.

Setting up map menus and thematic files in the SOSMAP the digitising program

Map menus have to be created in SOSMAP before the surveying. The structure of all surveying for all mapped elements has to be defined in these menus. For the study, 15 linear codes for input data were demanded as well as 10 additional linear codes for demarcating areas and area codes for describing the survey areas.

A thematic file in SOSMAP implies that only one group of active codes is shown. Hence, it is possible to work in many layers within the same map database.

Mapping with the analytical stereo plotter

The actual mapping was carried out by model and by study area since the survey areas overlap.

Step 1: All deciduous forest (even narrow zones) adjoining agricultural land was surveyed with the aim of stating the quality of forest edges. It is more efficient to let auto-procedures in ArcInfo code the forest edges than doing it manually. Open forest edges were coded manually though. During this step the prepared material was checked and edited when necessary.

Step 2: The area objects are surveyed. Easily mapped objects such as cultivated or grazed fields were surveyed first. Next, permanent grasslands areas were surveyed. The difficult part lies in distinguishing between semi-natural pastures and cultivated pastures. Air-photos from 1945 were used to get more reliable interpretations. Any signs of possible cultivation were investigated in particular. Such areas were transferred to the class “cultivated grasslands”. Remaining parts of the semi-natural grasslands were controlled for any signs of cultivation after 1945. If uncertain, the area was marked for control by field survey.

Step 3: All linear and all point elements were surveyed.

The time for each surveying moment was recorded.

Data processing in ArcInfo before starting with the air-photo survey

All processing of map data and tables was carried out using ArcInfo AMLs. AMLs rationalize the work significantly and document all actions at the same time.

- Preparations of the topographic map (areal objects): Areal objects of the topographic map are processed in ArcInfo (see legends of land use for land classes, Table 39)
- Preparations of block data: In this project, block data with attribute tables from year 2001 were transformed into the object classes “arable fields” and “permanent grasslands” (pastures). Information that the area was included in administrative blocks was registered.
- Merging the topographic map with block data: The merged data set of the topographic map and the block data were imported into a database. Many small areas arose along borders of fields, for example. All small areas were later dissolved and added to the larger adjoining area, except field islets. The addition was made not to change the original geometry of block data or field borders.
- Field islets: All field islets were surveyed automatically in ArcInfo and registered with a value in a column.
- Forest edges. All forest edges facing agricultural land were registered with a default linear code based on whether it adjoins deciduous or conifer forest according to the Topographic map.

The produced results were then converted to a format readable by the analytical stereo-plotter to become the base for the air-photo interpretations.

1.2 Visualisation and analysis of the study area

Land use / land cover classification

Table 39: CORINE land use classification adopted / modified in the study area

Code AGOS, MAKER	Mapped land use categories Sweden (AEMBAC)	CORINE No.	CORINE Land use / land cover
-	-	0	Without determination
9	Exploited land	1000	unspecified settlement / exploited land
90	Settlement - denser	1000	unspecified settlement / exploited land
10	Other non-forested land	1400	Unspecified non-forested land (not arable and grown land)
40	Bedrock – non-forested	1400	Unspecified non-forested land (not arable and grown land)
2	Field - grazed	2310	Pastures
20	Deciduous forest	3110	Broad-leaved forest
70	Wetland - Deciduous forest	3110	Broad-leaved forest
4	Grassland – Semi-natural	3211	Natural grassland
5	Grassland – Semi-natural – Heath type	3212	Natural grassland
60	Wetland – non-forested	4120	Wetland - open
1	Field	2110	Non-irrigated arable land
1, 6	Field	2210	Fruit trees and berry plantations
30	Coniferous and mixed forest	3120 3120	Coniferous forest Mixed forest
50	Coniferous and mixed forest / Bedrock	3120 3120	Coniferous forest Mixed forest
75	Wetland - Coniferous forest	3120 3120	Coniferous forest Mixed forest
3	Grassland - Cultivated	3210 2310	Natural grassland Pastures
80	Lake or broader stream	5110 5120	Water courses Water bodies

Table 39 shows how the mapped land use classes were converted to fit Corine Land Cover types. To make Land Use classes convertible into Natura2000-habitats would have been possible, but field-work would probably been necessary to confirm mapping data.

Table 40: Classification "scheme" for the land use classes

Mapped land use categories Sweden (AEMBAC)		Interpretation from Terrängkartan
1	Field	I
2	Field - grazed	I
3	Grassland - Cultivated	I
4	Grassland – Semi-natural	I
5	Grassland – Semi-natural – Heath type	I
9	Exploited land	I
10	Other non-forested land	T
20	Deciduous forest	T
30	Coniferous and mixed forest	T
40	Bedrock – non-forested	T
50	Coniferous and mixed forest / Bedrock	T
60	Wetland – non-forested	T
70	Wetland - Deciduous forest	T
75	Wetland - Coniferous forest	T
80	Lake or broader stream	T
90	Settlement – more dense	T

1.3 Analysis and Visualisation of Environmental Functions

State Indicators

Altogether landscape indicators and seven object indicators were analysed, describing environmental qualities of the respective objects. All object indicators are illustrated by maps. It is not meaningful to illustrate a landscape indicator for a single study area, since there is just one indicator estimate for the whole landscape. At a national or regional level, however, landscape indicator estimates could be illustrated by maps. All indicators (although not all their component variables) were estimated using aerial photos and GIS, except L10, L11 and L12. These three landscape indicators mainly rely on field surveys, although they indirectly need GIS for determining the number of objects and area.

Object indicators and landscape indicators operate on different scales and serve different purposes (see pp 30-31, 44- and 86- in the Swedish WP 3 report). Landscape indicators are estimated and operated at landscape level. They are used for monitoring, to see if the land use in a district is sustainable (EMR) or if there is a need for strengthening the policy measures. Object indicators are estimated for each single object (a pasture, forest edge, etc.), and are supposed to determine the allocation of agri-environmental payments. The indicators were classified according to the criteria presented in the wp3-report.

Data processing in ArcInfo after the surveying

The operations described below have been carried out automatically by means of AML-scripts that have been developed to increase the efficiency of this project. AMLs are ArcInfo Workstation commands in files that may replace manual commands.

Data transfer

The database can be transferred from SOSMAP, for instance, via the formats gen-plus or shape. In ArcInfo, the datebase was transformed into a "coverage".

Margin databases, column adjustments and corrections of errors

The survey database was merged with the Topographic/Block map by ArcInfo: Union. Redundant columns after the merging were eliminated (ArcInfo: DROPITEM). At this stage, a series of error checks were performed, and unpermitted combinations of codes etc. were corrected.

Forest edge codes

Forest edges are a sub-set of the demarcation lines of the areas. Only specified types of edges are interpreted manually: three types of open fringes. The demarcation lines against agricultural land were otherwise registered by codes for the edge types "deciduous" or "conifer", based on the coding of deciduous or conifer forest areas.

Borders of field islets, the survey areas and other boundary lines were identified with codes.

GIS-analyses

Permanent grasslands near farm centres

Permanent grasslands that in some of its parts within 50 m from a farm centre (as registered in the GSD-Topographic map's point layer) were marked in the database.

Cultural objects and ancient relics

Fields' and pastures' cultural heritage values are normally higher if they embrace or adjoin relics of antiquity, such as rune stones or bronze-age grave-mounds. Their presence has been used to estimate the cultural heritage variable of the environmental value indicators. Fields, permanent grasslands and field islets embracing or laying within a specified distance from such objects were marked in the database by an AML. Cultural objects from the vector database of the Topographic map were used, buffered according to specified distances (see tale below).

Table 41: Mapped object types and buffering distances

Type of object	**Notation**	**Distance for buffering [m]**
Boundary of ancient monument	GC01 14 FORN.B	10
Ancient monuments symbol of information	GC01 773 FORN.S	10
Point ancient monument	GC01 786 FORN.C	10
Linear ancient monument	GC01 97 FORN.M	10
Church	BB16 741 KYRKA.C	50
Ruin, boundary line	BB17 694 RUIN.K	10
Ruin, centre line	BB17 695 RUIN.M	10
Ruin	BB17 746 RUIN.C	10
Farm	731 HUSGÅRD.C	50

A description of the step-by-step methodology can be provided on request.

Visibility

Landscape objects that are seen by more people have larger use values, in terms of scenic experiences, etc. Accordingly, the indicator estimates of objects that are visible from railroads or roads with more traffic are weighted up considering this factor. The development of a map layer for visibility is a methodology work to further progress.

The method is similar to the method for ascribing cultural relics to agricultural fields. It involves:

- buffering of roads, and
- to register a value to those agricultural objects that are in the buffer zone of the roads in a new column of the area database.

The problem is that some objects in the buffer zone are hidden by woods near the roads. Such objects were de-marked manually in this study. To become efficient, an automatic AML has to be developed for this purpose.

Ascribing objects to agricultural areas

Stone-walls, headlands, ponds, field islets and other linear or point objects have to be ascribed to their respective agricultural field or pasture, so that their farmers can be identified and the agri-environmental payments directed to the producer. An extended topographic analysis was carried out in this phase. With this in view, a an AML was constructed that check the surroundings of each arable field or permanent grassland area (agricultural area objects) and ascribe it the linear and point elements (including field islets) that belongs to it. A problem is that linear or point elements may be surrounded by several area objects. An even more difficult problem is that linear elements can run along several agricultural area objects. Point and linear elements on the borders or junctions of area objects are shared between these by dividing it by the number of times it has been ascribed.

Step 1: The programme starts by preparing a point, linear and area base as per the following operations:

- Columns are created for all respective attributes (variables) that will be estimated.
- The lines are split into 10-meter lengths so that every segment can be ascribed to its most adjacent area object. Simultaneously, a new temporary id-number series is created to relate the right segment in the temporary base back to the original linear database.
- All area attributes are converted into point and linear objects.
- Demarcation lines of areas that are registered as forest edges are marked with a value “20 meter”, while other linear objects are marked with “0 meter”. The aim is to make it possible to create buffers later around the areas depending the surrounding class of land.
- A map database for field islets is created.

Step 2: The programme does in the next step go into a loop where a counter checked all areas. It involved the following, major procedures:

- checking whether the area is an agricultural area but not a field islet; if not, it departs from the loop and goes to the next area,
- buffering the surrounding lines of the area according to the appropriate distance settled in the preparation,
- merging the selected area with the buffer and removing redundant lines inside the buffer,
- cutting in the linear layer by means of the buffer, creating a new map database of the lines within the buffer (if such exist),
- cutting in the field islet database, creating a new map database of field islets within the buffer (if such exist),

- cutting in the point element database, creating a new map database of point elements within the buffer (if such exist),
- constructing relations between the temporary, cut map databases and respective original database by means of id-numbers,
- ascribing due polygon numbers for the areas in the original map database and adding to the number of times that the object has been ascribed if the area of the field islet is > 20% of the original surface,
- ascribing due polygon numbers for the demarcation linear layer in the original map database and adding to the number of times that the object has been ascribed if it is a forest edge,
- ascribing due polygon numbers in the original map database and adding to the number of times that the object has been ascribed if it is a field islet,
- ascribing due polygon numbers in the original map database and adding to the number of times that the object has been ascribed if it lies outside agricultural land or lies within a field islet, and
- eliminates all temporary map databases.

The computer time to perform the procedures for Vetlanda study area was c. 25 hours, using 2 x 700 PC. Having performed all the loops, cleaning and washing procedures were done.

Indicator values

The produced result tables were delivered to the principal, SLU. State indicator values on the environmental qualities of every agricultural landscape object were then calculated based on the GIS-data, the air-photo surveys and the field surveys (see chapter **Fel! Hittar inte referenskälla.** above). Thus calculated indicator values were in the next step sent back to the GIS-subcontractor (NaturGIS), who could produce maps using the objects' id-numbers and the original map database. For examples of such maps, see chapter **Fel! Hittar inte referenskälla.**.

Air-photo material, support points and up-to-dateness

The best base presently for this kind of surveying is infra-red dia-slides.

The data sources of this study differed in age. The Topographic map data were older than 1998, while the block data were from 2001, IRF from 1996 and the field surveys from 2002. It is desirable to get recent IR-photos for the surveys.

Environmental Function Performance

Environmental functions have been analysed based on the estimated state indicators that are described in 9.3.1. above. No further GIS-work, remote sensing or other surveys was carried out in the study.

11.4 Analysis, Evaluation and Visualisation of the sustainability of local agricultural pressures and development of recommendations

GIS-based analysis was used for gap analyses at the landscape level. Recommendations for land-use and land maintenance are suggested at the object level, partly based on GIS ad the air-photo surveys. The gap analyses have been carried out partly based on the state indicators that are described in the chapters above. No further GIS-work, remote sensing or other surveys have been carried out in the study specific for the gap analysis.

The air-photo surveys and GIS-based analyses hence serve three major functions in the work. They are important instruments for analysing and assessing the environmental situation in a landscape area. Investigation data have – jointly with data from other sources – been evaluated against EMR-criteria and what would be an optimal agri-environmental situation for the society. Secondly, by providing data on environmental quantity and quality variables at low cost for each object in the landscape (each pasture, ditch, etc.), they make it possible to develop efficient agri-environmental policy measures directed on the targets. Thirdly, the produced maps have proved to be effective in communicating the agri-environmental conditions of the study areas and their landscape components.

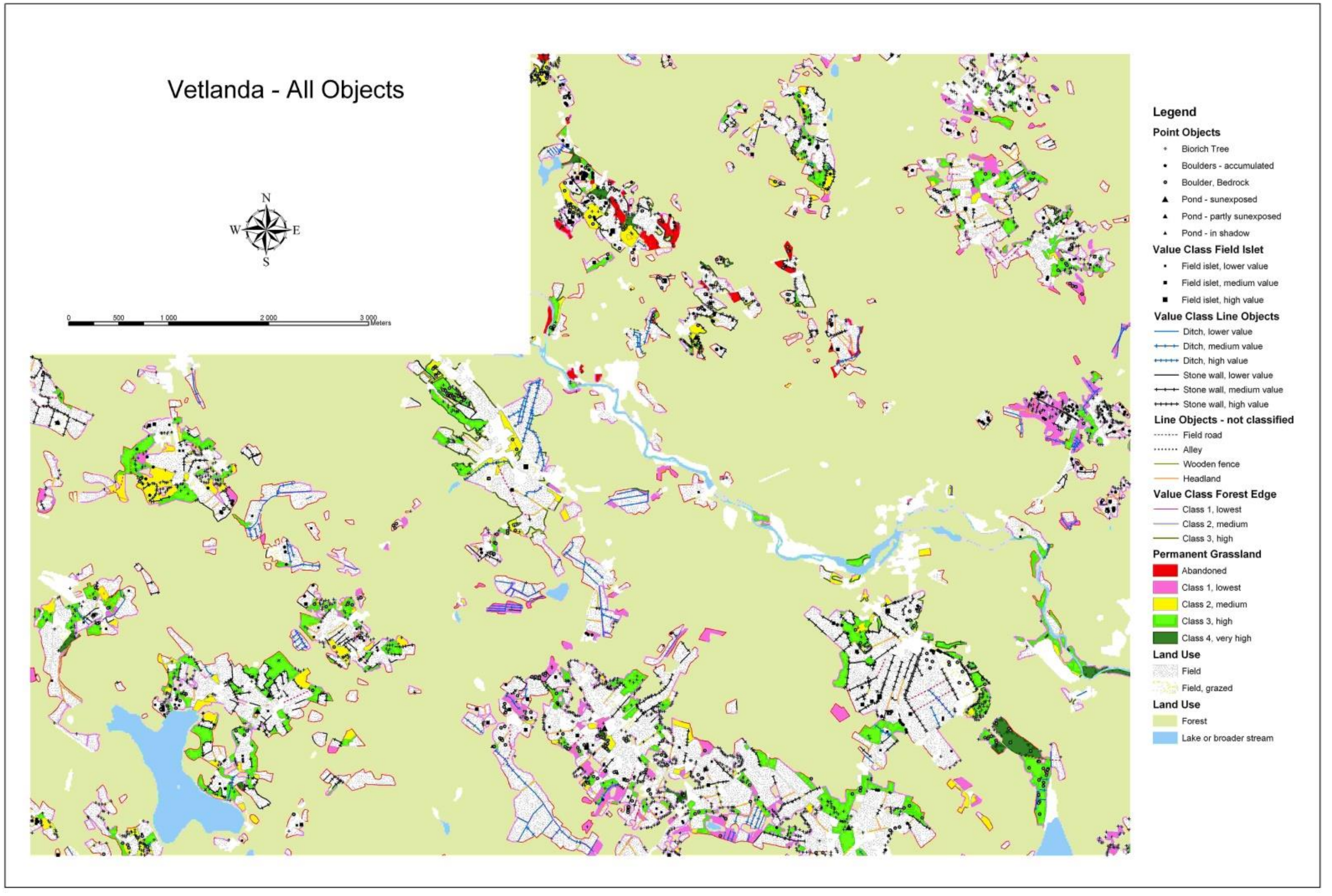

Table 42: Environmental qualities for the Vetlanda study area

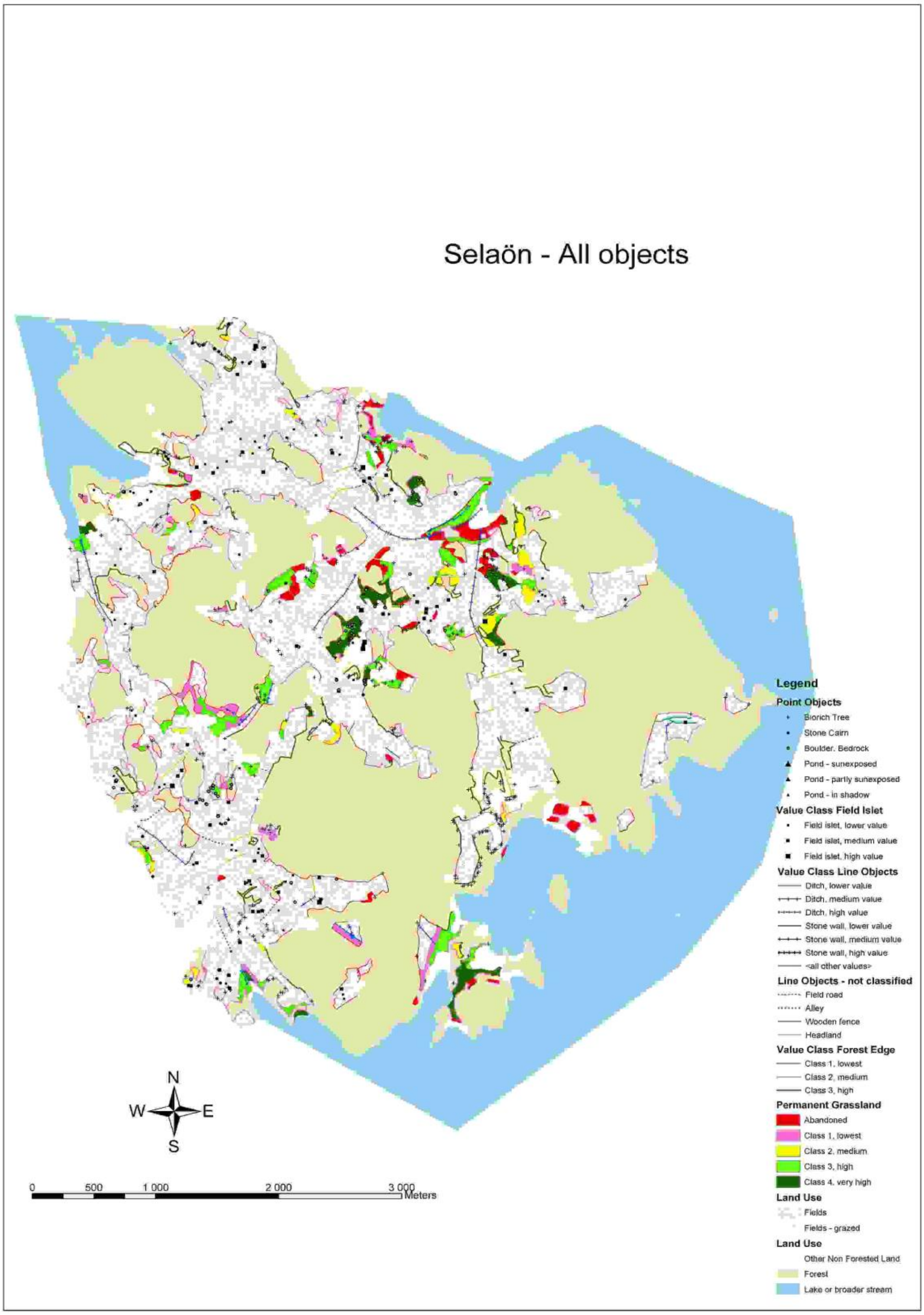

Table 43: Environmental qualities for the Selaö study area

References

Jordbruksverket. 2005a, *Ängs- och betesmarksinventeringen 2002 - 2004*, [Swedish Board of Agriculture], Jönköping, 2005:1.

Jordbruksverket. 2005b, *Indikatorsystem för ängs- och betesmarker*, Jordbruksverket [Swedish Board of Agriculture], Jönköping, 2005:8.

Jordbruksverket. 2005c, *Indikatorsystem för småbiotoper*, Jordbruksverket [Swedish Board of Agriculture], Jönköping, 2005:7.

Bastian, O. & Lutz, M. 2006, "Landscape functions as indicators for the development of local agri-environmental measures". *Ecological Indicators*, vol. 6, no. 1, pp. 215-227.

Dramstad, W. E., Tveit, M. S., Fjellstad, W. J., & Fry, G. L. A. 2006, "Relationships between visual landscape preferences and map-based indicators of landscape structure". *Landscape and Urban Planning*, vol. 78, no. 4, pp. 465-474.

Ode, Å., Tveit, M. S., & Fry, G. 2008, "Capturing Landscape Visual Character Using Indicators: Touching Base with Landscape Aesthetic Theory". *Landscape Research*, vol. 33, no. 1, pp. 89-117.

Piorr, H. P. 2003, "Environmental policy, agri-environmental indicators and landscape indicators". *Agriculture, Ecosystems & Environment*, vol. 98, no. 1-3, pp. 17-33.

Romstad, E. 1998, "Theoretical Considerations in the Development of Environmental Indicators," in *Environmental Indicators and Agricultural Policy*, F. Brouwer & B. Crabtree, eds., CAB International, Wallingford, pp. 13-23.

Zalidis, G. C., Tsiafouli, M. A., Takavakoglou, V., Bilas, G., & Misopolinos, N. 2004, "Selecting agri-environmental indicators to facilitate monitoring and assessment of EU agri-environmental measures effectiveness". *Journal of Environmental Management*, vol. 70, no. 4, pp. 315-321.