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Integrating landscape-based values—Norwegian monitoring of agricultural landscapes

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Abstract

An accumulating body of research identifies the importance of landscape structure for a wide range of countryside interests. Landscape structure reflects the results of policies and practices, and is well-suited as a target for management actions. New landscape metrics represent a potential for indicator-based management, provided such metrics relate consistently to the landscape values of interest. In this paper we propose that aspects of landscape structure, specifically heterogeneity, may be related to landscape-based values such as biodiversity, cultural heritage and human appreciation. Birds and vascular plants correlated well with our index for the heterogeneity of land types, whereas insects did not. Occurrence of prehistoric graves was also associated with land type heterogeneity, though other types of cultural remains were not. Landscape experience seems to be associated with the heterogeneity of landscape space rather than heterogeneity of land types. Different aspects of heterogeneity, scale, and variation over time all contribute to explain how our measures of landscape-based values vary in their relationship to landscape heterogeneity. Successful integration between disciplines in landscape studies depends on having a common operational framework, a shared theoretical basis, and a harmonised approach to data collection. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

The agricultural landscape is a multifunctional landscape where numerous interests interact, and occasionally cause conflict. This landscape has a long history of human use and management leaving numerous cultural history features, it supports a wide array of species, and has a large potential for recreation and amenity functions. At the same time, it is a production landscape and source of income. Agricultural landscapes are also dynamic and undergo frequent change. Since major agricultural areas are commonly located near cities and towns, they are part of the everyday landscape for a large number of people. Agriculture is thus one sector where direct public intervention remains the norm rather than the exception (Anon, 2000).

Landscape changes influence a wide range of countryside interests. Land use change, implying habitat loss and alteration, has been identified as the most

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important factor driving changes in biological diversity at a global scale (Ehrlich and Wilson, 1991; Heywood, 1995; Stanners and Bourdeau, 1995). Such changes affect both the quality of habitats and the structure of the landscape itself. Landscape character, including the services landscape provides, can be threatened by landscape change (Usher, 1999).

Agricultural policies and modernisation of agriculture, especially, have brought about large changes in European agricultural landscapes over the last 50 years (Meeus, 1993). Farming has been abandoned in less productive regions, and meadows and pastures have been replaced by forests via spontaneous regrowth or planting. In more productive regions there has been an intensification of agriculture, including widespread land consolidation, with consequential removal of landscape elements such as field boundaries and patches of semi-natural grassland. Such changes have been implicated in the decline of many animal and plant species, the simplification of the visual landscape and damage to important cultural heritage interests. Our knowledge, however, tends to be restricted to single interest and/or small-scale case studies (Bunce and Howard, 1990; Bunce et al., 1993; Framstad and Lid, 1998; Ashmore and Knapp, 1999; Wascher, 2000; Wascher and Jongman, 2000). Therefore, there is a need to gather further data based on interdisciplinary approaches and larger scales.

The dynamics of future change will depend on national and international agricultural policies. The impact of environmental grants and payments will be central to this development. How best to use these payments to affect landscape values positively remains controversial. In view of our limited understanding of the effects of landscape change, more sustainable landscape management will first require a systematic quantification of landscape change and its consequences. Several international initiatives use measures of landscape structure as indicators in environmental and sustainability monitoring (Brouwer and Crabtree, 1999; OECD, 1999a,b; Smeets and Weterings, 1999). However, the scientific basis for interpreting this type of information is weak. Research has yet to establish clear links between specific landscape metrics and the combined interests of biodiversity, cultural heritage, sustainability, amenity or aesthetic qualities. In addition, landscape structures that are positive for one interest may not be so for others.

In this paper we explore how landscape structure may be quantified and linked to landscape-based interests of different disciplines. We use the Norwegian national monitoring programme for agricultural landscapes as a case study and focus on the three issues of special interest—biodiversity, cultural heritage and human experience of landscapes.

2. A Norwegian case study—the "3Q programme"

The Norwegian Ministries of Agriculture and Environment initiated a monitoring programme of the agricultural landscape, the "3Q programme", in order to monitor changes in the agricultural landscape and to identify effects of policy and measures pertaining to this landscape. This programme focuses on the spatial structure of the landscape, and includes aspects of biodiversity, cultural heritage and human accessibility. True colour aerial photographs (scale 1:17,000 for 1998 and 1:12,500 from 1999 onwards) are the main data source for the programme. The monitoring programme is sample-based, with a total of 1474 sample squares of 1 km $\times$ 1 km distributed over the entire country in proportion to the amount of agricultural land (see Fig. 1). The aerial photographs are interpreted and mapped according to a hierarchical classification system of land types (see Dramstad et al., 2001 for further information). From these maps a number of indicators are calculated. Monitoring commenced in 1998, and will cover the entire country on a 5-year rotation. Change will thus be recorded starting in 2003, when the sample squares first photographed in 1998 are recorded for the second time.

The national 3Q monitoring programme was used as a basis for a 3-year research project funded by the Norwegian Research Council. In this project we explore in greater depth the relationships between landscape structure and biodiversity, cultural heritage and human landscape perception. Data from the 3Q programme were supplemented by additional field data from selected 3Q squares, and the analyses of relationships are developed in greater detail than in the 3Q programme proper.

The 3Q monitoring programme has a multidisciplinary approach and the associated research project

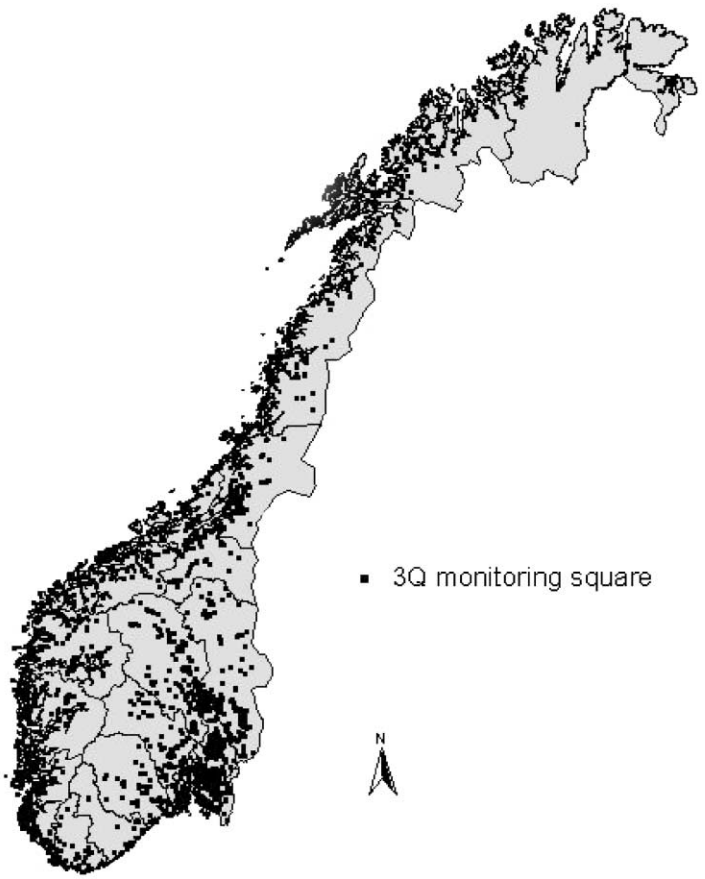


Fig. 1. Map of Norway showing the location of the 1474 3Q monitoring squares. Squares are distributed in proportion with the area of agricultural land in a region.

is well-suited to explore the challenges of integrating the various, disparate interests in the landscape.

3. Landscape structure and relationships to landscape values

An accumulating body of theory and empirical data provides evidence of the importance of landscape structure for a wide array of countryside interests. The term landscape structure is used to describe the content and spatial configuration of a geographical unit. The size of the unit will be dependent on the scale of the objects or processes being investigated (Forman and Godron, 1986; Wiens, 1989). Landscape configuration refers to the juxtaposition of landscape elements and to the mosaics and patterns that are formed (Forman, 1995; Dramstad et al., 1996). The theoretical basis for studying the effects of landscape structure is to a large extent drawn from the field of landscape ecology.

Although interest in spatial structure is increasing and its application in spatial planning is much discussed (Selman, 1993; Dramstad et al., 1996; Forman and Collinge, 1997; Selman, 2000), it is a complex phenomenon. This complexity makes understanding of how landscape patterns affect landscape processes difficult. To explore the links between landscape structure and different countryside interests we need to be able to quantify landscapes. We require information on both how different driving forces shape the landscape and how these patterns affect different countryside interests as well as how these interests interact with each other. Good indicators must represent the

Table 1
Indicators used in the Norwegian monitoring programme for agricultural landscapes (the "3Q" programme)[a]

	Landscape spatial structure	Biological diversity	Cultural heritage	Accessibility
Area of agricultural and non-agricultural land types	x	x	x	x
Patches of habitat distribution (average size of patches, number of patches per square kilometre)	x	x		
Length of different types of edge between adjacent land types	x	x		
Diversity (Shannon's diversity index)	x	x		
Heterogeneity	x	x	x	
Number and spatial distribution of point features, e.g. ponds, rocky outcrops, solitary trees, semi-natural habitat islands	x	x		
Number and length of linear elements, e.g. streams, ditches, hedges	x	x		
Length of edge between water and different land cover categories	x	x		
Area of different land cover categories within a 10 wide buffer zone beside water	x	x		
Number of historical agricultural buildings (from before 1900)			x	
Number of grave-mounds, ruins, cairns and signs of earlier cultivation			x	
Number and length of fences and stone walls			x	
Number and length of historical roads and paths			x	
Length of roads and paths				x
Connectivity in the road/path network				x
Area within 100 m distance intervals from roads and built-up areas		x		x
Proportion of the agricultural landscape that is legally and physically accessible to the general public				x

[a] Indicators are assumed to be relevant for the themes indicated by a cross in the table.

phenomena of interest in a meaningful way, they must have a clear relationship to changes in landscape structure and must show real, statistically detectable change if the landscape changes. They must also be cheap, easy, and robust to measure and communicate well with user needs. A range of measures of spatial structure (see Table 1) was made available from the 3Q monitoring programme.

3.1. Heterogeneity as a unifying measure of landscape structure?

In reviewing the various landscape measures important for each of the three interests, we found that landscape heterogeneity had the potential to be a common theme. Heterogeneity is defined here as the spatial variation of a landscape, which in agricultural landscapes commonly provides information on both the diversity of land types and their degree of interspersion. Further, heterogeneity is a measurable attribute that is attracting increasing research interest (Turner, 1990; Turner and Gardner, 1991; Pickett and Cadenasso, 1995; Klopatek and Gardner, 1999). We therefore chose to use heterogeneity in the analysis of how each interest—biological diversity, cultural heritage and landscape experience is related to spatial structure and to examine whether heterogeneity can function as a common indicator for the combined interests.

To quantify landscape heterogeneity, we used an index for the heterogeneity of land types (HIX), as it is applied in the 3Q programme (Fjellstad et al., 2001). HIX is calculated from land types recorded by a 10×10 lattice of points evenly spread across the 1 km^2 sampling square. Each point in the lattice has a number of nearest neighbours, usually eight but fewer along the edges of the study area. The total number of nearest neighbour relationships in a 10×10 lattice with no missing data is thus 684. The index value is calculated by recording similarity between land types for each point and its nearest neighbours for all points in the 100-point grid. The greater the spatial variation of land types in a sample square, the greater the proportion of dissimilar neighbours and the greater the index value. This index provided a gradient of values clearly separating the range of 1 km^2 sample squares used in the study.

3.2. Landscape structure and biodiversity

Many aspects of landscape structure have been related to biological diversity. The importance of edges in managing game birds was already pointed out by Leopold (1933). Since then, habitat fragmentation has been recognised as a major threat (Harris, 1984; Wilcox and Murphy, 1985) and theoretical development has taken place at the metapopulation level (Hanski, 1999). Biodiversity is affected by various aspects of the patch-corridor-matrix model (Forman, 1995), particularly heterogeneity (Gustafson and Gardner, 1996) and connectivity (With et al., 1997).

The biodiversity aspects recorded in this project were as follows:

1. breeding birds—point sampling recording all species within 50 m radius of points in a 3×3 regular grid per monitoring square;
2. vascular plants—all species recorded in 20 random $1\,m \times 1\,m$ quadrates from grassland vegetation within each monitoring square;
3. butterflies and bumblebees—recorded from standard $50\,m \times 3\,m$ transects along random edges within each monitoring square.

We found that several aspects of biodiversity were significantly correlated to heterogeneity as measured by the HIX index. The total number of bird species (breeding pairs) per monitoring square was highly correlated with landscape heterogeneity (Kendall's $\tau = 0.592$; $P < 0.01$) (Fig. 2a). The number of vascular plant species was also significantly correlated to heterogeneity (Kendall's $\tau = 0.516$; $P < 0.01$) (Fig. 2b). The insect groups, however, showed no significant relationships to this measure of heterogeneity (Kendall's $\tau = -0.110$; $P = 0.618$). For these groups, local environmental conditions such as edge width and numbers of flowers seemed to be more important than landscape variables, possibly reflecting the limited spatial coverage of field sampling, which may not adequately reflect diversity in a whole monitoring square.

3.3. Landscape structure and cultural heritage interests

Terrain features have long been known to influence the siting of settlements, grave-mounds and monuments (Tilley, 1994; Ashmore and Knapp, 1999). Within agricultural landscapes, cultural heritage interests are linked to landscape structure through the importance of farm buildings and the historical boundaries between farm ownership, between field systems and between cultivated and wooded areas. These types of uncultivated areas are often linked to prehistoric sites, including grave-fields and fossil field systems (Anon, 1996). Structural elements such as watercourses, lakes and old road systems (e.g. drove roads) in the landscape are important locational indicators of cultural heritage interests, particularly for certain settlement sites. Prehistoric settlement sites are often situated on lighter soil-types in the middle of current cultivation areas, and therefore have a link to today's production landscape. Quantifiable aspects of

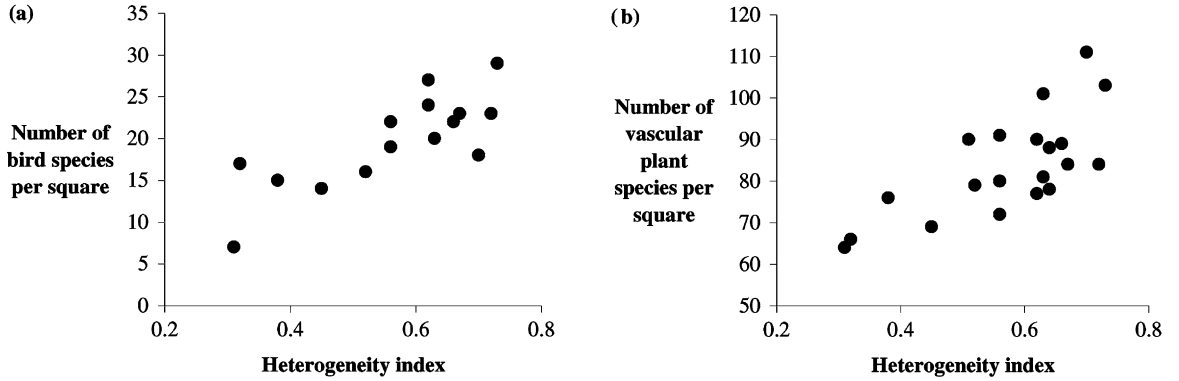


Fig. 2. The relationship between the heterogeneity index HIX and (a) number of species of breeding birds, and (b) number of vascular plant species per monitoring square.

landscape structure are, therefore, assumed to reflect the cultural heritage interests and time depth of a landscape.

The intensification of farming in productive areas of Norway leads to larger farms and fields. Common consequences of this development are the removal of stone walls, fences and other boundaries between fields, new cultivation or ditching, draining and closing of watercourses, all of which represent significant threats to the preservation of archaeological sites (Gaukstad, 2000). In addition, ploughing and erosion are other factors that have important implications for sites located in arable fields (most likely representing 80% of all protected sites). Following extensification in more remote areas, farms are abandoned, resulting in the dilapidation of buildings and farmhouses (Riksantikvarieämbetet, 1994).

The cultural heritage features recorded in this project were buildings, farmsteads, prehistoric settlements, prehistoric graves, historical roads, stone walls, traditional fences, and clearance cairns.

For most cultural heritage types there were few, if any, observations per kilometre square, making it difficult to test statistically relationships for the limited number of squares studied (22). There were however, a higher number of prehistoric graves and these showed a slight association with HIX, although not statistically significant (Kendall's $\tau = 0.306$; $P = 0.062$). One square was a clear outlier, with an exceptionally high number of graves (59 compared with fewer than 16 in all other squares). These graves were all located in two, previously studied grave-fields. When this square was removed from the analysis, the relationship with HIX was statistically significant for the remaining squares (Kendall's $\tau = 0.347$; $P < 0.05$) (Fig. 3a). Clearly, data from a grave-field are auto-correlated; the graves are not independent of one another. To avoid this problem, grave-fields were treated as single observations, on a par with solitary grave-mounds (Fig. 3b). Using this measure for all squares, the relationship with HIX appeared stronger (Kendall's $\tau = 0.438$; $P = 0.01$). This exemplifies the need for a thorough understanding of what represents an appropriate unit of data within each field.

3.4. Aspects of landscape experience and landscape structure

The visual exploration of landscapes is clearly linked to landscape structure. Within environmental psychology, the exploration potential in a landscape has been found to be one of the strongest predictors of human preference (Kaplan and Kaplan, 1989). The role of landscape pattern in visual perception is described more fully in Bell (1999), Weinstoeffer and Girardin (2000) and Muir (1999). Land type diversity, the contrast between forest and open fields, and grain size define the possibilities of visual exploration in agricultural landscapes. Processes of agricultural intensification can simplify landscape structure to form larger open spaces that deprive the landscape of variation and complexity; loss of these aspects will reduce the quality of the landscape

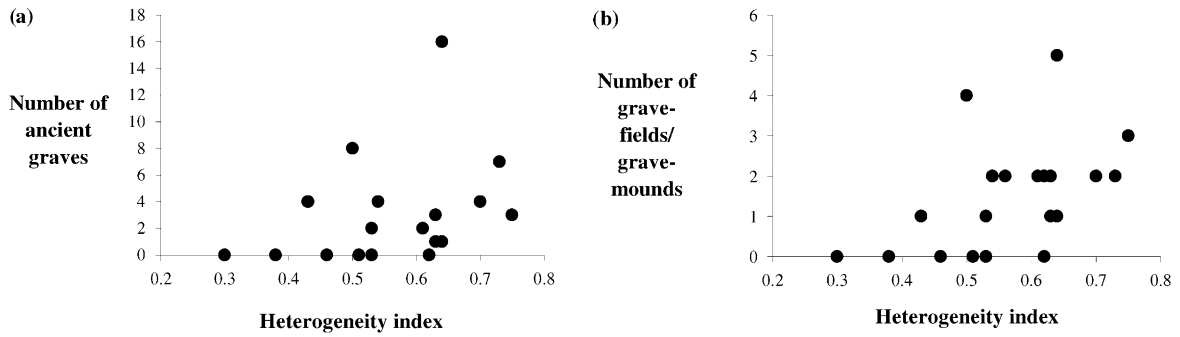


Fig. 3. Relationship between the heterogeneity index HIX and a) number of ancient graves (one 3Q square, having a total of 59 graves, is excluded from the figure); and b) number of grave-fields/grave-mounds, where each clusters of graves (a grave-field) is counted as a single observation (data included for all squares).

experience of visitors to the countryside. Landscape studies using the expert paradigm as well as methods of landscape assessment and character assessment (Bishop and Hulse, 1994; Nassauer, 1995; Coeterier, 1996; Usher, 1999) refer to landscape structure as an important landscape component. We can thus expect links between human responses to landscape and the structure of landscapes.

These research findings support the role of landscape heterogeneity as a summary measure of many visual aspects significant for both expert and public landscape preferences. Similarly, landscape heterogeneity has been found to affect the results of qualitative approaches to landscape assessment where the object is not the physical landscape but the way the physical landscape and its structure are perceived and interpreted (Nassauer, 1997).

To investigate the link between landscape structure and visual aspects of landscapes we examined people's reaction to landscapes which are as follows:

1. Visual preferences
   We examined student and public visual preferences for agricultural scenes from the study squares, assessed through ranking photographs and analysis of free text. We accepted that it would be difficult to gain sets of pictures that could objectively characterise entire 1 km × 1 km monitoring squares, so photographs were instead selected to represent clearly defined classes of openness.
2. Landscape phenomenology
   Results from preference studies were compared with experiential evaluations. Specifically, a phenomenological description of the study squares was drafted based on site visits, reflection and dialogue.

The results of both landscape preference studies and expert landscape appraisal focussed attention on the importance of landscape heterogeneity. The grain size of perceptual units was found to be one of the most important visual aspects. Grain size from a visual perspective is parallel to considering the scale of landscape rooms separated by the landscape elements forming walls and floors of landscape units (Lynch, 1960).

Results from analysing the landscape preferences of public and student groups showed significant differences between the two groups even within the comparatively narrow visual range of arable farming landscapes. These differences were evident in both preference scores (ranking of photographs) and in free text data. Student preferences were dominated largely by landscape structure (Fig. 4), while the presence of buildings was most important in shaping public preferences. It is suggested that the revealed divergence in preferences between the two groups is a result of differences in familiarity and especially in formal knowledge and expertise. Openness (or grain size) was found important in shaping landscape preferences in both groups, as were complexity, topography and the presence of human-made structures.

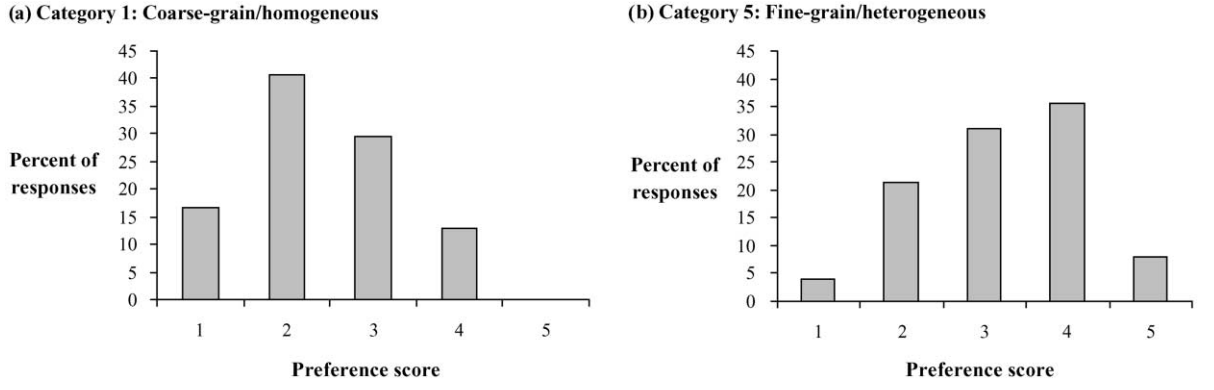


Fig. 4. Relationship between student landscape preferences and grain size for photographs in (a) Category 1, comprising the most coarse-grained, homogeneous landscapes, and (b) Category 5, comprising the most fine-grained, heterogeneous landscapes. Preference scores were given on a scale from 1 to 5, where 1 is the least preferred and 5 is the most preferred. There were 18 student informants and 31 landscape photographs, thus a total of 558 'responses'. The preference scores for the two categories were significantly different ($G = 42.213$; $P < 0.001$).

Table 2
The major landscape attributes used in an expert assessment and their descriptors[a]

Landscape attributes	Visual features
Land form	Terrain, topography, steepness, variation
Stewardship	Condition, upkeep, tidiness, buildings
Time depth	Historical continuity (visual) and diversity
Static	Dynamic visual axis reflecting signs of change
Scale	Large/small-scale
Heterogeneity	Grain size, small landscape rooms
Diversity	Visual variation in landscape elements
Disturbance/ tranquility	Intrusion of traffic, industry, etc.
Grandness	Estate farm to small holding
Boundaries	Visual screens dividing visual units, mystery
Access and infrastructure	Roads, paths, railways
Naturalness	Intensity of management

[a] Many have clear relationships with landscape structure (other commonly used visual descriptors that were not possible to quantify from map data were coherence, productiveness, and 'including–excluding').

Results from text analysis provided a phenomenological description of the study sites as well as identification of the visual aspects most commonly cited and their axes of variation. Of these, the size and nature of landscape rooms appeared as very important factors reflecting the scale of the perceived landscape (grain size) and landscape diversity/heterogeneity. Several of the other dominant visual aspects (Table 2) were also related to grain size.

The results of the preference analysis, the text analysis and the landscape experience were in agreement on the importance of a number of dimensions for defining visual aspects of agricultural landscapes. Quantification of these form the basis for comparisons with the other landscape interests and the starting point for discussing the potential and limitations of expert or personal landscape evaluations. The landscape descriptors provided further evidence of the importance of landscape structure and are valuable starting points in the development of integrated landscape assessment.

4. The process of integration

Aiming to integrate different disciplines within the framework of one research project implies a number of challenges. These include differences in academic traditions, different use and understanding of scientific terms, different traditions regarding data acquisition, analyses and use of statistics. We hoped that by narrowing the scope through focussing on one common feature of interest in the landscape, heterogeneity, it would be easier to work together and reduce the number of obstacles to integration. It did, but there were still several issues to deal with, including conceptual differences in the understanding of what heterogeneity is in different disciplines, and which aspect of heterogeneity is of most importance. There were also discussions on what data from each subject can be best used to test the relationship with heterogeneity measures. Additionally, agreement had to be reached on numerous issues regarding the standardisation of methods for data collection.

In order to provide a basis for interdisciplinarity, certain prerequisites should be fulfilled at the outset to allow meaningful comparisons. The most important of these is a common frame of reference. In our case this is the working hypothesis that the spatial structure of the landscape affects both the distribution and abundance of species, as well as human use and appreciation of landscape. This common frame of reference should preferably be supported by a reasonable theoretical basis.

A second aspect of concern is to ensure a common framework for data collection, thorough integration in time and space and, as far as possible, in choice of sampling methods. In our case, the project consists of closely integrated and interdependent sub-projects, where the same field sites are used to study biodiversity, cultural heritage and human responses to landscape. All sub-projects refer to the same basic data set for measures of landscape structure.

To limit problems associated with data compatibility between disciplines, especially the comparison of quantitative and qualitative data, we found the following questions of importance.

- Can we identify the data needed for the theme?
- Are the data available (including cost, time delay, etc. in this project)?
- Can the data be quantified (on a numerical scale or into categories)?
- Is the process of data acquisition transparent and repeatable?
- Can the data be linked to theory?

This enabled both direct comparisons of the various interests in landscape studies, as well as exposing the underlying theoretical basis for linking landscape structure to the various themes.

One of the aims of the project is the development of new and integrated landscape theory. The aim is ambitious, and will only succeed if our research can transcend the level of parallel studies conducted at the same field sites. Our current priority is to link approaches from the humanities and natural sciences to provide new insights into agricultural landscapes and the functions that they provide. This paper focuses on one element in this process, the identification of the importance of landscape heterogeneity to different landscape interests. The first stage of integration thus involved direct comparisons of results of landscape analysis from each subject discipline. This provided information about whether landscapes important for biodiversity might also be important for cultural heritage or for human appreciation of the landscape. At a practical level, the results allow us to comment on the consequences of different landscape management options on natural and cultural heritage conservation goals as well as which options will have the most impact on visual quality.

To reach beyond parallel projects involved considerable additional effort from individual researchers to read academic literature across disciplines, study methodology and participate in the joint collection of data in the field. This work clearly takes time and resources and thus requires a high level of commitment. To provide both motivation and make each discipline more accessible to the others, we instigated a process involving joint seminars and workshops to discuss definitions, the nature of data, selection of landscape descriptors, specific language and conceptual problems between academic disciplines, and scale issues. One of the major discussions at an early stage related to the project aims and the purpose of landscape analysis. Later, the discussion focused more on the theory and practice of landscape analysis and more specifically on the how and why of quantification, and particularly the differences between qualitative and quantitative approaches. Much of this debate is well-trodden ground between the natural sciences and humanities approaches to data and knowledge. Such debates demand much from the participants regarding mutual trust and respect. The major steps in the integration process were thus to make sure that there was a clear understanding of issues and the shared problem (the role of landscape structure) as well as a commitment to the overarching objective of contributing to the integration of the subjects.

5. Common patterns and underlying processes

In this paper, we compare the effects of landscape structure, as reflected in different aspects of landscape heterogeneity, on biodiversity, cultural heritage and landscape experience. By using harmonised methods to examine the role of heterogeneity for all landscape issues, we found a common pattern, namely the positive effect of increasing heterogeneity for aspects of all of the landscape-based values.

The heterogeneity index used in the monitoring programme, HIX, was initially designed to indicate conditions for biological diversity. The correlations with aspects of biodiversity in the field are thus encouraging. Support was found for the hypothesis that HIX is also of relevance for aspects of cultural heritage, although there remain many uncertainties. If we consider each type of cultural heritage object class as a species, we also find that the relationship between cultural heritage interests and landscape heterogeneity is clearer. We may be able to identify relationships between species occurrence and landscape structure for a few common species. However, for the majority of species, these relationships would require collection of standardised field data from a much larger number of sample squares. Analyses are further complicated by the fact that different species show different relationships to landscape structure, just as the distribution of different types of cultural heritage sites and artifacts may show different relationships to landscape structure.

For both themes, some of these challenges can be overcome by working with broader groups rather than individual species. In further analysis of cultural heritage data, it may be beneficial to group specific types of cultural heritage objects to reflect their social significance (Llobera, 1996). In the analysis of biodiversity, the use of ecological groups is likely to provide a better understanding of the ecological causes for relationships with landscape structure.

More work is needed, however, to determine suitable groupings for both themes.

Grouping the objects of interest also provided useful insights for the landscape experience theme. By dividing people into two 'functional groups'—students and public—we were able to obtain a better understanding of some of the underlying factors influencing people's landscape preferences. Students from the Agricultural University of Norway used more landscape terminology in free text responses than the public, suggesting a greater awareness of landscape as a topic of interest and implying that they are influenced by their education and background. Results from the student group supported the hypothesis that landscape structure is important for people's preferences. Landscape ecology students were singled out as a group with very high preferences for heterogeneous landscapes. The public group, on the other hand, were more influenced by the presence of cultural elements, such as buildings, in the photographs.

The results of both the preference study and the phenomenological study indicate that people are influenced by a mixture of logic and emotion that incorporates aspects of landscape structure, biodiversity and cultural heritage (Table 2).

It seems likely that the selected scale of 1 km may not be equally suitable to all themes or even for different interests within each theme. The spatial patterns of resources determining prehistoric settlements in the landscape or the perceptual units important for experience of the view may, for instance, be at much larger scales than those structuring the distribution of plants and animals. As such there will never be an ideal scale at which to monitor agricultural landscapes but a multitude of scales, each appropriate to a specific function or interest. For general monitoring a compromise must be made, preferably one that allows for moving up or down in a hierarchy of scales when needed. Shared discussions on appropriate scales and landscape measures were found of great value by the research group. These slowly began linking to disciplinary theory between and across subjects, with the result that the common area of work is greater than what separates our disciplines.

For all themes, it is likely that indicators-based purely on data from land cover maps will be limited in their ability to capture qualitative characteristics that are of importance at the local level. For example, two dimensions found in real landscapes but missing from our map data are the vertical structure of the landscape and the temporal dimension. In many agricultural landscapes, individual fields have traditionally been separated by grass banks, stone walls, or narrow rows of trees. These elements increase the visual heterogeneity, but have a low probability of influencing the HIX value. Large-scale agricultural areas of one or a few crop types but with many field margins are thus likely to have low HIX values reflecting the extensive coverage of homogeneous agricultural land types. Yet visually they are more comparable with more heterogeneous small-scale landscapes with high HIX values. This points to a limitation in the use of aerial photographic information, and the need for supplementary data to fulfill particular monitoring objectives.

In order to incorporate some aspects of vertical structure, indicators could be developed based on a simple, coarse classification of vegetation types into different height categories. An indicator-based on edges and field margin vegetation would also be of interest, both for human-based interests and biodiversity. Development of such an indicator will require a clear definition of an ''edge'' (in terms of width, length, vegetation type, etc.). Preliminary results from this project suggest that the importance of different edge characteristics may differ between themes, and a further development of indicators will take this into account.

Time depth is another important landscape characteristic. Past landscape structure has been shown to be relevant for present day species occurrence (Burel, 1993), and cultural environments that have a long continuity are habitat types recognised as important for certain species and communities (Cousins and Erikson, 2001). Knowledge of the landscape structure in the recent or remote past will improve our ability to take the temporal dimension explicitly into account. It was nevertheless encouraging that we were able to find certain aspects of contemporary landscape structure that reflect diverse interests in the landscape.

Our preliminary results support Nassauer (1995) and others who argue that the landscape typology used for a landscape ecological analysis of landscapes may be relevant for cultural and aesthetic analyses. This project is exploring this possibility of using shared landscape descriptors as well as a wider conceptual

transfer between subjects. The importance of heterogeneity found in this project provides connections between visual aspects of landscapes and biodiversity values. Similarly, cultural heritage sites include today's settlement structure and farm buildings that contribute significantly to the visual landscape and give the landscape meaning. Cultural landscapes also comprise many elements such as field boundaries, green roads, ponds, and traditional land uses that are also important for biodiversity. Understanding the underlying processes involved in such linkages is important in developing perspectives for a sustainable agriculture.

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