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Characterisation and mapping of landscape types, a case study from Norway

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Introduction

1 The definition of *landscape*[1] adopted by the European Landscape Convention (Council of Europe, 2000), explicitly takes human perception of landscapes into account ("as people perceive it"). This is motivated by an intention of broadening the landscape perspective from an arena for experts into an arena for involvement of citizens in general ("people"), and to empower the latter with influence over landscape assessment, valuation and management (Jones *et al.*, 2007). The flipside of this is a series of theoretical and practical questions linked to landscape perception (e.g., see de la Fuente de Val *et al.*, 2006; Ode *et al.*, 2009; Sevenant & Antrop, 2009): Who shall represent "people" in this setting (Déjeant-Pons, 2006)? Who shall have the power to define landscape values and landscape strategies (Jones, 2007)? In his short 2007 paper (Howard, 2007), Peter Howard summarised these challenges as follows: "*The realisation of the intentions of a legal convention as far-reaching as this will not be without problems... There is a real danger of legal nightmares ahead*".

2 Land(scape) management implies implementation of concrete land-use guidelines for land owned, and used, by people. Landscape management therefore requires methods for defining and delineating "landscape areas", to which a specific set of guidelines shall apply. The landscape discourse is a potentially important part of the process that leads to

approval of such guidelines by decision-makers, but to become important this discourse has to lead to concrete, general recommendations. This is particularly important on national scales where enforcement of legislation requires robust tools for assessment of comparability and similarity between areas. A major challenge with the ELC landscape definition is therefore to operationalise the loose phrase "as people perceive it" into generalised legislative management actions and general management strategies.

3 The ELC landscape definition contrasts definitions of landscape commonly used in landscape ecology (Sarlöv Herlin, 2007), e.g. as a tangible area of a certain given size and/ or related to a certain spatial scale, with specific, pre-defined characteristics. In principle, landscape ecological definitions are operationalised by setting the criteria that define one or several "landscape categories" that are to be subjected to management or other actions. By implicitly facilitating a landscape typology, this definition also facilitates mapping of landscapes, which is an important practical tool for management. This definition does, however, not (with necessity) include non-expert involvement in the management process. At a first glance, the two landscape definitions may appear incompatible. If so, implementation of the ELC may imply the inevitable dilemma that real influence on decisions can only be gained on the expense of involvement.

4 Our aims with this paper are: (1) to propose a solution to the dilemma of two apparently incompatible landscape definitions, associated with two traditions in landscape research, and (2) to outline a natural science-based methodology for landscape characterisation and typification, to exemplify practical implementation of this methodology in landscape mapping, and to discuss the usefulness of the resulting landscape maps for management and scientific research and for non-expert participation in landscape evaluation. The County of Nordland in North Norway is used as a case in this paper.

Making the two landscape definitions complementary

5 In our opinion, a major reason why the two landscape definitions appear incompatible, is that the vast majority of studies of landscape-related issues jump directly into an assessment of landscape qualities, valuation and proposals for management actions, typically with the aim of selecting the landscapes of value for protection or other specific management actions, without a prior characterisation of landscapes (description of material landscape characteristics). This is unfortunate because landscapes can be exhaustively characterised in user-independent ways once explicit rules for typification and description have been defined by a consensus process (comparable to the rules for defining and naming of plant and animal species, minerals and bedrock types, and other landscape attributes). Such landscape-type systems (LTS) may serve as a common basis for landscape analysis by different stakeholders, from which different perspectives and criteria will reach different conclusions about priorities and recommended management actions. This analytic phase, which provides the basis for decision-making, is the appropriate stage for democratic involvement of people. Accordingly, involvement of people and human perception in landscape processes *can* be combined with the demands of natural science for observer-independent landscape characterisation by realising that the two perspectives belong to different phases of the decision-making process. With their separate strengths and weaknesses, they bring complementary rather than opposing perspectives into landscape characterisation and mapping as well as landscape analysis and management.

6 The material understanding of landscapes taken from landscape ecology and geography offers the possibility to characterise landscapes in a consistent manner over large areas by applying a consistent set of criteria that makes the resulting LTS well suited for landscape mapping. This will aid communication about landscapes and landscape assessment. This approach has been used in several landscape mapping projects (see, for example, Mücher *et al.*, 2010).

7 The demand of ELC to take human perception into account and to actively involve people thus belongs to the landscape assessment and evaluation phases of landscape analysis, in which interactions between man and environment (landscape), including cultural and sociological elements of human perception, are central. However, different people tend to perceive and assess the landscape in different ways (Kaltenborn & Bjerke, 2002) and human perception may vary with landscape type at least for some used perception indicators (Tveit *et al.*, 2006; Sevenant & Antrop, 2009). This is reflected in the multitude of different, yet relevant, ways to evaluate the environment on a landscape scale (geological/geomorphological, ecological, cultural heritage, aesthetical etc.). This diversity of approaches strongly underpins the need for a basic knowledge platform which includes a set of basic terms and concepts that may facilitate communication among all relevant "stakeholders" and hence enhance involvement. Establishment of such a platform may also promote development of a common understanding among people with different interests. In our opinion, this is an additional argument against initiatives for generalising the human perception perspective of the ELC landscape definition into landscape characterisation and mapping of LTSs.

8 To make these two traditions complementary and avoid choosing between the two, both desirable, landscape definitions, we thus propose a two-step approach for treatment of landscape issues. This two-step approach implies that landscapes are first typified, characterised and mapped in accordance with the natural science-based material landscape tradition. These characterisations should be as exhaustive as possible with respect to properties of importance for the subsequent landscape analysis that includes perspectives of human perception and participation. These perspectives work as democratic elements in the procedures for landscape assessment, evaluation and, eventually decision-making and complies with the ELC intentions.

9 A method for landscape characterisation (LTS) will only serve its purpose as a knowledge base for landscape analysis if it gains general acceptance by all stakeholder groups. It therefore has to meet some basic criteria, of which the following are likely to be the most important:

- general patterns in the variation of landscape characteristics need to be addressed
- only characteristics (variables) that are observable on a relevant (i.e., landscape) scale taken into account
- the characterisation must be so exhaustive that the needs of all stakeholders for information is satisfied
- the terms and concepts used in landscape characterisation, including criteria for definition of types, need to be explicitly defined and applied in a way that meets the demand for repeatability in scientific studies.

10 Any characterisation of landscapes by a limited set of variables that are selected and operationalised by procedures from which subjective decisions cannot be circumvented, will be open for criticism for being biased and for representing one specific view of landscapes and/or landscape values. Therefore, a broadest possible selection of landscape

attributes should be recorded. Furthermore, type systems should be obtained from sets of recorded variables in a large sample of landscape units by statistical analyses which elucidate relationships between these landscape attributes.

A method for landscape characterisation, exemplified by landscape mapping of Nordland County

The study area

11 Nordland County is used as a case for development and testing of a new system for landscape typification and characterisation (LTS), and for using this LTS for landscape-type mapping. Nordland is situated in northern Norway, intersected by the Arctic Circle. It is dominated by mountains, but also has a long and complex coastline (figure 1). Most inhabitants live along the coast in a few larger valleys and, most notably, where valleys meet fjords. The deepest fjords stretch far inland and, in the most extreme cases, leave less than six kilometres from the fjord head to the border on Sweden. Mountains are used as traditional reindeer grazing land for the Sami population. A coastal platform (the strandflat), up to 65 kilometres wide and with shallow waters and small and larger islands and skerries, dominates the outer coast. In the north of the county, the Lofoten and Vesterålen archipelagos reach far from the mainland and have for a long time been centres of Norwegian cod fisheries.

Figure 1. Location of Nordland County (Geonorge, 2016).

Establishment of a landscape typology for Nordland and implementation of this in landscape mapping

12 Nordland County serves as a pilot for development of a new system for description and typification of landscapes and ecosystems in Norway, based on the criteria for a good LTS given above. The Nordland pilot study was guided by the applied purpose that the map resulting from landscape typification and delineation of landscape areas should be a useful tool for the county- and municipality-scale landscape analysis by human perception and involvement processes leading to decisions about planning and management actions.

13 In accordance with the considerations above, we define the term "landscape" for subsequent operationalization in a landscape typology as *a geographical area, characterised by its content of observable, natural and human-induced, landscape elements* and "Landscape elements" as *natural or human-induced objects, categories or characteristics, including ecosystem types, which are observable at landscape scale.* By both including natural and human-induced landscape characteristics, this definition provides a LTS that combines geo-ecological and land-use characteristics. As our aim was to find generalizable patterns of variation in landscape characteristics, operationalised as landscape element content, we utilised all relevant data that could be obtained from existing databases and maps, and that were also available for the rest of Norway. These data were organised in a GIS. The *landscape scale* was interpreted so that the resulting landscape units should be suited for mapping to scale 1:50 000, with area units typically more than 4 km^2 each.

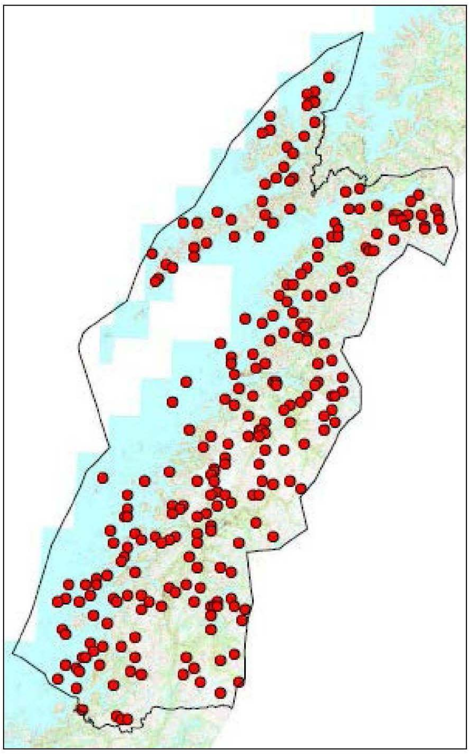
14 Landscape-type systems based on more or less similar principles have previously been developed for other European countries (Wascher, 2005; Mücher *et al.*, 2010). Existing LTSs do, however, vary much in detail. Some systems address very fine spatial scales and put large demands on access to detailed data on, for example, land use and soils, while others address coarser scales and primarily address climatic regions (e.g., Metzger *et al.*, 2005; Bakkestuen *et al.*, 2008). In the European landscape mapping project (Mücher *et al.*, 2010), the main criteria on which the classification was based were climate (precipitation and temperature), elevation and land use.

15 For the Nordland LTS system, neither bioclimatic variables (climatic variables, vegetation zones and sections; cf. Halvorsen *et al.*, 2009) nor elevation were taken into consideration *as such*; neither of these represent directly observable landscape elements according to our definition. Instead, our main emphasis was on landscape elements observable on finer than regional scales, such as landforms, ecosystems and expressions of land use. The distribution and abundance of several landscape elements do, however, have a bioclimatic basis, e.g., boreal forest vs. treeless alpine/arctic areas. Rather than taking elevation into account *as such*, we used a digital elevation model (DEM, 100 m resolution, that also included bathymetric data) to characterise landforms and other geomorphological features by use of specific indices such as the relative relief and the topographic position index (TPI). The TPI (Jenness, 2006), calculated for a neighbourhood with radius 3 km, was used to define valleys and fjords, while the relief (Erikstad & Blumentrath, 2010) was used to identify and characterise plains. In addition to these geomorphometric variables, data from digital maps and databases were used to characterise infrastructure (e.g., roads, airports, buildings), land use (e.g., fields and pastures) and observable cultural heritage objects. Aerial photos and field observations

were used to complement the data obtained from databases. A total of 279 variables were originally registered, of which 173 were used in analysis.

16 A total of 258 quadrats, each 5 × 5 km, which will be referred to as observation units (OUs), were distributed over Nordland (figure 2) using a stratified random sampling procedure. Stratification was accomplished according to a pilot division of Nordland into main landscape units (plains, valleys, fjords, hill- and mountain landscapes) by geomorphological interpretation of relevant variables. This stratification ensured that the main variation in landscape features in Nordland was represented in the set of OUs. All variables were recorded for all the 258 OUs.

Figure 2. Placement of 258 OUs in Nordland County.



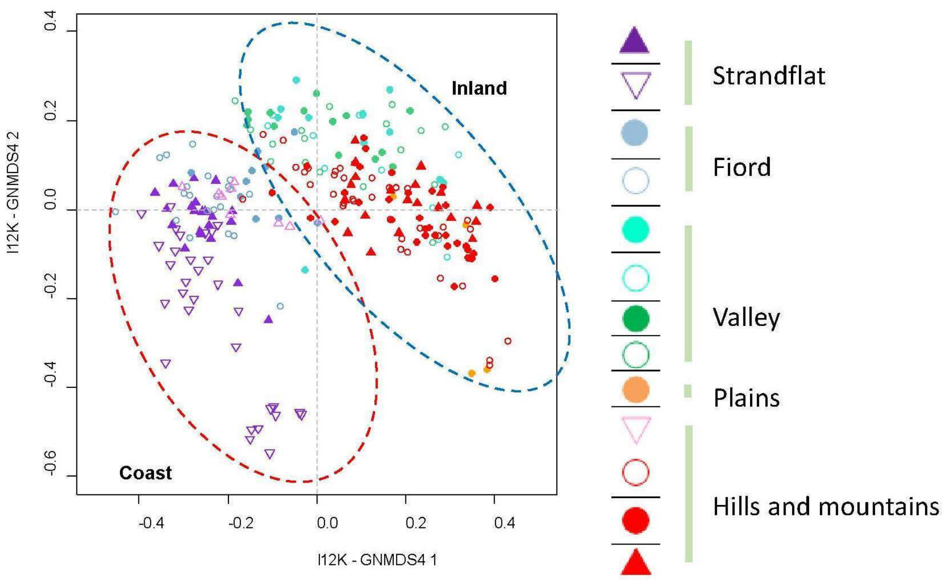
17 We subjected data for the 173 landscape variables recorded in the 258 OUs to multivariate analyses with the aim of identifying "landscape gradients", i.e., *parallel, gradual or step-wise variation in the presence and/or abundance of landscape elements* (i.e., observable landscape characteristics such as physical elements and measurable properties). The landscape gradients were obtained as axes of multivariate ordinations of the full data set and subsets thereof. We used two different ordination techniques, global nonmetric multidimensional scaling (GNMDS; Kruskal, 1964a, b; Kruskal *et al.*, 1973; Minchin, 1987) and detrended correspondence analysis (DCA; Hill, 1979; Hill & Gauch, 1980) in parallel, as recommended by Økland (1996). Only accepting ordination axes identified by both methods ensured that eventual shortcomings of the methods (all ordination methods occasionally produce artefactual results (Minchin, 1987; Økland, 1990) were identified and that the identified gradients represented real structure in the data (Økland, 1996).

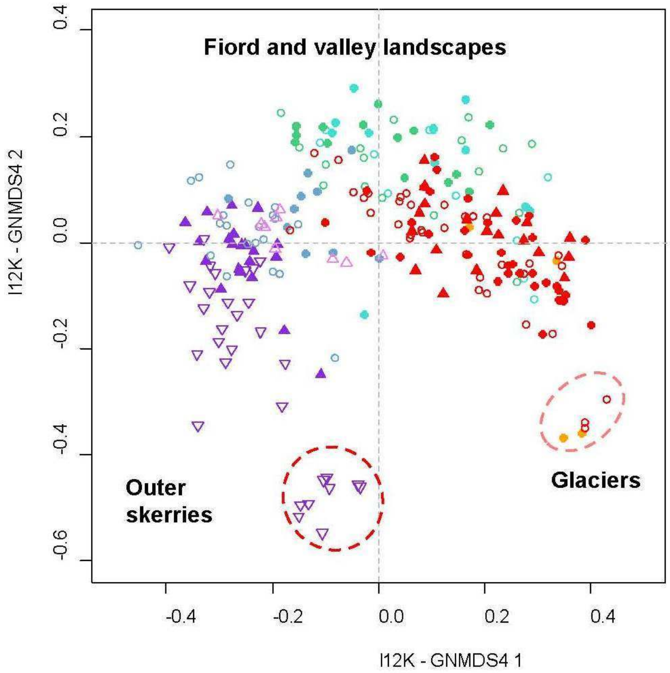
18 The ordination methods sort the OUs so that OUs with similar landscape characteristics (i.e., similar values for the landscape variables) are placed near each other and OUs that are most different in these respects are placed farthest apart (e.g., Økland, 1990; Legendre

& Legendre, 2012). The patterns of the OUs on the different axes of the ordination represent the complex relationships between the characteristics of the OUs with respect to all measured variables. To transform these patterns into a clear understanding of relevant landscape gradients the ordination results have to be *interpreted* (Økland, 1990). The interpretation can be viewed as a process for generalising the variation of landscape characteristics that is expressed as patterns along the ordination axes. Interpretation was performed by statistical methods such as correlation analysis as well as by use of statistical visualisation tools and GIS.

19 Ordination methods sort OUs along axes of decreasing importance (i.e., in order of decreasing variation in landscape characteristics explained). Results are exemplified in figure 3, which shows the ordination of 240 OUs (18 OUs falling entirely on sea were omitted). The first axis mainly separated coastal OUs (OUs with a coastline) from inland OUs (figure 3a). Several land-use characteristics varied along this main gradient.

Figure 3. GNMDS ordination of 240 observation units in Nordland County, characterised by 173 landscape variable, axes 1 and 2, with different information plotted for interpretation.





The pilot division into main landscape units (plains, valleys, fjords, hill- and mountain landscapes) is shown by symbols. 3a (above): The horizontal axis (axis 1) explains as much of the variation that can be explained along one dimension, mainly separating coast from inland. 3b (below): The vertical axis (axis 2) separates fjords and valleys (on one hand) from the strandflat and undulating hills and mountains (on the other), also representing variation in intensity of land use. Scaling of axes: 1.0 represents a half-change unit (50% similarity).

20 The second ordination axis provided a finer division of the OUs within each of the coastal and inland groups; separating the strandflat (with variation from remote, unused skerries to areas with extensive infrastructure) from fjords, and separating barren glaciers and middle-to-high alpine areas with hill-and-mountain terrain from valleys, typically with extensive infrastructure (figure 3b).

21 Finer details in the structure of the dataset were obtained by separate ordinations of data subsets, e.g., the subsets of coastal and inland OUs. A total of 10 landscape gradients (Table 1) were identified. Two of these reflected relief; valley shape calculated in valleys and fjords, and relief (elevation range within a circular observation neighbourhood with radius 500 m) calculated in hills-and-mountain terrain. Other landscape gradients that were identified by interpretation of the ordinations were presence (or not) of an alpine relief (cirque mountains, arêtes); glaciers; island character based on the size of largest island; position relative to treeline (boreal and/or alpine character); lake, mire and agricultural characters (areal coverage by lakes, mires and agricultural land, respectively); and amount of infrastructure (Table 1). Key variables were defined to characterise position along each gradient. The key variables could be simple area measures that were transformed into a simple index, or more complex indices. Typically, key variables were obtained as frequencies registered in a standard raster of 81 grid cells, each 100 × 100 m, in a circular neighborhood with radius 500 m. If, for example, 10 grid cells possessed a specific key property, a value of the key variable of 10 or, measured as a frequency, 10/81 = 0.123, was recorded. The more complex infrastructure index was obtained as the sum of three indices, quantifying and weighing the frequencies of

buildings, roads, and other visible signs of human infrastructure and non-agricultural land-use.

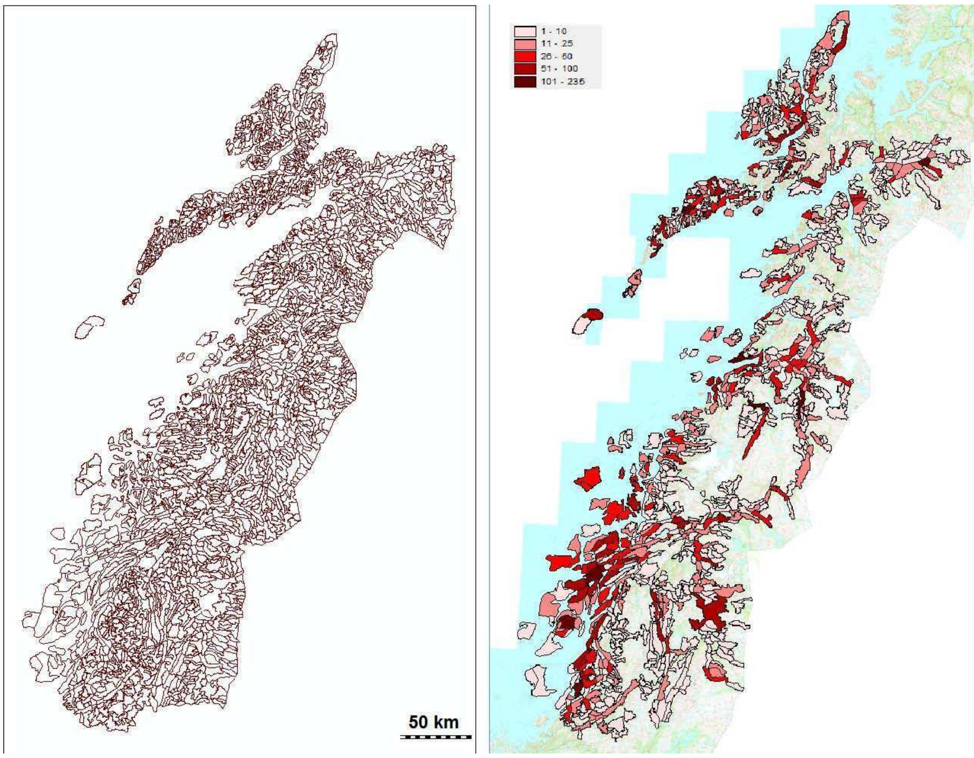
22 A landscape-type system was derived from the analytical results by first defining six non-marine *main landscape types* on the basis of the large-scale geomorphological structures that were interpreted as important. The first division was into coast and inland. The coast was further divided into the strandflat, fjord and hill-and-mountain coast, while the inland was divided into plains, valleys and hills-and-mountain landscapes. Marine main types can be defined similarly, but were not addressed in the Nordland project. Subdivision of each main type was carried out by dividing each key variable into 2–6 categories, the number of categories for each gradient pragmatically depending on the amount of variation expressed on the ordination axes (Table 1). A simple division into two categories was used for presence (or not) of lake, mire and glacier character simply by defining a minimum area required for adjacent 100 × 100 m grid cells to have values for the key variable above a pre-set threshold value, for delineating a landscape-type area with the respective character. A division into three categories was used for agricultural character as well as boreal and/or alpine character (under, on and above the tree limit). The island and infrastructure character gradients were divided into six categories each.

Table 1. Overview of landscape gradients with key variables used for landscape typification in Nordland County.

Gradient-group	Landscape gradient	Number of categories	Key variable
Geo-ecological landscape gradients	Valley shape (only used for valleys and fjords)	4	Valley width divided by depth measured along deepest part of the valley
	Relief (used on hill mountain and plains)	3	Relative relief (range of elevation) within standard circle
	Island character (area of largest island in the polygon	6	Area of largest island
	Alpine mountain character	2	Sharp arêtes as characterised by TPI within a standard circle
	Glacier character	2	Frequency of glacier grid cells in a standard circle
	Lake character	2	Frequency of lake grid cells in a standard circle
	Mire character	2	Frequency of mire grid cells in a standard circle
	Boreal and/or alpine character	3	Below, within or above the forest limit
Land-use gradients	Infrastructure character	6	Complex weighted index based on all mapped human-induced landscape elements except agricultural land (buildings, roads, other land-use, etc.)
	Agricultural character	3	Frequency of grid cells in a standard circle with signs of agricultural land use

23 A *basic landscape type* was defined as a unique combination of categories for the ten landscape gradients, and belonging to one specific main landscape type. In theory, the gradient categories can be combined into 62,208 types (Table 1), but the vast majority of these are not realised, partly because not all gradients are relevant for all main landscape types. In Nordland, a total of 2,689 polygons (landscape areas) were delineated by a sequential process by which explicit criteria were used to turn the distribution of key variables into landscape areas (figure 4). This procedure made use of a size filter, which secured that each polygon normally had a minimum size of 4 km^2 (exceptions were made for small side valleys and fjords which were allowed to be as small as 2 km^2 when meeting specific criteria. Polygons not meeting the demand for minimum size were amalgamated with larger neighbours by a standard procedure. A total of 380 basic landscape types (combinations of key-variable categories) were observed in Nordland. For practical use, these were grouped into 75 types, which were referred to as landscape types.

Figure 4. The 2689 landscape polygons of Nordland (to the left) and an illustration of the use of available descriptive data (to the right) collected for each landscape area and stored in a landscape-type information database.



The scale from light to dark red in this example shows frequency of houses known to be older than year 1900. Data from the Norwegian old house register SEFRAK, a part of the cultural heritage database of Norway.

Berg, 2001

24 The procedure yielded polygons (landscape areas) that varied in size from 2 to 20 km^2. These are basically characterised by the landscape gradient categories that define them, but a more precise characterisation can be obtained by using the whole set of data used for the multivariate ordination analyses, which is kept in a landscape-type information database. This allows for a wide range of potential uses, such as defining landscape character, assessment of landscape value (based on stakeholder-specific criteria), analysis of human perception issues, as well as for all sorts of statistical comparisons (see figure 4 for an example).

Future perspectives: a landscape map for Norway

25 The principles for data collection and data analysis applied in the Nordland project are presently (2016), with some modifications, applied to the entire Norwegian mainland. Our ambition is to obtain a landscape-type system for the entire country in the near future. In order to fulfil this ambition, we perform new ordination analyses of a sample of observation units that is representative for landscape variation in the entire country, to identify the set of nationally relevant landscape gradients. These will in turn be used to define landscape types for Norway, within each of the six main landscape types. This system of landscape types will form a part of the second version of NiN, the national

Norwegian system for description and typification of natural variation, owned and made publicly available by the Norwegian Biodiversity Information Centre (www.biodiversity.no). A main motivation for developing the NiN landscape-type system is to provide a knowledge basis for improved landscape analysis in Norway, within the framework of implementing the European landscape convention. Hopefully, the typification system will be useful for obtaining a unified map of landscape types for Norway within a timeframe of 2 to 4 years. Such a map will be useful as an infrastructure for scientific research as well as for management purposes. It will allow for cross-disciplinary research and cross-sectorial management and planning, among others by providing aggregated information about the frequency of landscape types and individual landscape elements. This information will, in turn, assist assessments of landscape uniqueness and representativity at different spatial scales. Thus, the landscape-type system will serve as an infrastructure for improved landscape analyses and improve comparative studies of landscapes in a wide sense.

Conclusion

26 The apparent lack of compatibility between the ELC landscape definition and natural science-based landscape definitions is a challenge for implementation of the landscape as an important issue in planning processes and scientific research. The ELC definition is directly linked to human perception and calls for participation of citizens in processes that lead to landscape management actions while the natural science-based definition emphasises general landscape properties. This may potentially drive landscape management into paralysis because clear-cut natural science-based definitions of landscape types and descriptions of landscapes limit the inclusion of human perception issues and involvement of citizens.

27 The two concepts of landscape and landscape characterisation are both valid, and can be made complementary by incorporation in different phases of the treatment of landscape issues. We argue that the natural science-based definition should be used for basic typification, characterisation and mapping of landscapes. The resulting landscape maps and dataset form an excellent infrastructure for landscape analysis, which includes assessment of landscape character and human perception issues, landscape valuation, and citizen participation. Understanding and using the strengths of both concepts and approaches open for improved strategies for landscape management that better comply with the intentions of the European landscape Convention to incorporate landscapes in democratic processes.

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NOTES

1. “Landscape” means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors.

ABSTRACTS

The European Landscape Convention emphasises the human perception of landscapes in its definition of the landscape, and promotes citizen participation in landscape management processes. On the other hand, landscape definitions adopted by the natural scientific tradition of landscape research, emphasises a material understanding of the landscape, with a more descriptive focus that includes landscape mapping. We discuss the inherent conflict between the ELC definition and propose that the ELC and natural scientific landscape definitions can be made complementary by considering landscape research as a two-phase process. The landscapes are typified, characterised and mapped in accordance with the natural science-based material landscape tradition in the first phase, and stakeholders of all kinds can be invited into an open process of landscape evaluation and development of management strategies and policies in a second phase of landscape analysis. We exemplify how the first phase in this two-phase process can be carried out, giving an overview of the system for landscape typification and characterisation developed for Nordland County, Norway as part of the Nature in Norway (NiN) system for typification and description of nature's variation. The role of such a system in landscape research is briefly outlined and plans for further development of the system into a landscape classification system intended for mapping of landscapes in all of Norway, are presented.

Das Europäisches Landschaftsübereinkommen (ELK) definiert Landschaft als "ein vom Menschen als solches wahrgenommenes Gebiet, dessen Charakter das Ergebnis des Wirkens und Zusammenwirkens natürlicher und/oder anthropogener Faktoren ist" und betont die Notwendigkeit die Öffentlichkeit aktiv an der Entwicklung von Landschaften zu beteiligen. Der vorliegende Artikel diskutiert den Konflikt zwischen der Landschaftsdefinition der ELK, die die menschliche Wahrnehmung ins Zentrum rückt, und einem naturwissenschaftlichen Verständnis des Landschaftsbegriffes, welches mehr auf die physischen Gegebenheiten und deren Erfassung und Beschreibung konzentriert ist. Um diese unterschiedlichen Perspektiven zusammenzubringen wird ein zweistufiger Ansatz zur Landschaftsanalyse vorgestellt: In der ersten Phase werden die Landschaften im Untersuchingsgebiet - einer naturwissenschaftlichen Herangehensweise folgend - anhand ihrer physischen Gegebenheiten typisiert, karakterisiert und kartiert, Auf dieser Grundlage können dann in der zweiten Phase Anspruchsgruppen und die Öffentlichkeit an der weiteren Landschaftsanalyse, sowie ihrer Bewertung und der Indentifikation von Zielen und Massnahmen der Landschaftsentwicklung beteiligt werden.
Am Beispiel des norwegischen Regierungsbezirkes "Nordland" wird aufgezeigt, wie die erste Phase eines solchen Zwei-Stufen-Prozesses umgesetzt werden kann. Es wird das hierfür entwickelte System zur Typisierung and Karakterisierung der Landschaften vorgestellt und mögliche Anwendungsbereiche eines solchen Systems in der Landschaftsforschung diskutiert. Schliesslich werden Pläne für eine Weiterentwicklung dieses Systems für eine nationale Anwendung in Norwegen umrissen.

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