31 INTEGRATING CULTURAL THEMES IN LANDSCAPE TYPOLOGIES

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INTRODUCTION

Landscape character assessment (LCA) and making landscape typologies became very popular in the last decade, particularly in Europe. This is due to the fast and important changes that are taking place: traditional cultural landscapes disappear rapidly and new ones are created (Antrop, 2000). The overall effect is a loss of cultural diversity and of character, in particular of cultural landscapes. The Dobříš assessment of Europe's environment formulated this problem for the first time (Stanners and Bourdeau, 1995). To make the assessment, a typology of landscapes at European level was needed and a first attempt was made by Meeus (1995).

The Dobříš assessments lead to the initiative of the Council of Europe to develop the European Landscape Convention (Council of Europe, 2000). The draft text was examined by the Committee for the activities of the Council of Europe in the field of biological and landscape diversity (CO-DBP) and the Cultural Heritage Committee (CC-PAT), which contributed to the integration of the interests of the conservation of biodiversity and cultural heritage. The text also refers to the UNESCO Convention concerning the Protection of the World Cultural and Natural Heritage, the Convention for the Protection of the Architectural Heritage of Europe, the Convention on the Conservation of European Wildlife and Natural Habitats, and the European Convention for the Protection of the Archaeological Heritage. Consequently, a broad and comprehensive definition of landscape was proposed: "Landscape means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors." (European Landscape Convention, Article 1).

Four general measures are formulated to realise the objectives of the Convention; the first is "to recognise landscapes in law as an essential component of people's surroundings, an expression of the diversity of their shared cultural and natural heritage, and a foundation of their identity" (Council of Europe, 2000). Five specific measures indicate how this can be achieved. It requires "research and studies in order to identify landscapes and analyse their characteristics and the dynamics and pressures which affect them." (Council of Europe, 2000). As a result, national surveys and landscape characterisation were started, as well as attempts to integrate these at European level. In most cases only map layers are used which cover the whole of Europe and are digitally available, so GIS-based classifications are possible. Most often the data layers refer to climate, bio-geographical zones, elevation data, parent material, soils, and land use. Cultural themes, such as settlement types and patterns, traditional rural architecture, building materials, farming styles, field patterns, hedgerow and planting patterns, signs, and place names, are significant but not included in the landscape typology and characterisation. Land cover is very often interpreted as the only cultural landscape component.

This article explores the possibilities to integrate cultural with natural themes in a more balanced way when making landscape typologies. First, cultural themes in some existing map classifications at European and national scale are analysed. Next, the nature of map representations of cultural themes is discussed. Most of these are analogue and represent one or several themes on a single map. Consequently they need transformation to make them useful in statistical analyses and GIS-based classifications. Four methods are discussed to transform data in continuous GIS-data layers. Finally, a method is proposed to make a landscape characterisation linked to an open database and based on the integration of all themes in a raster map, of which the cells are assigned a landscape type. This is applied to the case of Belgium.

CULTURAL THEMES IN LANDSCAPE TYPOLOGIES

Landscape typologies using analogue methods

Maps of cultural themes and synthetic landscape typologies have common properties. They are very general, use generic types, and are often represented as choropleths. Many of them are based on studies in human geography and available as analogue maps, which are often outdated. Several methods used for typologies can be recognised. Three will be discussed in the context of this paper: the original analogue map overlaying, the holistic classification of singular themes and of synthetic landscape types made by expert judgement, and an early example of statistical sampling and analysis for landscape classification.

One of the oldest systematic and multi-theme classifications of landscapes was made for Estonia by Johannes Granö (Granö, 1929; Peil *et al.*, 2004). He used a cartographic overlay technique combining natural and cultural themes on analogue maps. Therefore he defined homogenous core areas and fuzzy transitions formed by the borders between the themes (Granö, 1935, 1952). In a GIS-environment, these fuzzy transitions should be called slivers. However, Granö did not consider these as disturbing artefacts but as characteristics of the transition landscapes. The core areas of the regions are defined according to the number of themes (which he calls elements) that describe the units (Granö, 1929). Consequently, he introduced the notion of landscape heterogeneity within the classification. The result is a detailed but complex map.

The second method is based on expert judgement to describe generic types and a holistic way of mapping them. Series of different cultural themes are often made separately. One of the rare series is compiled in the book Europe's Cultural Area, first published by Jordan in 1973 covering Western Europe (Jordan, 1973) and later extended to the whole of Europe (Jordan-Bychkov & Bychkova-Jordan, 2002). Themes such as language, religion, rural architecture, rural building materials, farming types, etc. are represented in generalised thematic maps, compiled from a wide variety of more local and regional sources. Today, many of these themes are outdated and reflect traditional characteristics of rural landscapes that no longer exist. New recent developments, such as urbanisation and fragmentation by transport infrastructure, are not included.

A holistic mapping of synthetic landscape types for Europe and France is given by Lebeau (1979). Meeus (1995) used a similar method in the Dobříš assessment and this is a recent example of an expert judgement. It is based on his personal assessment and knowledge, resulting in generalised holistic and generic landscape types. Only the main landscape types are described in a very general way and illustrated with sketches (Meeus, 1995; Meeus *et al.*, 1990). Because the mapping was done on a small scale and too few different types occur within countries, this typology is not very useful for policy and planning purposes. This criticism has led to new typologies such as the one made by Vervloet & Spek (2003), largely based upon the main physical characteristics such as elevation and landform, and the European LANMAP2 typology (Mücher *et al.*, 2003; Wascher, 2005).

A third approach was proposed by Kilchemann (1971), using thematic maps from a national atlas of Kenya. It is one of the first applications of statistical analysis for landscape classification in the pre-GIS time. He used analogue maps representing rain fall, vegetation, elevation, ethical groups, agricultural systems, and geology. These data were sampled with a regular grid to make a multivariable dataset. This was analysed using information theory, factor analysis, and cluster analysis to classify the sample points. Similar points were manually grouped to form landscape regions. The method can be applied nowadays in a finer and easier way using geostatistics and GIS. The use of information theory is an interesting approach to assess the information content of base maps and to compare the quality of typologies (Kilchenmann, 1973).

A GIS-based landscape typologies – LANMAP 2 as an example for Europe

The most recent version of a pan-European landscape typology (LANMAP2) was realised in the scope of the European Landscape Character Assessment Initiative (ELCAI) (Mücher *et al.*, 2003; Wascher, 2005). The LANMAP2 map is based upon four themes: climate, a digital elevation model, parent material, and land use (Wascher, 2005). The climatic regions show fifteen categories and are based on the Environmental Classification (Metzger *et al.*, 2005) and the biogeographic classification of EEA. The global USGS GTOPO30 is used as digital elevation model and shows 18 classes. The parent material is derived from the FAO-UNESCO Soil Map and the European Soil Database and shows fifteen categories. Land use is obtained from the data bases of CORINE, PELCOM and GLC2000; ten categories are used. The different thematic maps are combined as “spectral” bands to form a composite image. This is successively analysed with object-oriented image classification software (eCognition) for segmenting the image into landscape units with unique combinations between the composing themes and resulted in about 14000 mapping units. Subsequently, a cluster analysis is used to group these landscape units into 375 landscape types.

All themes refer to natural components of the landscape. In this series, land cover is considered as a cultural as well as a natural component. The use of land cover as the sole component of cultural landscape character proved to be unsatisfactory and resulted in erroneous mapping of the cultural landscape diversity for the SPESP using CORINE Land Cover data (Anzuini *et al.*, 2000). Simultaneously with the elaboration of the European typology, many national and regional typologies and maps have been developed as well. Some of them have been used to validate and evaluate the LANMAP2 typology. Fitting national typologies remains problematic, as well as joining transborder landscapes (Stiles, 2005; Wascher & Pérez-Soba, 2004).

THE NATURE OF CULTURAL MAP THEMES

Cultural map themes refer to individual objects or show aggregated properties that are represented in spatial units or as surfaces. The cartographic representation of cultural objects depends on the scale and can be done using a coding in points (such as churches, farms, monuments, castles), lines (old road system, hedgerows), and polygons (relict areas, woodland).

Very often, cultural themes are represented in generalised and small-scale thematic maps, which show large mapping units with crisp borders that can rarely be observed in the landscape. When combining this kind of maps with natural features, such as landform, soils, and land cover and which represent detailed and spatially better defined units, the large and general themes dominate the outcome. This is illustrated in the example of the distribution of openness of the landscapes in Belgium according to the National Atlas on original scale of 1:400000. This very generalised choropleth map shows only two categories, open and enclosed landscapes, and was combined with three more detailed ones describing land cover, parent material, and elevation. A cluster analysis was used to define the landscape types. The result clearly shows that the most general and least informative base map, the one with openness of the landscape, dominates the output map.

As formulated in the European Landscape Convention, landscape perception is an essential part of the definition of landscape. Landscape perception and experiencing is existentially important and related to landscape aesthetics and valuing and it is essentially a cultural theme. However, data about landscape perception and aesthetical qualities are mainly available as descriptions and narratives. These are difficult to be used in landscape typology, in particular when the outcome should be a map. Some visual qualities can be linked or derived from other themes. The holistic image of urban, rural and forest can be derived from land cover maps. Also, open space can be associated with land cover categories and landform. Order and chaos are associated with landscape heterogeneity. Visual contrasts are often caused by sudden changes in land cover and landform, thus by crisp borders. So, even when it is difficult to map visual properties, they can easily be added to the description of landscape types.

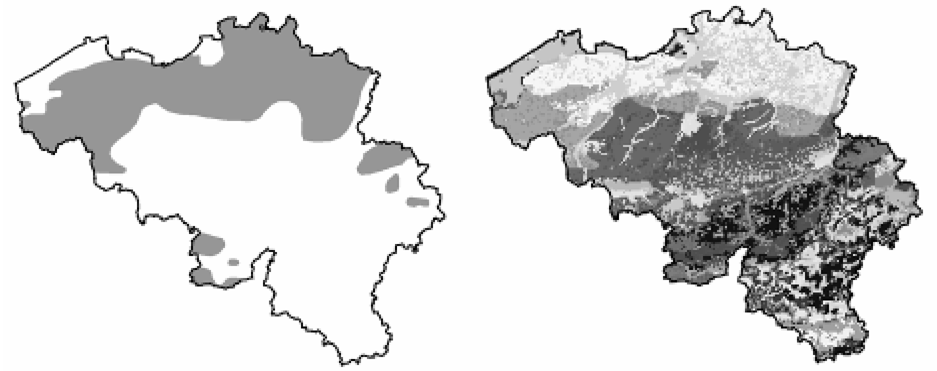

Figure 1: Distribution of openfield and bocage landscapes in the National Atlas of Belgium (left) and the combination of this theme with land cover, soils and land form (right).

Various sources contain information about the cultural landscape. Cultural map themes can be:

- derived from other thematic maps;
- derived from historical topographical maps;
- based on statistical data; and
- derived from settlement analysis.

Each has specific geo-spatial properties that will be discussed below.

Cultural themes derived from other thematic maps

The classic example is the use of land cover to make an assessment of the cultural aspects of the landscape through land use. The CORINE Land Cover database is often used in this way. Land cover categories are aggregated in groups that reflect visual or functional aspect related to the dominating land use. Typical groups are: open-enclosed landscapes, urban fabric, industrial, commercial and transport infrastructure, forest, and semi-natural areas. The result gives spatial units with a heterogeneous content represented by homogeneous polygons and with crisp borders. The derived visual or functional landscape types are of course highly related to land cover.

Cultural themes derived from historical topographical maps

Historical maps contain a lot of information that is significant for cultural landscape themes. Old topographical maps are often geometrically distorted, so using these in GIS overlaying is not straightforward and demands laborious manual work. However, using series of historical maps is essential in determining the time depth of a landscape (Fairclough, 2003) and to study landscape trajectories (Käyhkö & Skånes, 2006). The extraction of significant data from these maps demands careful selection of the way of encoding the selected features for further analysis. Basically, this encoding is scale dependent and four possibilities exist: features can be represented as objects such as points, lines, and polygons, or as a continuous field or geographical surface. Settlement patterns are a typical example: sites can be mapped as points or polygons describing also the shape of the settlement, and the settlement density can be represented by a dot map or a choropleth map by administrative unit, or by a geographical surface with isolines. The further use of this information in landscape typologies will give very different results.

Cultural themes based on statistical data

Some cultural significant themes are collected by statistical or administrative units. Examples are population data, crop production, number and age of houses. These are all data aggregated in spatial units that differ from landscape units. The map representations are cartodiagrams or choropleth maps, which are difficult to use. Anyhow, a necessary step is to transform the discrete information into a continuous coverage to be combined with other themes.

Cultural themes derived from settlement analysis

Settlement types and patterns and properties of territories such as size and shape, are very indicative for the study of landscape history (Baker, 1971; Unwin & Nash, 1992) and for landscape structure (Van Eetvelde & Antrop, 2005). Numerical indicators such as shape indices, eccentricity of settlement sites, concentration of housing, and land use intensity zoning can be derived from maps, aerial photographs, and field studies. They are often linked to territorial units and have similar properties as themes derived from statistical data.

MAPPING AN INTEGRATED LANDSCAPE TYPOLOGY

Maps representing landscape types or character areas are mostly coloured choropleths. These assume that all information is equally distributed within the polygons and that all variation occurs at the boundaries (Burrough & McDonnell, 1998). The polygons are considered as isotropic space, boundaries are always crisp. This model is easy to read but does not describe the spatial variation of landscapes well and certainly not the cultural and visual aspects that can be perceived.

The proposed method tries to solve some of these problems by using the following principles:

- natural and cultural themes add to the characterisation in a balanced way;
- the negative effects of choropleths are reduced by transforming the theme into a continuous geographical surface if necessary;
- thematic maps with the highest information content are used first;

- attributes are classified according to the way they will contribute to the characterisation; and
- the cartography expresses visual properties of the landscapes.

The procedure of the proposed method is given in Fig. 2 and the successive steps are discussed below. Fig. 3 and Table 2 give an example of its application to the new landscape typology of Belgium.

Data collection and analysis of the map properties

Basic sources are thematic maps and images such as aerial photographs and satellite images, which can be divided in three types: natural and cultural themes, and a holistic representation of the landscape such as an image (Antrop & Van Eetvelde, 2000). Their properties are analysed considering the data format (raster or vector, digital or analogue), the way of encoding the data (as point, line, polygon or surface), the type of the data (discrete or continuous), the nature of the borders on the map (crisp of fuzzy), the number of legend classes, and the information content expressed as information entropy if possible (Table 1).

Data transformation and the creation of a continuous data coverage

All themes must be available as thematic maps covering the whole study area. If necessary, data have to be transformed or derived to obtain these maps. Also some reclassification of the legends may be needed. It is important to keep the number of categories between the themes more or less the same, as this influences the information content of the maps in an important way (Table 2). Discrete, non-continuous data, such as point of line data, can be transformed into continuous geographical surfaces. For example, the survey data about the age of the buildings is made by administrative units (municipalities). The number of houses by age class is assigned to the centre and encoded as point data. These can be used to interpolate a geographical surface showing the density of the building by age class. As a result, sharp boundaries caused by choropleth mapping of the municipalities are avoided and smooth surface is created.

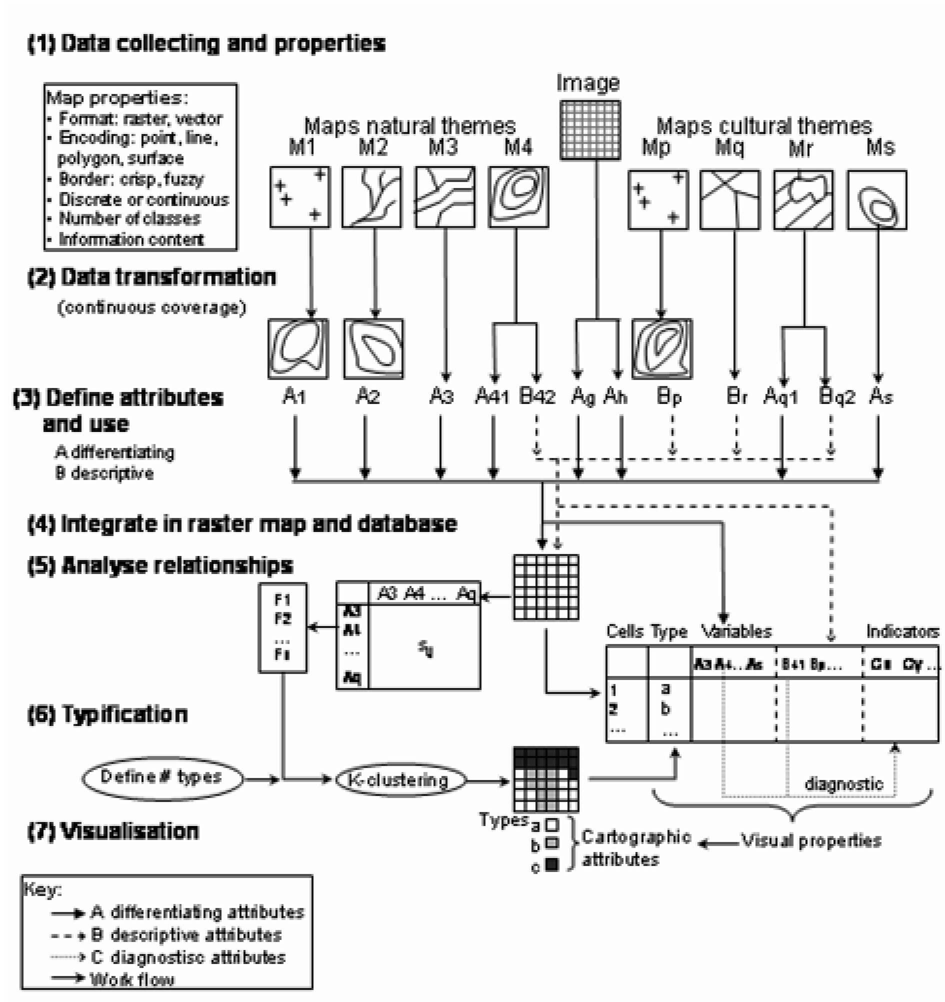

Figure 2: Procedure of mapping landscape typology.

Defining attributes and their use

The selection of themes attempts to include as much uncorrelated information as possible. Attributes describing the themes are derived from the base maps; several attributes can be derived from a singe base map. For example, a land cover map allows to define attributes as urban land uses, or all built-up areas (urban and industrial), as well as agricultural land, etc. Also additional properties can be derived, such as scenic attributes defining open spaces.

According to Vink (1980), attributes that describe landscape properties can be defined in different ways according to their contribution to the final classification. He distinguishes differentiating, descriptive, and diagnostic attributes. Differentiating attributes define the landscape types and units and also the delineation of the map units.

Purely descriptive attributes can be added to previously defined types or units, without changing the classification. Some attributes can be meaningful for the assessment of complex characteristics. For example, the information entropy of a satellite image can be used as an assessment of landscape heterogeneity. These diagnostic attributes can also be combined to form indicators.

Table 1 summarizes the themes, their properties, and attributes defined in the case of the Belgian landscape typology.

Table 1: Selected themes for the landscape typology of Belgium and their properties.

THEME GROUP	THEME NAME	SOURCE (MAP TYPE)	ATTRIBUTES / VARIABLES (UNITS/KM²)	NC *	ICBC *****	BT **	VP ***	USE ****
Natural	Elevation	DEM (digital grid)	- average elevation/km²	6	2.35	fuzzy	No	Dif
			- standard deviation/km²	5	1.87	fuzzy	Yes	Dif
Natural	Soils	Soil association map (choropleth)	- % by soil type/km²	9	2.40	fuzzy	No	Dif
Natural + cultural	Land Cover	CORINE (choropleth)	- % by land cover category/km²	6	1.99	crisp + fuzzy	Yes	Dif
Cultural	Heterogeneity	Landsat TM (raster)	- entropy/km²	5	1.80	fuzzy	Yes	Dif Dia
Cultural	Settlement pattern	Spatial analysis (continous)	- shape index	9	1.97	fuzzy	No	Dif
			- eccentricity index	7	1.62	fuzzy	No	Dif
Cultural	Ages of houses	Statistical data (continous)	- % houses build before 1990	7	1.90	fuzzy	Yes	Dif
			- % houses build between 1900-18	7	1.68	fuzzy	Yes	Dif
			- % houses build between 1918-45	7	1.64	fuzzy	Yes	Dif
			- % houses build between 1945-61	7	1.86	fuzzy	Yes	Dif
			- % houses build between 1961-71	7	1.89	fuzzy	Yes	Dif
			- % houses build between 1971-81	7	1.79	fuzzy	Yes	Dif
			- % houses build after 1981	7	1.86	fuzzy	Yes	Dif

* NC: Number of Categories

** BT: Border Type

*** VP: Visual Properties

**** Dif: Differentiating, Des: descriptive, Dia: diagnostic

***** ICBC: Information Content (Entropy) Based On Categories (Bits)

Integrating themes in a raster map

All attributes are integrated into a raster map in vector format. The cells of the map serve as spatial integrators for the different information. For example, land cover information about urban land is expressed as the percentage of the cell covered with that category. This rasterizing technique is also useful to transform qualitative attributes into numerical ones, which are assigned to each cell. The effect is also a smoothing of the crisp borders of the original map, depending on the size of the grid (grain, pixel) that is used. This is useful when the original theme has a continuous distribution in space, which was lost by representing it in a choropleth map.

A frequent cell size used in national typologies is one square kilometre. This is the case in the example of Belgium: the Lambert co-ordinate grid is used to integrate different surveys as for example in environmental monitoring. The cell size sets the grain or resolution of the final map (Burel & Baudry, 2003). It is commonly used in landscape monitoring (Bunce *et al.*, 2005). Simultaneously, the raster map serves as a spatial database: each cell is a record containing all available information. Not only are the differentiating attributes used, but also the descriptive and diagnostic ones are included in the database.

Analysing relationships between differentiating attributes

Differentiating attributes will define the landscape types and map units. A correlation matrix is used to analyse similarities between these attributes. Uncorrelated factors are extracted before defining the landscape types by clustering.

Typification of the raster cells

The cells of the raster map serve as cases for the clustering into landscape types. Because of their large number (31473), k-means clustering is necessary, which demands choosing to choose the number of types (clusters) to be defined a priori. This can be based upon the properties of the base maps, in particular the ones related to the information content, such as the number of categories in the legend and patches in the map. A land type is assigned to each cell in the raster map. Because of the artificial nature of the raster map, this does not result in a real landscape typology, but more in a typification of the raster cells resulting in patterns. Landscape metrics can be used to characterise these patterns and describe their properties. Finally, attributes can be selected to create indicators that can be used in a diagnostic way.

Visualisation of the typology map

For the final cartographic representation, colours were assigned to the square kilometre cells according to the visual properties of each landscape types. These visual properties were derived from the attributes in the database. The result is a map which expresses the main visual properties associated with each cell: urban, industrial, infrastructure, rural, forested, as well as flat or undulating land form and large and small landscape units (Fig. 3).

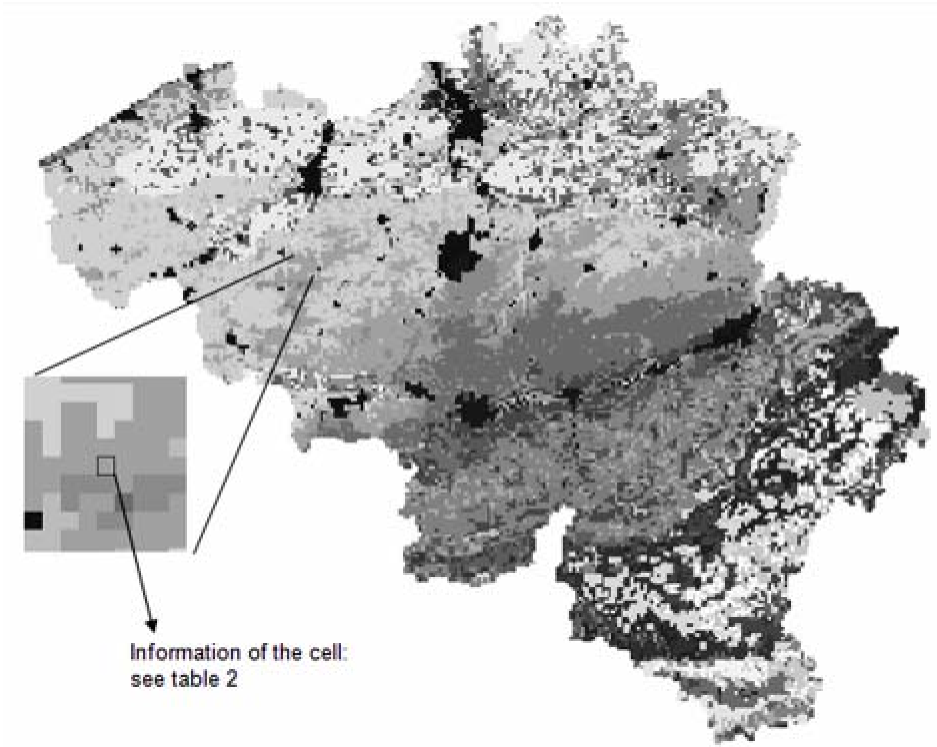

Figure 3: Grid based classification of the landscapes of Belgium, with an extract of a single cell (information in Table 2).

Table 2: Extract of the database information liked to the single cell of Figure 3.

THEME NAME (UNIT)	ATTRIBUTES - VARIABLE	USE *	VALUE
	ID of raster cell	Des	11097
	X coordinate in m	Des	237500
	Y coordinate in m	Des	170500
Land Cover (% / km²)	Urban fabric; artificial non-agricultural vegetated areas	Dif	3.57
	Industrial, commercial and transport units; mine, dump and construction sites	Dif	0.00
	Arable land; permanent crops; heterogeneous agricultural areas	Dif	96.43
	Pastures; natural grassland	Dif	0.00
	Forest and semi-natural areas; inland wetlands	Dif	0.00
	Wetlands; water bodies; open spaces with little or no vegetations	Dif	0.00
Soils (%/km²)	Polders	Dif	0.00
	Alluvial	Dif	0.00
	Sandy	Dif	0.00
	Loamy	Dif	100.00
	Skeletal	Dif	0.00

	Steep	Dif	0.00
	Sandy and clayish	Dif	0.00
	Peat	Dif	0.00
	Not mapped	Des	0.00
Elevation (m)	Minimum altitude	Des	77
	Maximum altitude	Des	92
	Range of altitude	Des	15
	Main Altitude	Dif	84.14
	Variation of altitude	Des	17.04
	Relief Variation	Dif	4.13
Heterogeneity (-)	Heterogeneity satellite image	Dif Dia	2.86
Visual properties	Urbanization	Dif	3.57
(% / km²)	Openness	Dif	96.43
Forest on historical maps (% / km²)	Area forest pre-industrial period (1775)	Des	0.00
	Area forest industrial period (1860-1880)	Des	0.00
	Area forest actual period (1990)	Des	0.00
Settlement properties (-)	Corrected shape index	Dif	1.32
	Eccentricity index	Dif	6.74
Age of building (% / km²)	Houses build before 1900	Dif	9.32
	Houses build between 1900 and 1918	Dif	5.87
	Houses build between 1918 and 1945	Dif	12.04
	Houses build between 1945 and 1961	Dif	16.73
	Houses build between 1961 and 1971	Dif	13.76
	Houses build between 1971 and 1981	Dif	17.31
	Houses build after 1981	Dif	24.90

* Dif: differentiating, Des: descriptive, Dia: diagnostic.

CONCLUSIONS

Cultural properties are underestimated in most of the landscape typology, which are mainly based on the natural characteristics of the landscape. Mostly land cover is the only theme that describes the cultural component. One of the reasons is that maps and data that describe the cultural elements are difficult to deal with; they are small-scaled, generalized maps with large mapping units. The crisp borders in the maps cannot be observed in the landscape, but can influence the classification. The properties of the map themes, both with natural and cultural data, must be taken into account. Cultural map themes can be derived from thematic or historical topographical maps or can be based on statistical data or data derived from settlement analysis. The discrete data or data with crisp borders, like choropleths, must be transformed into a continuous surface. To combine and use them for creating a landscape typology and mapping, the transformed themes need to be in a similar format and with approximately similar information properties as the other themes used in the procedure.

In the method used to set up the landscape characterisation for Belgium, natural and cultural themes were added in a balanced way. The themes were transformed into continuous geographical surfaces if necessary and the attributes and variables were derived. This was achieved using a raster map where the cells (km^2) are used as spatial integrating units and linked to a database, which contains the different attributes. The distinction between the differentiating attributes, which will define the landscape types and map units, and additional descriptive attributes allows to include themes in the database which otherwise would be lost in the classification. Furthermore, some diagnostic attributes can be included, which can be combined to form indicators to describe the landscape character change.

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