Chapter 10
Identifying, Mapping and Assessing Landscapes

Abstract The complex, varied and continuous landscape can be understood better when classified in types and spatial units. The classification process comprises three phases: identification, assessment and monitoring. Several methods for identifying and mapping landscape types and regions have been developed for different needs. Typologies classify landscapes that are distinct from each other based on a set of differentiating attributes, irrespective their location or geographical context. A chorology defines and delineates spatial landscape units and orders them in a hierarchy according to scale. Two approaches are possible in landscape classification: by subdivision or descending and by aggregation or ascending. Subdivision often used a holistic method similar to photo-interpretation. Aggregation follows a parametric method where first basic units are defined using a selection of attributes, which are subsequently clustered. Combined methods are possible and are more flexible in combining diverse data sources in a multi-scale context using holistic and parametric methods alternatively. The focus of the inventory can be on natural landscape regions, functional-historical characteristics of cultural landscapes and mapping the landscape scenery and mindscapes. This demands appropriate methods and different ways of representing the results, such as landscape atlases and catalogues. Assessment involves assigning values with a specific goal in mind. Landscape character assessment has become a common approach in landscape policy. As landscapes are dynamic, changes need to be monitored and different methods have been developed for different purposes.

Keywords Inventory • Land evaluation • Landscape atlas • Landscape character assessment • Landscape observatory • Monitoring

10.1 From Identification to Monitoring

Article 6 of the European Landscape Convention (Council of Europe 2000) lists the specific measures to be taken to realise the aims of the convention. The third one describes a huge task of identification and assessment "with a view to improving knowledge of its landscapes":

M. Antrop, V. Van Eetvelde, *Landscape Perspectives*, Landscape Series 23,
DOI 10.1007/978-94-024-1183-6_10

a. (i): to identify its own landscapes throughout its territory;
   (ii): to analyse their characteristics and the forces and pressures transforming them;
   (iii): to take note of changes;
b. to assess the landscapes thus identified, taking into account the particular values assigned to them by the interested parties and the population concerned.

This implies defining and describing landscape types and spatial units. It means inventorying and mapping their characteristic in a dynamical way so the processes and forces changing the landscapes can be analysed and monitored. Next, each of the landscape units thus identified, need to be assessed in a participatory process involving all who are concerned.

This implies a series of methodological very different tasks:

1. Identification (inventorying and classification)
2. Assessing (including atlases)
3. Monitoring (including observatories)

Inventorying means essentially data collection about all aspects of the landscape and from any kind of source. *Classification* consists of analysing and ordering all collected information in a descriptive way (typology) and by mapping landscape units (chorology). Together these steps result in the identification of the landscapes that will be assessed and for which specific landscape quality objectives can be formulated. Monitoring covers both the 'natural' changes that go on as the effects of landscape planning and management.

10.1.1 Making Spatial Units

The geographical space is a continuum in which a variety of more or less well-delineated areas can be recognised. Land classification denotes the methods to order these spatial units for better understanding the landscape. Several classification systems have been developed according to the purpose the will serve and according to the approaches and methods used (Fig. 10.1).

Landscape classifications are made with a specific goal in mind. This can be for purely scientific purpose in order to obtain a deeper understanding of the different aspects of the landscape. Several thematic classifications will be necessary to cover the whole complexity of the landscape. Examples are the classifications of the geology, soils, landform, land cover and settlement systems. The classifications of landscape types and regions aim to make a synthesis. The land units or landscape units are then considered as holons and are hierarchically ordered. Classifications with a functional purpose serve specific applications. Typical are landscape assessments and classifications of land suitability. These can be policy supportive, such as Landscape Character Assessments.

An easy way to combine spatial, thematic and temporal observations is using a geographical data matrix (Fig. 10.2). Conventionally, spatial units form the rows

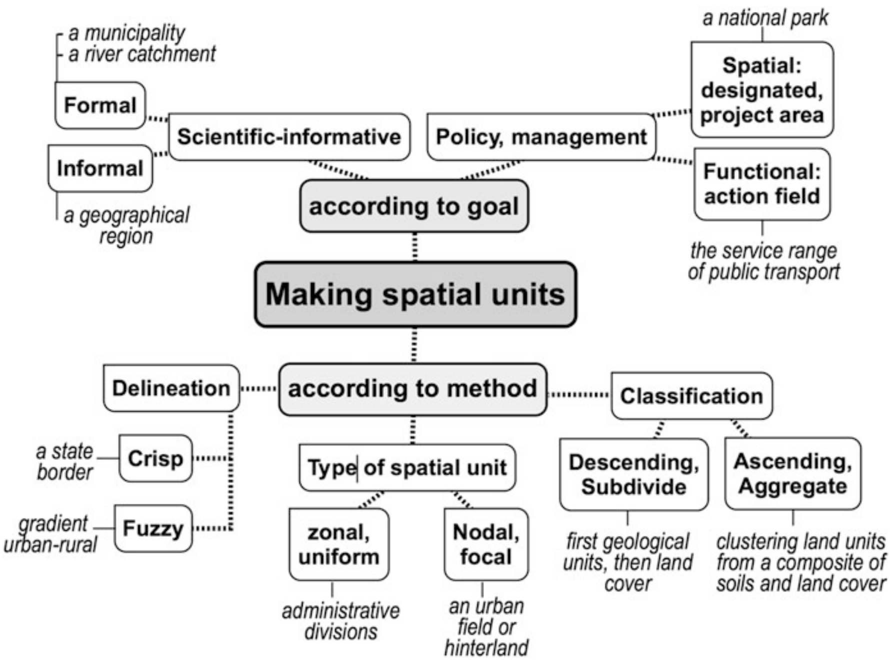

Fig. 10.1 Approaches and methods used in subdividing space

and their attributes columns. This allows a multivariate analysis using both the inter-variable covariance and the inter-object relationships (Davis 1986). Analysing the correspondence between the variables (rows) is similar to the approach in factor analysis, assuming that the variables are correlated with unknown underlying and uncorrelated factors in the data set and which can be extracted. In the context of landscape classification, one could say landscape types are like factors. The attributes and variables define also a thematic 'profile' for each spatial unit. The similarity between the 'profiles' allows grouping and defining spatial landscape units as regions. This can be done in hierarchical steps at different scale levels. Both ways of analysing the geographical data matrix allow two ways of classifying landscape units: typology and chorology. Comparing data on the time dimension allows defining landscape trajectories and paths as discussed in Chap. 7.

10.1.2 Typology and Chorology

Typology and chorology are two fundamentally different forms of landscape classification (Fig. 10.3). *Typology* is a classification of items into groups or types that are clearly distinct from each other according to the attributes used. It is a kind of generalisation as the groups or types refer to common characteristics. They can

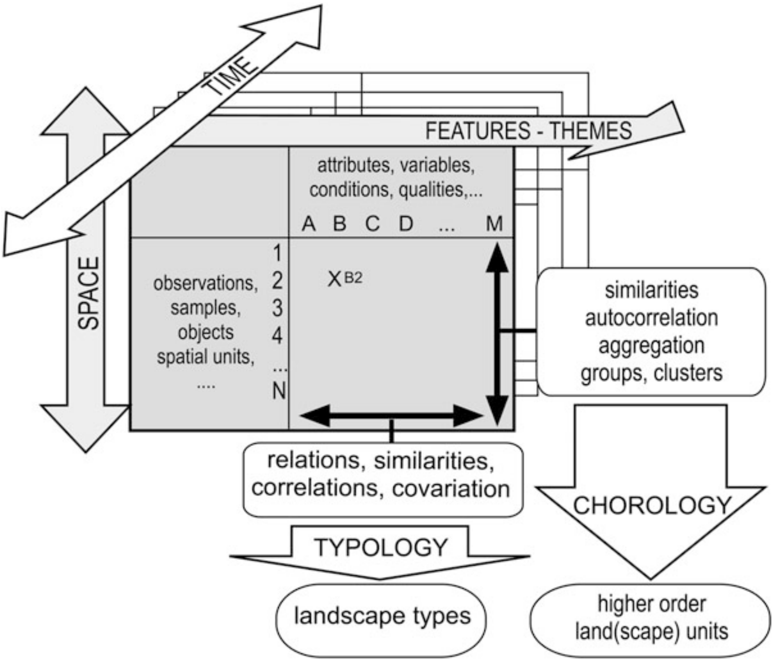

Fig. 10.2 The geographical data matrix combines three dimensions: space, time and feature-themes (feature space). Observed data are ordered for each time slice in a matrix combining spatial observations, samples, objects or spatial units with their characteristics measured by attributes (qualitative, categorical) and variables (quantitative). Comparing variables in columns allows to define relationships and types, comparing rows allows to define similarities between places and to define spatial units at different scales

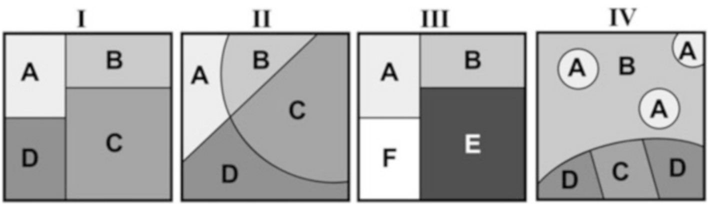

Fig. 10.3 Difference between typology and chorology. A, B, C, D, E, F are landscape types. I, II, III, IV are regions. The same landscape types can occur in different spatial context. Chorology is defined by the combination of types and spatial configuration. Regions I, II and IV are composed of the same landscape types A, B, C and D and have the same typology. However, their spatial configurations are different, which defines a different chorology. Regions I and III have the same spatial configuration, but they are composed of different landscape types, both regions are chorologically different

be considered generic ‘idealised types’ or models of the items at a higher level in the classification. Zonneveld (1995) speaks of ‘typification’ or non-spatial classification.

Typology works differently for discrete objects and continuous features. A typology of discrete objects is sometimes called categorization and often uses qualitative attributes. For continuous features, such as slope, water tables, etc., there is a fuzzy or gradual transition from one 'type' to another (e.g. from a gentle to a steep slope). In order to map the different types as spatial entities, differentiating attributes must be used and classes must be defined. This can be done in different ways and use different methods according to the properties of the attributes used. For example, the results will be different when the slope degree is measured on an ordinal scale using categories as 'flat', 'gentle', 'moderate' and 'steep', or measured in degrees or percentage. The number of classes and the methods of assigning values to classes must be chosen. Thus, different classifications are possible for one item and also for landscape types in one area.

Typologies are often hierarchically structured into as system defined by the level of generalisation or scale. Often criteria are used successively, meaning they get a different significance or weight. Main and subtypes can be defined, as well as variants, complexes and associations.

Following groups of landscape typologies are common:

1. *a geomorphological typology* of 'natural regions', based on landform, geomorphological, geological and climatic processes and of different age;
2. *a functional-historical typology* of the cultural landscape: landscape types are defined by the history of occupancy by humans and the ways people organised the landscape. The functional aspect relates both to ecological, social and economic aspects;
3. *a visual-spatial/physiognomic typology* makes types based on perceptual, physiognomic and preferential properties. Criteria as openness, naturalness scale, variation, stewardship, order, tranquillity, etc. are used.

Chorology considers the geographical context the different landscape types are spatially arranged in and also relates to scale in a hierarchical topology. Combining different adjacent typological entities allow defining larger spatial units composed of complexes or associations at a higher scale-level. These are called chorological units (from Greek *khōros*, 'place, space'). The German geographer Ferdinand von Richthofen (1833–1905) regarded chorology as a specialisation within geography, i.e. regional geography, and his pupil Alfred Hettner (1859–1941) considered the study of regions as the main field of geography. However, ancient and humanist scholars already used the concept.

The difference between typology and chorology can be understood easily with the following example. *Polder* is a general generic term of a landscape type characterised as a low-lying tract of land enclosed by embankments (dykes) that forms an artificial hydrological entity. It is a landscape entirely created by humans and managed by water boards (Dutch '*waterschap*' or '*polderschap*'). Different types can be recognised according to the period of land reclamation and the technology used. Examples are polders formed by land reclamation along coasts or rivers, others are the result of draining lakes and another type is the result of landscape restoration after peat extraction. The earliest polders date from the eleventh century and were land reclamations in the Scheldt estuary in Flanders and The Netherlands. The technique rapidly spread and today polders are found all over the world. During that long history, technology improved and different types of polders emerged. Inundations also caused restoration and the creation of new polders. Consequently, different spatial arrangements of polders developed, forming unique landscapes, which are chorological distinct.

In the 1960s–1970s, the interest for regional geography and chorology declined, but other disciplines took over the chorological classification (see Chap. 2). First, it was used in land evaluation in developing countries and based on aerial photo interpretation (Mabbutt 1968; Mitchell 1971, 1973; Howard and Mitchell 1980; Zonneveld 1972; Zonneveld 1995; Pedroli 1983). Different methods were developed according to the research domain and goals: e.g. in geological engineering (Aitchison and Grant 1968), military terrain assessment (Webster and Beckett 1970), biophysical land surveying (Mitchell 1973), assessing land suitability, soil surveying and land use planning (FAO 1976) and even in economic assessment (Rossiter 1995). In this approach, mainly physical landscape components were used to define the spatial units; hence terminology as land evaluation or classification, terrain classification and land surface classification instead of landscape evaluation or classification. Nevertheless, the methods can be used for landscape classification as well.

10.1.3 Basic Methodological Approaches

Basically, two basic approaches are possible in land(scape) classification: by subdivision and by aggregation (Mabbutt 1968; Mitchell 1973; Zonneveld 1972, 1995, 2005). Zonneveld (1995) refers to descending and ascending classification. The approach of subdividing the study area follows a holistic method and originated from the observation of the landscape on aerial photographs (Troll 1939). The aggregation approach starts by defining basic units that are described by a predefined set of attributes, which are used to cluster them into groups that can be represented on a map.

10.1.3.1 Descending: The Holistic Landscape Classification – Subdividing the Whole into the Parts

With the holistic method, geographical space is subdivided by visually distinct units (Fig. 10.4). This is the approach used in air photo interpretation and is based on the Gestalt-capability of our perception to recognise complex patterns. The successive subdivisions create a hierarchical structure of land units. Heuristic methods of photo-interpretation can be used to reduce subjectivity by using keys and decision rules. Nowadays also semi-automatic or hybrid forms are possible where the digital image sources being processed by segmentation and pattern recognition software

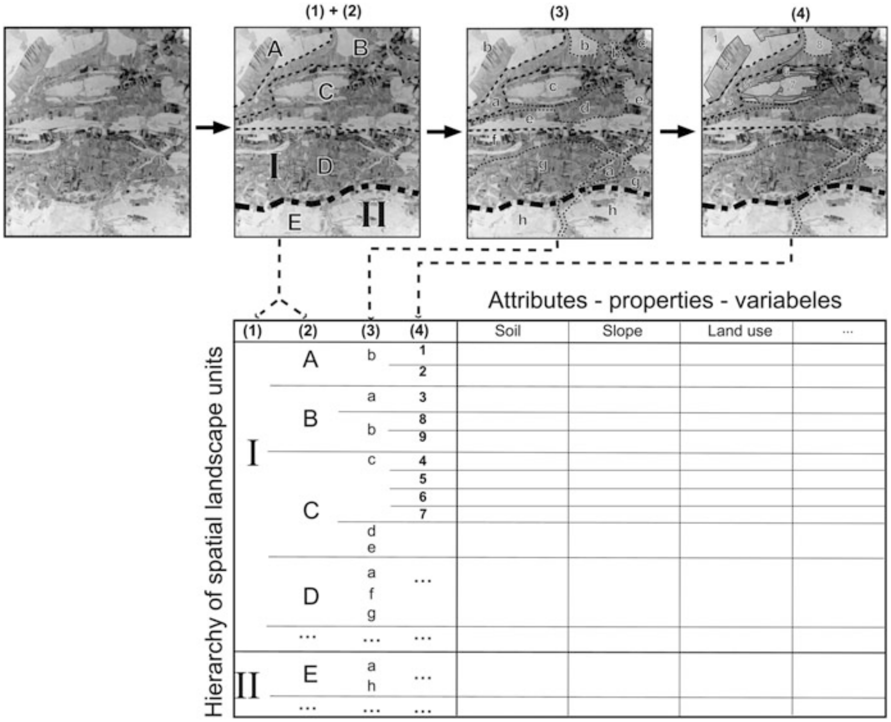

Fig. 10.4 The method of the holistic landscape classification using documents that give a synoptic view of the landscape such as aerial photographs or detailed topographical maps. Visual photo-interpretation allows delineating major landscape units which may be subdivided subsequently into smaller units (1–4) and described systematically in more detail and organised in a geographical data matrix

for automatic delineation of landscape units. The holistic landscape classification results in a zoning map with sharp boundaries. Gradients and fuzzy borders are not indicated in the delineation but can be represented as transition zones or described in the properties of the landscape units.

As the holistic method essentially based upon the knowledge and expertise of the interpreter, a certain degree of subjectivity is involved. Another criticism is that the resulting holistic landscape units are somewhat like *Pandora boxes* (Zonneveld 2005). However, the method has many advantages. Basically, it starts from a comprehensive observation of the landscape itself, indirectly by the aerial image and supported by field observations for building the interpretation key and eventually subsidiary maps. The method is fast to realise a classification covering the whole area of interest and allows dealing with inconsistencies, defects and all kinds of technical shortcomings in the data sources available for the classification. Once the spatial units are defined, a refinement of their delineation, content description is continuously possible.

10.1.3.2 Ascending: The ‘Parametric’ Landscape Classification – Aggregating Basic Units

The ascending approach first defines basic units using a set of attributes or, called in the old terminology of land evaluation, parameters (hence the ‘method of parametric land classification). These basic units can be used for typification (non-spatial typology) or can be aggregated to larger spatial units. There are different ways to define the basic mapping units. Most elementary, samples of point observations of different attributes are used to define types, from which spatial units are aggregated (Kilchenmann 1971, 1973). Somewhat similar is sampling raster cells in a regular grid overlaying theme maps or using grid cells or pixels in digital raster maps or images to define the types (Van Eetvelde and Antrop 2009).

However, most often, map overlaying is used to combine different thematic theme maps into a synthetic composite map, where the resulting spatial units (grid cells or polygons) are characterised by the joint properties of each theme used (Fig. 10.5). When thematic maps are available in digital format, this is easily done in GIS-overlay. In raster maps, each cell is described by a series of attributes in the linked attribute table and statistical analysis is further needed to define landscape types and to build land units. With vector maps, overlaying always results in a composite map composed of polygons that can be regarded as land units defined by the theme attributes used. However, also many meaningless sliver polygons are created as well (Delafontaine et al. 2009).

In many cases, existing thematic maps are combined, which means using data sources that are already the result of a complex and often not well-known processes of data collecting, interpretation and mapping procedures. Most often themes are chosen referring to the substrate (geology, parent material, soil conditions), landforms (elevation, slope degree and orientation), vegetation, land cover or land use. Some thematic maps can represent different attributes in a combined way: e.g. soils series represent unique combinations of attributes as parent material, texture, drainage and profile development.

Although the parametric method may seem more objective than the holistic method, a lot of subjective input and uncertainty is involved. The thematic base maps used as sources for the classification are already the result of a long map-making process. Differences in scale, accuracy, resolution, and time differences can complicate comparison and combination. Also, the map units shown do rarely define real terrain ‘objects’ or crisp borders but are the result of interpolation and cartographic trade-offs. Combining thematic vector maps in GIS also result in spatial units with crisp borders and creates many sliver polygons of which many are not relevant. A careful (visual) inspection is needed to see if they represent map errors and inaccuracies of corresponding to real gradients on the terrain. Anyhow, the result of automatic map overlaying always demands careful and critical interpretation.

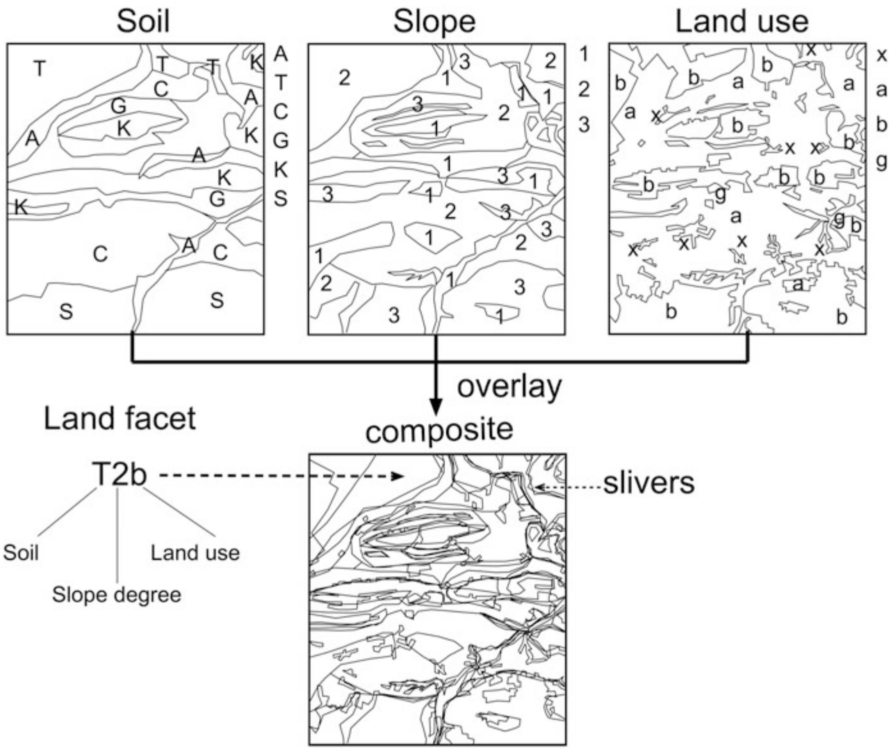

Fig. 10.5 The method of parametric landscape classification using basic units that are the result of overlaying thematic maps and then aggregated according to their properties. In this example, three basic map themes are used: the substrate, landform and land cover. On each theme, each map unit is described by an attribute code. After map overlaying, composite land units are obtained, characterised by the joint properties of the themes. These are clustered into types and adjacent spatial units can be aggregated to form larger spatial units

10.1.3.3 Combining Holistic and Parametric Methods

Van Eetvelde and Antrop (2009) used a combination of holistic and parametric approaches to make a landscape characterisation of Belgium at two scale levels (Fig. 10.6). The method also used square cells to sample a series of base map of varying scales, properties and qualities, a method introduced by Kilchenmann (1973). The use of raster cells (as vector polygons) not only allows integrating map themes with different forms of representation but allows also to integrate different scales. This was essential in making a landscape characterisation at the national level in a federal state as Belgium, as the number of datasets at the federal level is limited and most landscape classifications are based on maps having an extent at the regional level, as landscape planning and protection is the competence of the regions. The methods allowed inter-regional integration to realise a national overview (Van Hecke et al. 2010).

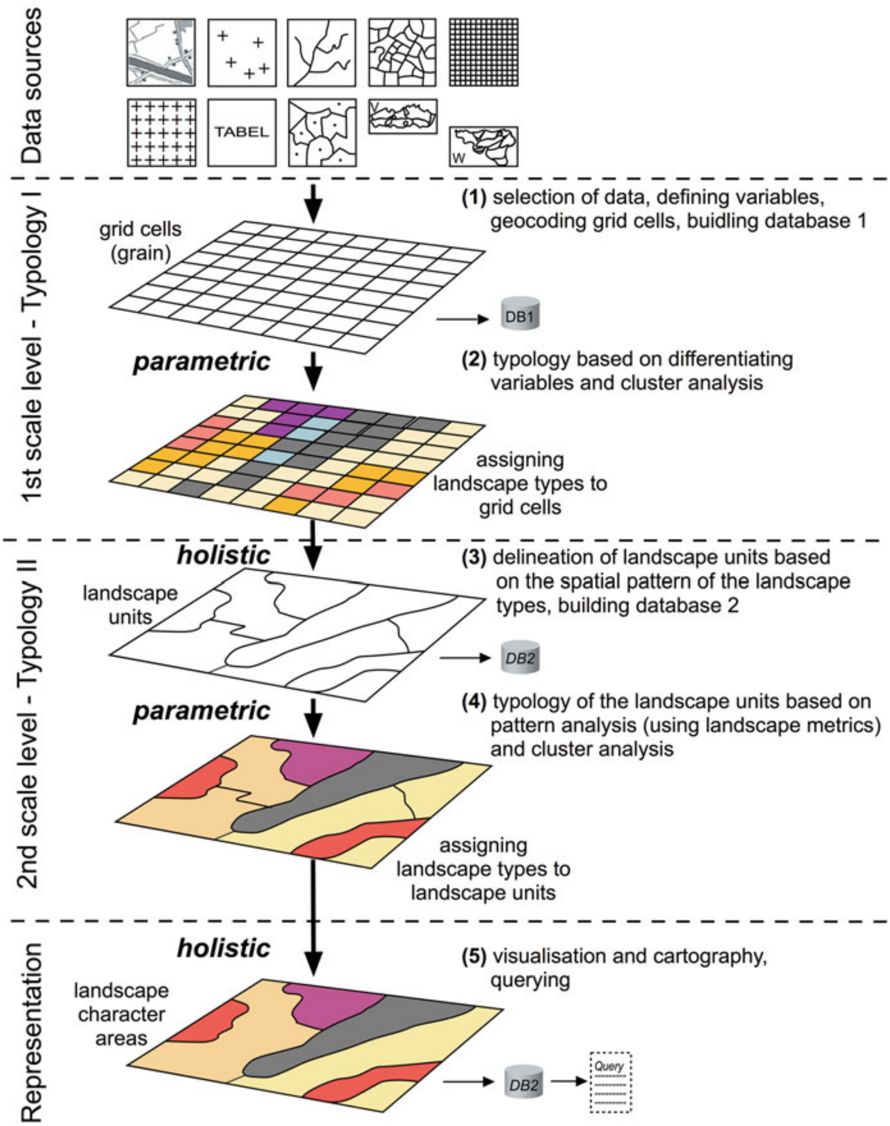

Fig. 10.6 The stepwise method of landscape classification at two scale levels using cells as basic units to typify landscapes and combining parametric and holistic methods (Van Eetvelde and Antrop 2009)

10.1.4 Adding the Third Dimension

Terrain elevation and landform are essential variables in any kind of landscape classification. Today, Digital Elevation Models contain the basic altimetric information, which can be used to derive various properties describing the landform, such as slope degree and shape. Burrough (1986) defined a Digital Terrain Model (DTM) or Digital Elevation Model (DEM) as "any digital representation of the continuous variation of the relief over space". To create a DEM, different solutions are possible according to the data properties, the data format and structure in the GIS and the objectives of the study. Basically, three formats of digital models are used and each has different characteristics in data storage efficiency and accuracy in representing the relief. *Contour lines* can be interpolated from point data but are the least efficient to store and manipulate data. However, they give the smoothest representation of the landform. *Triangulated Irregular Networks* (TINs) represent the surface by a set of contiguous and non-overlapping triangles connecting the original data points. The TIN model fits triangular polygons to land facets and calculates automatically slope angle and slope orientation for each triangle. They have quality properties between GDEM and contour lines (Ramirez 2006). *Grid Digital Elevation Models* (GDEMs) represent the relief as a two-dimensional regular grid whereby each grid cell contains one elevation value. This format is the simplest and most efficient in terms of storage. GDEMs allow easy manipulation of the resolution and a broad range of spatial analysis procedures are available. However, they are relatively poor in visualising the relief.

Since the 1980s Airborne LiDAR technology is used to create detailed digital elevation models (Ackermann 1999; Drosos and Farmakis 2006; Liu 2008). LiDAR is an active remote sensing technique for laser altimetry. It registers x-, y- and z-coordinates of sub-randomly distributed terrain point data. An advantage of LiDAR altimetry is that it also penetrates vegetation and allows acquiring ground level points. The raw LiDAR data give the terrain elevation when the laser beam reaches the ground, but also any object such as vegetation and buildings. This is called the *envelope elevation model* of the actual terrain. Various filtering methods are used to separate vegetation and obstacles points and ground points, so also a DEM of the ground level points can be created, although some filtering artefacts remain (Crutchley 2009; Liu 2008).

Because only coordinates are provided and no object information is given, the raw data have to be interpreted as an aerial photograph. However, the exceptional planimetric accuracy at centimetre level and the very dense scan pattern allows identifying small landscape elements. LiDAR-DEMs are used in a broad range of applications, such as geomorphological research (Kasai et al. 2009), coastal zone monitoring (Fernandes da Silva and Cripps 2011; Lohr 1998; Mutlu et al. 2008; Saye et al. 2005; Utkin et al. 2002; Zhou and Xie 2009), forest fire management (Mutlu et al. 2008; Utkin et al. 2002), infrastructural and environmental projects (Challis et al. 2008; Wehr and Lohr 1999) and in landscape archaeology (Bewley et al. 2005; Challis 2006; Devereux et al. 2008; English Heritage 2009, Gallagher and Josephs 2008; Harmon et al. 2006; Powlesland et al. 2006; Gheyle et al. 2014).

The first example (Fig. 10.7) shows a LiDAR DEM overlaid with a historical topographical map of 1909. The contour lines of the map were drawn from triangulated elevation points during the terrain survey. The result is a smoothed topography depending on the equidistance of one meter between the contour lines.

Fig. 10.7 LiDAR-GDEM overlaid with a historical topographical map of 1909. The LiDAR data have an average sampling density of 1 point/2 m^2, resulting in an altimetric accuracy varying between 7 and 20 cm and a planimetric accuracy of 50 cm. The GDEM shows how fields are related to the micro-topography, revealing the artificial convex field topography resulting from digging drainage ditches at the borders and concentric ploughing, Artefacts from filtering out recent buildings are indicated by arrows (After Werbrouck et al. 2011, topographical background: historical Belgian topographical base map at scale 1:20,000, Dépot de la Guerre 1909, National Geographical Insitute)

The LiDAR point data were filtered to remove vertical objects as trees and buildings to obtain the ground surface with the height accuracy of 7–20 cm. The field borders and hedgerows of the map correspond in detail with the micro-topography, illustrating the accurate adaptation of the land use.

Analytical hill shading is a common technique to enhance micro-topography and small elements on planar LiDAR DEMs. The second example (Fig. 10.8) shows a LIDAR DEM map used to survey a battlefield from the First World War visualised with Sky-view factor technique based on diffuse illumination so all directions are enhanced equally (Zakšek et al. 2011; Kokalj et al. 2011). This allowed detecting buried field structures and small above-ground features such as shell holes, traces of

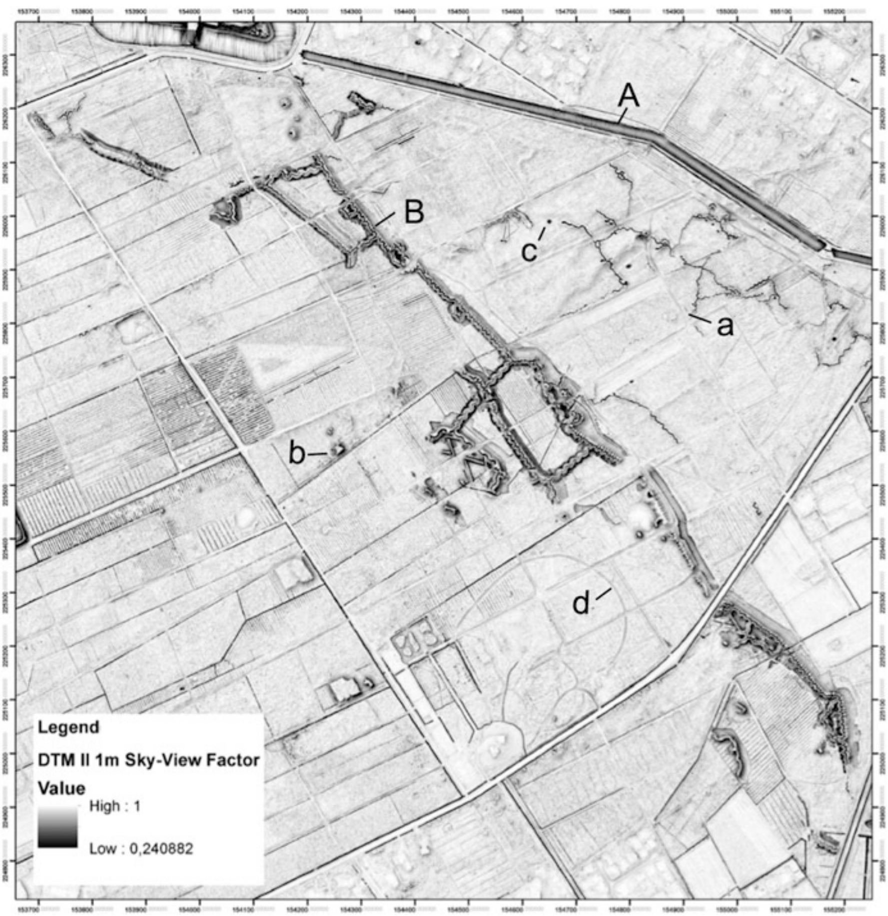

Fig. 10.8 A hill-shaded LiDAR-DEM of the battlefield of the First World War north of Antwerp (Belgium). Diffuse hill shading reveals old buried field structures, above-ground features such as shell holes, remains of narrow-gauge railways and trenches that are not visible on the aerial photographs. A: anti-tank ditch, B: defence line 1917, (**a**) tranch, (**b**) bunker, (**c**) shell hole, (**d**) trace of a narrow-gauge railway (After Gheyle et al. 2014)

narrow-gauge railways and trenches that are invisible on the aerial images taken during the Great War (Gheyle et al. 2014).

10.1.5 Dealing with Borders

The borders between landscape features can be crisp or fuzzy gradients, tangible of immaterial as many administrative divisions. Overlaying thematic maps generates many sliver polygons of which many have no significance. Some borders or

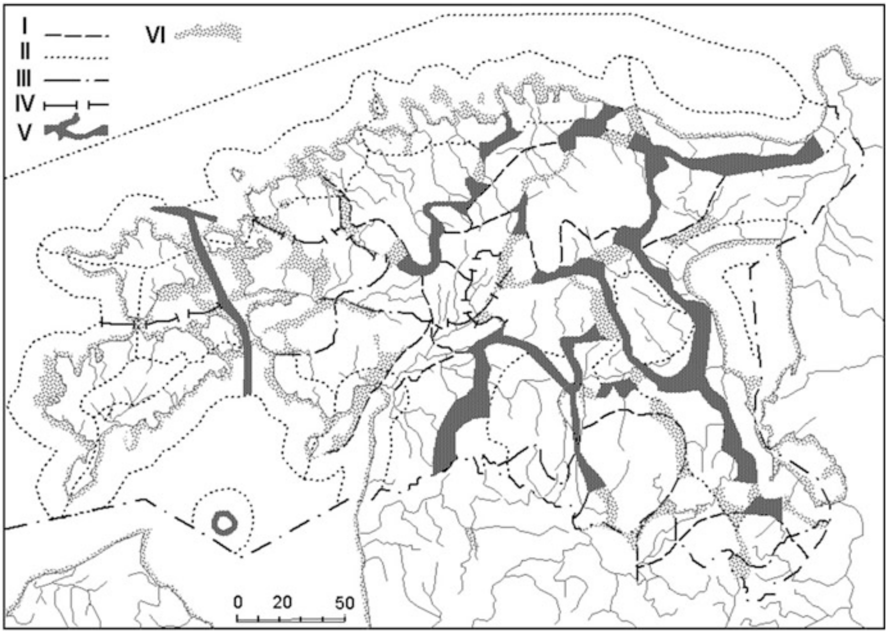

Fig. 10.9 Geographical regions of Estonia with transitional borders as defined by thematic map overlaying. Borders become transitional zones when the differentiating themes (*I–IV*) do not overlap within a width of 10 km. When three or four themes change, the border zone (*V*) gives a stronger differentiation between de adjacent areas than when only two themes change (*VI*) (Granö 1929, 1952; Granö and Paasi 1997)

transitions are important, others are not. Tracing borders of map units is always a risky decision. Delineating geographical regions is a problem from the beginnings of landscape science. Already in 1929 Johannes Granö (1929, 1952, Granö and Paasi 1997) formulated a method to delineate geographical regions by overlaying thematic maps, using the sliver polygons to define core areas and transitional borders (Fig. 10.9). Granö called the themes elements and the spatial units regions. The area where all theme units overlap forms the core of a 'pure' region. He defined also transitional zones when the width of the 'slivers' formed by the borders of the themes exceeds 10 km.

10.1.6 A Hierarchy of Landscape Units

As landscape elements and spatial units vary in size, there is an optimal scale to view them in a comprehensive way. Zooming in and out is a common practice to obtain a better understanding of the landscape structure. Forman and Godron (1986) referred to the technique of *shuttle analysis*. The classic method in geography to represent chorological classifications is using different map scales. This follows entirely the idea of a hierarchical structure of embedded holons (Naveh and Liebermann 1994) (see Chap. 5).

A great variety of hierarchical land classification systems has been developed in regional geography and later in land evaluation. Terminology and map scales for representing the hierarchical units varied widely. Several extensive overviews have been given (Mabbutt 1968; Mitchell 1973, 1991; Zonneveld 1972, 1995, 2005; Stewart 1968; Fernandes da Silva and Cripps 2011). The spatial units that are represented on maps are called land units according to many methods of land classification or land evaluation. They are considered as holistic 'black boxes' (Zonneveld 2005). In geography, these units are referred to as landscape units, which is more appropriate considering the descriptions at various scale levels. Jongman and Bunce (2000) considered the traditional landscape classifications qualitative and intuitive and suggested they could be improved by using quantitative classification methods from ecology.

Table 10.1 gives a synopsis of the most common units and their logic to structure them hierarchically. Note that all scale limits are approximated. Table 10.2 gives a brief overview of classification systems that were common in the early days of land evaluation.

The smallest unit is called *ecotope, geotope, site* or *land element*. Essentially this is the smallest area that will be observed and its size also depends on the measurement to be made, e.g. a slope degree. In soil science, this corresponds to the concept of a *pedon*, which corresponds to 1 m^2 and a depth of 1–2 m. For land cover, this corresponds to a field or area with a homogeneous land cover type.

A *land facet* is usually defined as a homogeneous spatial unit characterised by slope, soils and land cover. Examples are meadows on flat alluvial soils, or woodland on steep, rocky slopes. Contiguous land facets form series can be arranged by topography and form a toposequence. Such a larger unit is called a *land catena*. In general, land facets and land catenas are not named but characterised by a code built from the attributes used to describe them (Fig. 10.10).

Contiguous land facets or *catenas* linked by horizontal relations define the functioning of a larger unit, called a *land system*. Examples are a river valley, a dune belt and a village territory. Landscape systems are often called according to the characterising landscape type or place. The term system is somewhat misleading since landscape units at all levels can be considered systems.

A *land region* is a unique geographical association of land systems. It has a distinct character and identity and often has a proper name.

Contiguous land regions that share a common genesis or history may form a *land province*. Many historical landscapes and counties belong to the level of a land province.

Land divisions are still larger grouping mostly corresponding to major geological structures as a tectonic basin or mountain belt.

Finally, *land zones* refer to large climatic and vegetation zones.

Table 10.1 A common hierarchy of land units

Land unit	Main characteristic	Scale of map representation
Geotope, site	Smallest tract of land allowing a description	> = 1:10,000
Land facet	Unique combination of slope, substrate (soil) and land cover/land use	1:10,000–1:50,000
Land catena	Toposequence of land facets	
Land system	Spatial and functional associations of land facet and/or -catenas	1:50,000–1:100,000
Land region	Unique spatial and geographical association of land systems	
Land province	Contiguous land regions with a common genesis or history	1:100,000–1:1,000,000
Land division	Large geographical units based on landform and geology	
Land zone	Climatic and vegetation zones	< 1,000,000

10.2 Landscape Identification

10.2.1 Atlases, Catalogues, Observatories

Identifying the landscapes is based on inventories of all data available about the landscapes. The data consist of descriptions, field observations, maps, illustrations, photographs and narratives. This information is ordered systematically in a landscape inventory, which is conceived for a specific scale and planning goals. Inventories use methods of landscape classification and exist in different forms.

Most of the information about landscapes at the national and international level is collected top-down by experts. To cover vast areas in a consistent way, inventories are based on available data that use a systematic description, i.e. maps with a comparable legend. As an example, we can mention the European landscape map (LANMAP2) (Mücher et al. 2003). General data about the physical environment such as geology, soils, terrain elevation and land cover are often available on a continental scale and allow transborder consistency in their legends. Land cover data are widely available with remote sensing imagery, allowing making regular updates. Often land cover is used as a proxy of the cultural features of the landscapes. This is the case for example with the European CORINE Land Cover data that are used and reused in various ways in agriculture, forestry and urban planning as well as for making climate scenarios. The complementary LUCAS-programme (Palmieri et al. 2011), based on stratified sampling, makes a clear distinction between land cover and land use to monitor changes between the main categories. Land cover is also a common theme that allows studying changes over vast areas. An example is the international *Land Use and Land-Cover Change*

Table 10.2 Comparison between selected hierarchical land classification systems

System	> = 1:10,000	1:10,000–1:50,000	1:50,000–1:100,000	1:100,000–1:1,000,000	< 1:1000 000
[a]CSIRO 1957	Site	Land unit	Land system	Complex land system	Compound land system
[b]DOS 1962	–	–	Land facet	Land system	Land region, province, division, zone
Troll 1963	Ökotop	Fliesengefüge	Naturräumliche Haupteinheit	Gruppen Naturräumliche Haupteinheiten	–
Vinogradov et al. 1962, Vinogradov 1966, 1976	Facies	Urochishche	Mestnost	Mestnost	Landscape
Nakano 1962	Landform type	Series	Association	Section	Province
[c]MEXE 1965	Land element	Land facet	=Land system	Land system	land region, province, division, zone
Neef 1967	Ökotop	Microchore	Mesochore	Macrochore	Megachore
[d]PUCE 1970	Terrain component	=	Terrain unit	Terrain pattern	Province
Zonneveld 1972	Ecotoop, site	Land facet	Land system	Landscape	–
Howard and Mitchell 1980	Land element, land clump	Land facet, land catena	Land system	Land region	Land province, −division, −zone
Fernandes da Silva-Cripps 2011	Land element; Land subfacet; Land clump	Land facet	Land catena	Land system	Land region; Land province; Land zone

After Vinogradov et al. (1962), Vinogradov (1966, 1976), Christian and Stewart (1968), Aitchison and Grant (1968), Beckett and Webster (1969), Howard and Mitchell (1973), Mitchell (1973, 1991), Pedroli (1983), Zonneveld (1995)
[a]CSIRO Commonwealth Scientific and Industrial Research Organization (Christian and Stewart 1968)
[b]DOS (Commonwealth) Directory of Overseas Surveys
[c]MEXE Military Evaluation Experiment (Beckett and Webster 1969)
[d]PUCE Pattern Unit Component Evaluation (Aitchison and Grant 1968)

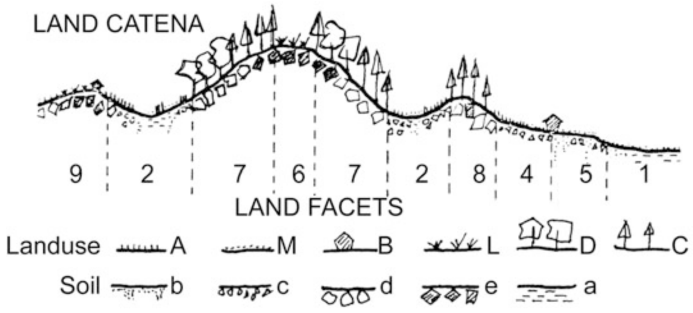

Fig. 10.10 A land catena consists of a series of land facets (1–9) organised by topography. Each land facet is defined by a unique vertical association of attributes, i.e. soil, slope and land use. *A* arable land, *M* meadow, *B* build land, *L* scrubland, *D* deciduous woodland, *C* coniferous woodland, *b* colluvium, *c* inceptisol deep, *d* inceptisol stony, *e* inceptisol shallow and very stony, *a* alluvium (Example Le Roptai catena in the Calestienne landscape region, Belgium, © M.Antrop)

(LULCC) programme in the framework of Global Change studies (Lambin and Geist 2006).

The spatial resolution of inventories on international (continental) scales is insufficient to represent individual elements of the landscape and data is often aggregated in abstract spatial units such as square kilometre cells. The goal is to compare and integrate countries and the results are used for international planning policies. The whole procedure is top-down and does not include public participation and the results are often difficult to interpret and for laypeople. At regional and local levels, landscape inventories need to be more detailed and concrete, complying with following:

- conceive public's participation from the beginning
- collect already existing, but partial and scattered information of all kinds already familiar to the local actors
- update data where necessary
- define a baseline, which can be used to compare different scenarios
- define a spatial reference frame to integrate all information and link comprehensive maps and visualisations
- clearly make the distinction between descriptive information and the valuation part

Many methods for landscape identification and assessment have been developed in a great diversity of approaches, formats, styles and names. Antrop (2004) gave an overview of landscape research in thirteen European countries involving making landscape inventories. Groom et al. (2006) made a methodological overview of existing classifications in Europe and how they used the approaches of Landscape Character Assessment. The conference Living Landscapes (UNISCAPE 2010) gave the state of the art 10 years after the European Landscape Convention was introduced. Most common is the *Landscape Character Assessment* (LCA), often based on the examples in England and Scotland (Swanwick 2004). Warnock and Griffiths (2015) describe how the process of landscape characterisation developed in LCA and has been refined in the Living Landscape Project. In non-English speaking countries concepts as landscape 'observatories' (*observatoire du paysage)* and landscape 'catalogues' are used, which mean more than just an inventory, but refer to a whole system of landscape assessment and monitoring changes. The *Landscape Catalogues of Catalonia* is a good example (Nogué et al. 2016). In the Netherlands, the concept of a *landscape biography* (*Landschapsbiografie* or *Biografie van het Landschap)* was introduced, in particular in applied interdisciplinary research for heritage management (Kolen et al. 2015).

Three main types of landscape inventories can be recognised: the landscape atlas, the landscape biography or catalogue and landscape photography databases:

- *Landscape atlases* present all information in a series of thematic maps, often in a GIS-database and web-environment and are becoming more and more interactive.
- *Landscape biographies and catalogues* have the format of a regional monograph, integrating text, maps, photographs, figures, tables and bibliographic references.
- *Landscape photographic inventories* are databases of geolocalised photographs of selected spots to represent the different landscape types or regions. Often historical archive photographs are used and rephotographed to illustrate landscape changes. This can be the base for a photographic landscape observatory and to set up a monitoring system.

Probably the first example of a holistic landscape atlas is the Atlas of the Irish Rural Landscape (Aalen et al. 1997). It consists of a series of thematic maps combined with explanatory essays. In France, Yves Luginbühl (Luginbühl et al. 1994) proposed a method for the elaboration of landscape atlases on a regional basis. The approach is holistic and integrated and includes using map-based landscape classification, identification and characterisation, but also history and dynamics. Important is also the use of iconographic representations and participation of the local public. The method was promoted by the French Ministry of Ecology and Sustainable Development and applied in several French regions. It was also adapted for the landscape atlases of Wallonia in Belgium (see CPDT 2007–2012 http://cpdt.wallonie.be) and Catalonia in Spain (Nogué and Sala 2006; Nogué et al. 2016).

Various types of landscape atlases can be recognised. In the simplest form, they consist of a synthetic landscape classification map with an extensive description of the landscape units. Sometimes different 'layers' of the landscape are discussed separately. This type is often included as a theme in National Atlases. These national or regional classifications used different data sets, methods and landscape types, which make merging adjacent maps difficult or impossible, as was shown with the European Landscape Character Assessment Initiative ELCAI (Pérez-Soba and Wascher 2005). Exemplary is the case of Belgium, which almost disappeared in international overviews since it became a federal state and each region adopted its own landscape policy (Van Eetvelde and Antrop 2009). In most European countries, landscape policy became a responsibility of the regions, so the concepts and methods of landscape atlases vary accordingly.

Photographic inventories are collections of very diverse iconographic documents, which can be geotagged in various ways. They are often intended to study the history of a landscape by its visual representations or to build a base for monitoring landscape change. Specific methods and guidelines make that photographs are taken in a systematic manner, including metadata and eventually additional field information. Examples of elaborated methods are the Norwegian system (Puschmann and Dramstad 2003) and the French photographic landscape observatory (Observatoire Photographique Transfrontalier des Paysages 2008). Often, new photographic recordings are made on the location of historical archive photographs, such as postcards. Examples of such rephotographing are *Recollecting Landscapes* in Belgium (Uyttenhove 2006), the *Visual Monitoring of Finnish Landscapes* (Heikkilä 2007) and the photographic observatories of transborder landscapes in river basins, as for the Semois river between France and Belgium (Lobet et al. 2006) and the Transborder Observatory of the Regional Landscape Park of Hainaut. In France, a specific methodology was developed based on nineteen landscape itineraries in the whole country (MEEDDAT 2008).

10.2.2 Generic Traditional Landscape Types

Traditional landscapes refer to the pre-industrial and pre-urbanised landscapes, which have been shaped during centuries mainly by agrarian and pastoral communities (Antrop 1997). Their spatial organisation shows a great ecological coherence and strong relations exist between substrate, soil, landform, land cover and land use. This makes that classifications of traditional landscapes closely follow the physical and natural qualities of the land, modified by cultural variations as differences in settlement patterns and field systems (see also Chap. 9). Traditional landscapes express regional character, culture and history, and different types can be recognised.

During the long history, landscapes were remodelled and adapted to changing natural conditions and societal needs. The landscape that we see can be compared to a *palimpsest* where older layers partially show through more recent ones (Claval 2005) (see also Chap. 7). Vos and Meekes (1999) proposed following succession:

- Natural/prehistoric landscape (from Palaeolithic till ancient Greek times)
- Antique landscape (from ancient Greek times till early Mediaeval times)
- Mediaeval landscape (from early Mediaeval times till Renaissance)
- Traditional agricultural landscape (from Renaissance till the nineteenth century, sometimes till today)

Table 10.3 Main groups of common historic-genetic traditional landscapes in Europe

Landscapes of agricultural land reclamation and development • Open field landscapes, champion landscapes • Polder landscapes, land reclamation on sea and rivers • Landscapes of peat extraction • Hedgerow/bocage landscapes, enclosures; ancient landscape • Landscapes of forest clearing • Mosaic landscapes (mixture fields, pasture and woodlots)
Landscapes of (animal) husbandry • Common pastoral landscapes – heathlands, wood-pastures • Enclosure-landscapes, enclosed common land • Mountain pastures of transhumance
Landscapes of Mediterranean polyculture • The *selva castanile* and *chataigneraie* • Montado – dehesa • Huerta • Irrigated/drained delta-landscapes • *Cultura promiscua*
Micro-landscapes • Estates, parks, gardens, . . . • The landscape settings of certain heritage • Monuments

- Industrial landscapes (mostly from mid-eighteenth till mid-twentieth century, in many places till today)

Particular in Europe, several historic-genetic landscape types have been identified (Table 10.3). Emanuelsson (2009), Butlin (1993), Lebeau (1979), Rackham (1986) and many others made typological classifications. For example, Lebeau (1979) recognised following rural landscape types in Europe (excluding the Soviet Union):

- Landscapes of enclosures and dispersed settlement, grasslands dominate
- Ancient open field landscapes with grouped settlement; evolved to dispersed settlement, field re-allotment and enclosure
- Landscapes of open fields with grouped settlement and large areas of cropland
- Open field landscapes transformed by collectivisation
- Reclamation landscapes of forest, heathland and marshland with linear settlement and stretched fieldstrips
- Open Mediterranean cropland, eventually with arboriculture, small patches of huertas and clustered and dispersed settlement
- Landscapes of *coltura promiscua*
- Estate landscape of montado and dehesa

Generic landscape types are holistic and can only be described fully by all composing characteristics including their relationship and development. For example, an 'open field landscape' consists of arable infields surrounded by extensively used outfields. Both are common lands for the community, which has specific property and use rights. Often the population lives in a clustered settlement in the centre of the territory, which was often a green-village type (see Chap. 9). The infields formed blocks of open cropland, i.e. without physical borders of hedges or ditches. The outfields were used as common grazing land. This type of landscape originated in the Middle Ages as a collective agricultural system based crop rotation around the centrally localised village. The oldest form was a two-field system, which used half of the land to grow crops, while the other half was left fallow to recover. To increase the production a three-field system was introduced. The land was divided into three fields: one-third lay fallow, one-third was sown in autumn with crops as wheat, and one-third was planted in spring with oats and legumes. The system became common in regions where there was sufficient rainfall during summer. The ownership of the fields was distributed equally over the infields. In continental Europe, the system of inheritance caused a continuous land subdivision of the properties resulting in narrow field strips arranged in blocks. Oliver Rackham called these landscapes 'champion' landscapes (Rackham 1986). In France, they are called 'campagne'. Land consolidation, up-scaling and mechanising of agriculture only kept the major structure of this type and many characteristic elements vanished or were transformed. In some areas of collectivisation, these historic field structures have been wiped away completely (Lipsky 1995; Palang et al. 2006), but the village structure remained.

Each place and landscape unit have a unique composition, configuration and history. For each, a unique narrative can be told. Generic landscape types aim to define the most common characteristics of landscape units that developed in a similar way and time period.

10.2.3 Mapping New Landscapes

It is not obvious to make a classification of the new landscapes that emerged with the industrialisation and urbanisation and which transformed, overlaid and eventually replaced the existing traditional landscapes. The resulting landscapes are eclectic complexes with mixed characteristics and many new elements and structures. The typical problem is demonstrated by the attempts of defining the landscapes of the urban fringe and 'rurban' landscapes (see Chap. 7). Vos and Meekes (1999) recognised following postmodern landscape types:

- the industrial production landscapes: landscape as an industry
- the overstressed multifunctional landscapes: landscape as a supermarket
- the archaic traditional landscapes: landscape as a historical museum
- the marginalised vanishing landscapes: landscape as a ruin
- the natural relict landscapes and new nature: landscape as a wilderness

Castells (2000) argued that our society develops as a network in which the relations are becoming less place-bound. Accordingly, Hidding and Teunissen (2002) recognised four interlaced networks that define the contemporary landscapes:

- The economic network in which accessibility is the most important factor. This network controls the development of the urban and industrial corridors.
- the transport network as the complex of all kinds transport and utility networks. Also referred to as 'grey' network
- the ecological network corresponds to the corridors greenways and open non-built land or 'green' network
- the water network or 'blue' network.

10.2.4 Mapping the Visual Landscape

Most landscape classifications result in maps, i.e. represent the landscape in a bird's-eye perspective. When dealing with properties that are specific for the horizontal, 'everyday' perspective of most people, the map representation becomes more abstract and alternatives have to be found. Besides mapping the visual landscape, also various forms of landscape visualisation developed, in particular for the purpose of planning, design and management (Nijhuis et al. 2011).

10.2.4.1 Mapping the Visual Landscape: The Beginnings

Granö (1929) gave the earliest examples of mapping perceptual properties of landscapes. De Veer and Burrough (1978) gave the first overview of methods used in The Netherlands for mapping the visual landscape or landscape physiognomy. They defined three approaches to the problem (Fig. 10.11):

1. The *compartment approach* makes a landscape classification using holistic methods and based on model 4 (see Chap. 8) for the analysis of landscape patterns, i.e. reducing the landscape to three primitives: masses, spaces and screens. This approach can start from field observations or analysis of topographical maps and aerial photographs. Space compartments are described by their size (area, defining the openness) and shape and the nature of their borders with masses (transparency).
2. The *field of view approach* is essentially field-based. The field of view is determined at regular or selected positions in the landscapes. The methods use sight lines to describe visual properties such as visibility, viewshed and openness.

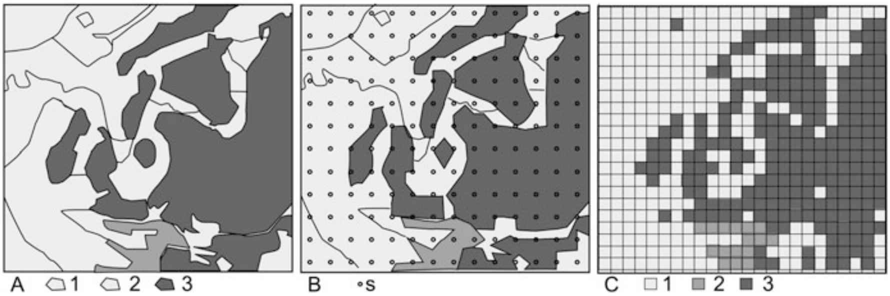

Fig. 10.11 Three mapping approaches for mapping visual landscape properties: (**a**) the compartment method, (**b**) the field of view method: the dots *s* are the viewpoints, (**c**) the grid cell method. (*1*) open spaces, (*2*) built zones, (*3*) vegetation masses

3. The *grid cell approach* samples the landscape by an overlay of a tessellation of cells for which variables that are significant for physiognomic properties. Most often a square grid is used overlaid on a detailed topographical map. Variables used are indicators of landscape diversity and complexity and expressed as landscape metrics.

Most of the early methods for mapping landscape physiognomy used field observations and analogue data sources as topographical maps and were very time-consuming and labour intensive. Using aerial photographs and terrain photographs (Palmer and Lankhorst 1998) allowed improving the efficiency through indirect analysis of visual features in the landscape. The development of GIS and spatial analysis rapidly allowed automated analyses of sight lines and viewsheds (Burrough et al. 1982; Burrough 1986; Tomlin 1990). However, detailed and reliable digital data were often lacking to obtain acceptable results.

10.2.4.2 The Impact of Digital Terrain Models and GIS-Analysis

New algorithms and better digital data, detailed digital elevation models (DEM), in particular, caused an exponential growth of the GIS-based analysis of the visual landscape and landscape visualisations (Nijhuis et al. 2011). New methods and concepts were introduced, e.g. using the space syntax introduced by Hillier and Hanson (1984). It refers to theory and methods for the analysis of spatial configurations and originally conceived for architectural design and analysing urban environments. Concepts related to spatial syntax are indicated with an asterisk* in following list, which gives a selection of the most important concepts in the GIS-based analysis of the visual landscape (Table 10.4). Note that some are not always exactly similar to the concepts used in perception studies as discussed in Chap. 6.

GIS allows the calculation of *viewsheds* or *isovists* for any point in a digital terrain model (Fig. 10.12). When more than one viewpoint is used, also the term

Table 10.4 Concepts related to the GIS-based analysis of the visual landscape

Axial line*	The longest sight line
Axial map*	Topological graph of a street or road network representing the longest and fewest axial lines
Central line of sight	The line of vision that bisects the view
Convex space	A space where all positions ('points') are visible for each other.
Isovist field	Cumulative field of isovists derived from multiple viewpoints
Isovist*	Sight field polygon representing the (eye-level) panoptical view from an observer at a certain viewpoint.
Obstacle or obstruction	Non-transparent volume or mass that limits the view.
Point depth analysis*	Delineating the degree of visibility from every point in the (public) space
Sight line	The direct line of vision between the observer's eye and a target object or point in space.
Transparency	Degree by which sight lines can penetrate obstructions.
View	The (composed) areas of the landscape covered by a horizontal, binocular field of vision with a given angle (usually varying between 20° and 60° angle)
Viewshed	The (GIS-)representation of areas of the landscape visible from one or more viewpoints.
Virtual 3D-landscapes	3D landscape representations created by computer modelling and rendering.
Visibilitime	View defined by a mobile observer and representing The time that points are visible.
Visibility	The geographical extent an object or an observation position can be seen.
Visible form	The visual appearance of the three-dimensional form (objects, volumes) in the landscapes and its relationship with the context space, expressed as the structural organisation.
Visualscape	The spatial representation of any visual property generated by, or associated with, a spatial configuration (Llobera 2003)

cumulative viewshed is used. The *total viewshed* refers to a cumulative viewshed using all points from the Digital Elevation Model (Llobera 2003). When viewsheds are combined by a logical function, the term *multiple viewshed* is used (Ruggles et al. 1993). Joly et al. (2009) make the distinction between the active and passive viewsheds. The *active viewshed* refers to the area that can be seen from a given observation position and corresponds to the prospect from that position; the *passive viewshed* corresponds to the area from where a given target can be seen and corresponds to the visibility of the target.

Properties of the viewshed and the viewpoint position can be used for a landscape character analysis reflecting the visual properties of the landscape. However, the reliability and validity of the outcome rely basically on the quality of the digital terrain model used.

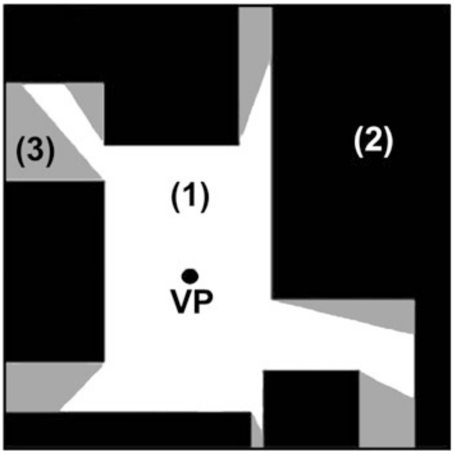

Fig. 10.12 The view and isovist concept: (*1*) view or isovist from viewpoint VP, (*2*) obstacle limiting the view, (*3*) part of the space not seen (*view shadow*) (After Llobera (2003))

Fig. 10.13 gives an example of the use of cumulative viewsheds calculated from the villages on the island of Paros (Greece). Note that the municipal boundaries follow approximately the watersheds and the high density of settlements on the eastern slopes of the island. Generally, about one-third of the municipal area falls in the viewshed of the village, but viewsheds extend over two to five other territories in the eastern part of the island. Nevertheless, the intervisibility amongst the villages is rather limited.

10.2.4.3 Analysing and Characterising the Visual Landscape

Ode et al. (2008) proposed visual landscape indicators in assessing the landscape visual character, which they define as "The visual expression of the spatial elements, structure and pattern in the landscape." (Ode et al. 2008, p. 90). They identified nine visual concepts that characterise the visual landscape and which are related to theories of landscape preference and experience: complexity, coherence, disturbance, stewardship, imageability, visual scale, naturalness, historicity and ephemera (Fig. 10.14) (see also Chap. 6). These concepts all refer to holistic aspects of the landscape structure. They are interrelated and some even overlap, while others are opposites. Similar concepts have different names in the literature (Tveit et al. 2006). For each concept, several indicators can be formulated using different kinds of data sets, dimensions of analysis and landscape attributes (Tveit et al. 2006). Ode et al. (2008) warn that the indicators should be used with great care as they make a reduction of the holistic experience observer's have of the landscape. They suggest an indicator selection ('filtering') based on criteria that identify indicators that are suitable for a specific project and landscape context. The filtering follows a sequence reducing the selection in each step: indicators should have a clear theoretical base, be transferable between landscapes, be quantifiable, mappable, available and relevant. Fry et al. (2009) demonstrated the common ground

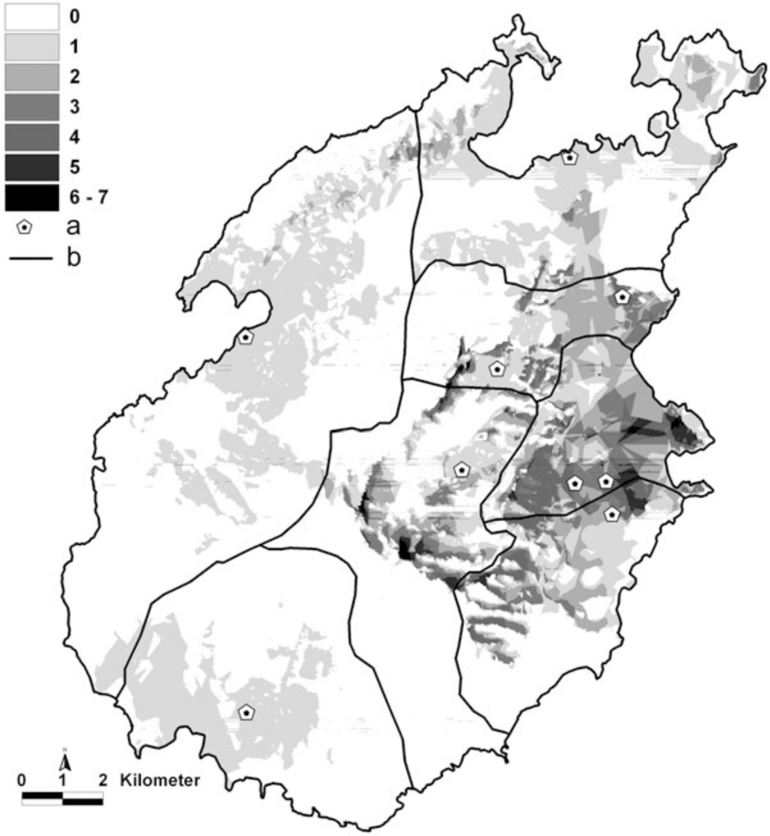

Fig. 10.13 Cumulative viewsheds from villages on the island of Paros (Greece): (**a**) village centre, (**b**) municipal boundaries. The visible area is *shaded* according to the number of times it is seen from one or more villages (After Sevenant and Antrop (2007))

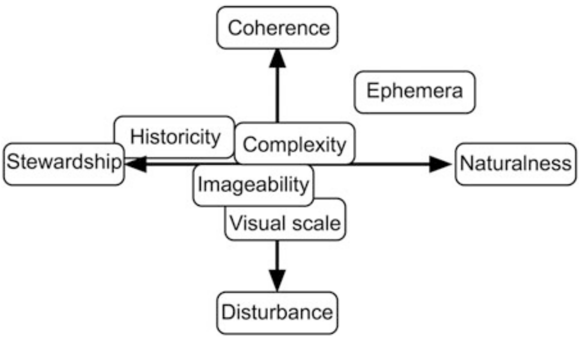

Fig. 10.14 Concepts characterising the visual landscape and their interrelations (After Ode et al. (2008))

between these visual landscape indicators and ecological landscape indicators. Tveit (2009) showed how two indicators of visual scale (percentage open land in the view and the size of the landscape rooms) predict the landscape preferences.

Nohl (2001) defined four aesthetically oriented prototypes of future landscapes: the traditional cultural landscape (based on the aesthetic category of ‘the beautiful’), the spontaneous landscape (based on the category ‘the (new) sublime’), the urban-industrial landscape (based on the category ‘the interesting’) and the rural functional landscape (based on the category ‘the plain’) (see also Chap. 6).

10.2.5 Mapping the Mindscape

In Chap. 8, we argued that *the map is not the landscape* but a representation affected by many choices made by the mapmaker. Maps are tools to visualise the landscape in a bird’s-eye perspective, to make immaterial phenomena and structures visible, and to communicate with others about the landscape. Maps represent material and intangible landscape features and use a specific graphical language. With geographical information systems and computer tools, mapmaking became easy for everyone. Non-cartographers often forget that some rules apply in good mapmaking. Abundant map producing making all possible combinations and using the default settings is not a good practice and does not help better understanding the landscape. It is easy to lie with maps, also by ignorance.

Mental mapping and *cognitive mapping* refer to methods of representing mindscapes in map form (Soini 2001; Gould and White 1974). From this perspective, *the landscape* ***is*** *a map* full of local knowledge and social values. This information is subjectively experienced, is different between insiders and outsiders, between lay people and experts. Social knowledge and values about the landscape are contextual, culturally-bound, place-related and vary spatially (Plets 2013; Tuan 1977). To capture this knowledge, active participation of the local inhabitants is essential (Sauer 1925). Basically, two approaches are used in mental mapping (Gould and White 1974). In one approach the participants draw map sketches of their landscape. The second approach is based on surveys using questionnaires to capture the cognition of the respondents in such way it can be located. Then, statistical trend surface analysis is used to create density maps of that knowledge. Besides using cognitive mapping in fundamental research on environmental perception and preference, it proved also useful in urban planning and design (Lynch 1960). The first approach led to the development of participatory mapping methods. With the help of GIS-functionality, it became easy to link local (mostly qualitative) and expert (quantitative) knowledge (Craig et al. 2002). Thus, *participatory geographical information systems* (PGIS) and *public participation GIS* (PPGIS) developed (Brown and Reed 2009) (see Chap. 12). Successful applications in transdisciplinary assessment of natural resources in rural communities (Fagerholm and Käyhkö 2009) and archaeological surveying for heritage protection (Plets 2013).

Corbett (2009) gave an overview of the methods of participative mapping, illustrated by cases of good practice. Following methods are ranked according to increasing IT-skills needed:

1. *Ground mapping*: a basic mapping method involving community members to draw maps on the ground using any available materials.
2. *Sketch mapping:* freehand drawings are made on large pieces of paper and from memory. They show the key features significant for the community and size and position reflects their importance. Hence, they do not rely on exact measurements, don't have a consistent scale and are not geo-referenced.
3. *Transect mapping*: a spatial cross-section of the community territory depicting geographic features along the transect (e.g. infrastructure, local markets, schools, land use and vegetation. Transect mapping can be done while walking and discussing with the locals.
4. *Scale mapping using existing maps*: a topographical map is used as a base map and elements are drawn on it as accurately as possible, allowing geo-referencing. Orthophoto maps, geo-referenced aerial photographs and detailed satellite imagery can be used for the same purpose.
5. *Using aerial and remote sensing images*: oblique aerial photographs and satellite imagery are not scale-consistent and geometrically distorted. Using these as reference base demands some help to interpret and precaution in using them.
6. *Scale mapping using survey techniques*: when no topographical maps are available, rudimentary maps can be made from scratch using surveying tools and GPS.
7. *Participatory 3-D modelling (P3DM)*: these are stand-alone three-dimensional relief models at a reduced scale. They are constructed from the contour lines on a topographic map and modelled using cardboard and paper-maché or foamed plastic. The model is finished with adding small elements and paint. The participation consists in making the model by the local community;
8. *GPS mapping*: a GPS receiver is used to capture the exact position of the features of interest. Coordinates are stored in a digital format to be used in GIS-mapping.
9. *Multimedia mapping*: the base maps are shown on a computer screen and interactively features can be added or additional information can be linked and consulted such as video, photos, text and theme maps (soils, geology, etc.).
10. *Participatory geographic information systems (PGIS*) are computer-based systems that capture, manage, analyse, store and visualise geo-referenced spatial information from a variety of sources. Specially trained PGIS practitioners from outside the community are needed to help the local community using the technology.
11. *Internet-based mapping* is similar to PGIS but uses web-based applications (e.g. Google Maps and Google Earth). The participation is less based on interactive communication with the local community (Figs. 10.15 and 10.16).

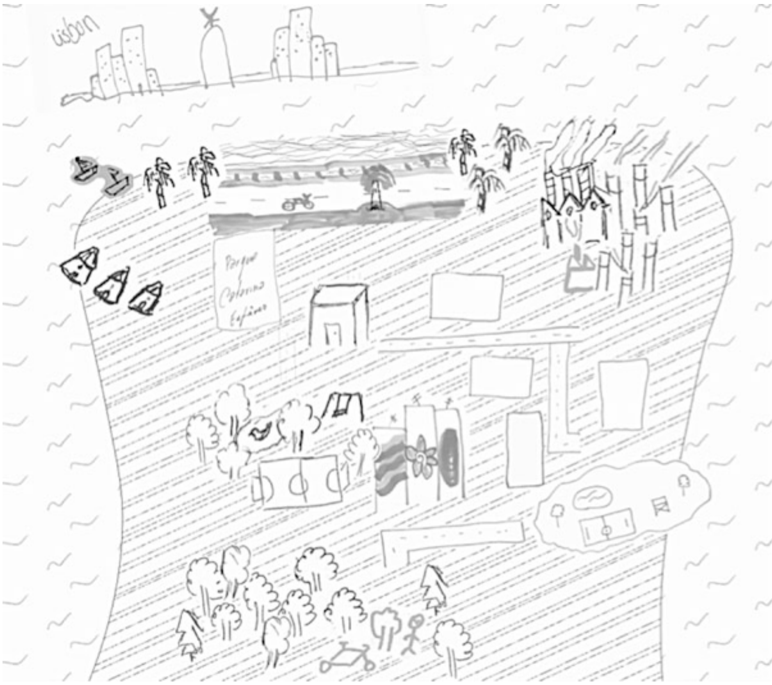

Fig. 10.15 Example of a mental map based on interviews using method 2 described above

10.3 Landscape Assessment

10.3.1 Attributes, Variables, Indicators and Criteria

Attributes describing properties of an item (element or spatial unit) are used to assign that specific item to a class. Formally this is done using techniques for clustering and ordination. Some landscape components are discrete objects; others are continuously varying (as landforms) (see Chap. 8). Some attributes describing spatial entities may have no spatial dimension. For example, architectural style, building height, age, function and condition may be significant to classify different buildings as discrete objects but have no spatial dimension. Vink (1980) and Kwakernaak (1984) defined different groups of attributes according to the ability to map spatial units and according to their purpose:

- *Differentiating attributes* are the ones used to define and delineate spatial units;
- *Purely descriptive attributes* are linked to previously defined spatial units and have no effect on their delineation;
- *Diagnostic attributes* are attributes used, eventually in combination, to formulate an indicator describing indirectly some characteristic. For example, age,

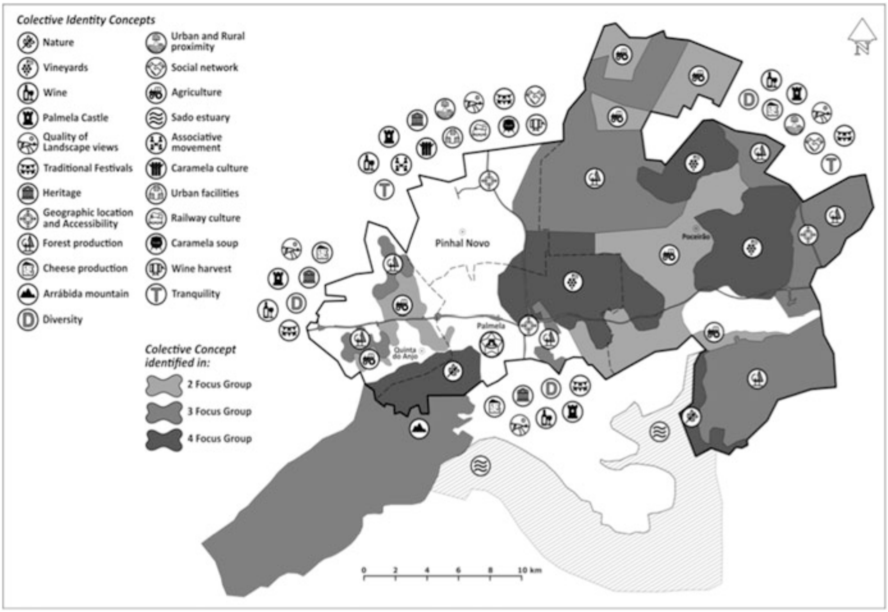

Fig. 10.16 Example of a collective participatory map identifying landscape elements important for the local identity, using methods 4 and 4 discussed above (Based on Loupa Ramos et al. 2017)

function and condition of a building can be used as an indicator to describe the degree of decay of a settlement.

The term *attributes* refers to qualities and used here in a general sense, covering all scales of measurement. Sometimes, it refers only to qualitative descriptions (the nominal or Boolean scale of measurement), while the term *variables* is used for quantitative attributes (measured on ordinal, interval and ratio scales). The term *criterion* is used to refer to attributes and variables that were selected for a multivariate analysis such as in multi-criteria assessment or clustering. Combined variables are referred to as *factors* or *indicators*.

The description of spatial entities with attributes is done systematically using a geographical data matrix (Fig. 10.2), which is consistent with database structures in GIS and matrices for statistical analysis: the spatial entities, places or objects form the cases (rows), and all attributes the variables (columns). These terms have different meaning according to the context they are used, in particular when combining applications in natural and social sciences, which is often the case in transdisciplinary landscape studies.

Attributes, variables, indicators and criteria are all used to describe landscape properties, characteristics and qualities. In landscape assessment, the English word quality is used in a neutral purely descriptive sense but may cause confusion when translated in other landscapes where it often gets a connotation of value (better-worse). Attributes and variables are sometimes used as synonyms, but also to

Table 10.5 Levels of measurement

Level of measurement	Properties	Examples/comments
1. Nominal	Assigning qualitative attributes to groups, determining equality of category. Counting frequency of items.	Land use categories, landscape types, LCA and HLC types and units, styles.
2. Ordinal	Ranking of classes using operators =, >, <; counting frequencies of classes	Slope classes: flat, gentle, steep
3. Interval	Measuring quantitative variables using an arbitrary zero and a scale with a constant interval: addition and subtraction arithmetic operators are applicable	Sometimes also referred to as scores. Negative values are possible, e.g. altitude, temperatures in °C or °F. the psychometric 5–point Likert-scale is considered as an interval level measurement
4. Ratio	Measuring quantitative variables using an absolute zero and a scale with a constant ratio between the values: all arithmetic operators allowed.	Distances, areas, temperature expressed in Kelvin

differentiate between qualitative and quantitative descriptions. An *attribute* is often intuitive and defined in a generic way. A *variable* needs to be operationalized by defining it formally and keeping in mind the further data processing, which mainly depends on the scale of measurement. The four levels of measurement define the types of mathematical and statistical analysis and the methods of combining measurements that can be made (Table 10.5).

In common meaning, also the term *parameter* is used as a synonym of variable, which is confusing in a mathematical or statistical context where variable and parameter have clearly a different meaning.

The concept *indicator* comes from environmental sciences and refers to a numerical value that helps to understand the state of the environment, ecosystems or human health. Indicators are quantitative variables measured over time to show the change of state of the environment at a predefined geographical scale. Often, series of indicators are needed to address the complexity of the environment. Also, an indicator can be constructed from a combination of standardised variables and is then called an *index*. Tracking over time made indicators much wanted instruments for policy analysis (Parris 2004) Ecological indicators are a specific subset of environmental indicators, as are agricultural and landscape indicators (Dramstad and Sogge 2003). Often, indicators are abstract and only partial expressions of complex holistic phenomena. To be useful for policy, indicators must be sensitive to detect significant changes, allow comparison between times and regions and link different scales. These conditions are rarely met and a lot of uncertainty remains in their interpretation.

Criteria are used in decision-making analysis, in particular in multi-criteria assessment or evaluation. A criterion gives some measure of a quality significant for the decision-making. Criteria describe properties and qualities in function of a selection or classification in a process of decision-making. Typically, multiple

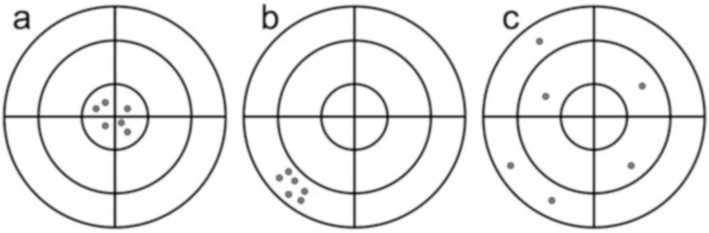

Fig. 10.17 The difference between accuracy and precision. The true value lies in the centre at the crossing of the lines. *Dots* represent measurements from a sample. The result (**a**) is accurate and precise, the result (**b**) is not accurate but has a high precision and result (**c**) is not accurate and not precise

conflicting criteria need to be compared and trade-offs need to be made, in particular when also multiple objectives or stakeholders are involved. Multi-criteria evaluation became a common technique in land evaluation and land use planning using GIS (Eastman et al. 1993). Often selected attributes and variables are transformed to make them useful in multi-criteria assessment procedures. Examples are reclassification and reordering values, transformation to Boolean variables, the use of thresholds and applying weighting procedures and error assessment (Fig. 10.17).

10.3.2 Assigning Values: What Is Significant and Important?

During the assessment phase, humans assign values to landscapes or elements of the landscape they consider important at the moment. Landscape evaluation methods have been initially based on land evaluation (Zonneveld 1995) but expanded when the participation of the public became important (see Chaps. 10 and 12).

When it comes to policy and planning, the expression of the values needs to meet particular requirements. First, the values are based on criteria that are a priori defined in policy, often as legal requirements. Criteria are variables that describe properties and qualities, which can be used for selection, classification or evaluation. Criteria or combinations of criteria can be indicative of the landscape properties that are not directly 'measurable', such as landscape character and other holistic properties. Some criteria are qualitative descriptions than can be used as guidelines, other are quantitative expressions using various levels of measurement, and some are expressed in monetary terms. Some criteria have a more technical meaning (e.g. class borders), some have a legal status, others describe specific landscape qualities.

Table 10.6 summarises commonly used criteria for the designation of sites and landscapes for heritage protection. Most often the criteria are generic and values expressed as qualities. The criteria used by UNESCO for nomination as World Heritage are an example of purely qualitative criteria (see also Chap. 12).

Table 10.6 Criteria used in the evaluation for heritage protection

Value of the site, landscape or landscape element
• *Intrinsic values*
– Natural
– Historical
– Cultural
– Aesthetical
– Symbolic
• *Context values*
– Site conditions
Scale of meaning or importance of the selected sites
• Local
• Regional
• National
• Universal
Functional meaning
• Actual use
• Potential use
• Restrictions and limitations in using the site
• Management goals for maintaining the values
• Spatial quality
Value expression
• Non-monetary, qualitative
• Monetary (e.g. value of the property)

Antrop (2004)

A second requirement is to combine related criteria in few synthetic and quantitative indicators. This is necessary to see if the policy decisions are effective and progress is made toward the intended goals (positive), or on the contrary negative effects can be detected. Table 10.7 gives an example of the requirements for policy-relevant environmental indicators formulated by the Organisation for Economic Co-operation and Development (OECD).

10.3.3 Landscape Character Assessment

The concept *landscape character* clearly refers to a holistic synthesis – a Gestalt – of all constituting components the landscape expresses in its appearance. Character is used here in a similar sense as a person's character. Landscape character became popular by the emphasis by the European Landscape Convention puts on the concept. A method for *Landscape Character Assessment* (LCA) developed in the UK (Swanwick 2002) as a framework for local and regional local stakeholders and authorities involved in a multi-scale and integrated planning, management and conservation in the context of sustainable development with a focus upon the

Table 10.7 Requirements of environmental indicators

Relevance
An environmental indicator must:
1. Provide a representative image of environmental conditions, the pressure on the environment and the social response;
2. Be simple, easy to interpret and able to show trends in time;
3. Be sensitive to changes in the environment and interrelated human activities;
4. Provide a basis for international comparison;
5. Be useable at both a national level and in issues of regional interest;
6. Be associated with a threshold or value of reference so the user can rapidly assess the determined level.
Analytical soundness
An environmental indicator must:
1. Be well defined from a theoretical point of view and in technical terms;
2. Be based on international standards and be validated at an international level;
3. Be ready for interfacing with economic models and territorial IT systems.
Measurability
The data necessary for the construction of the indicator must be:
1. Already available or obtainable at a reasonable cost/benefit;
2. Suitably documented and of a certifiable quality;
3. Revised at regular intervals in accordance with validation procedures.

After Dramstad and Sogge (2003)

countryside. Basically, LCA describes what is typical for a landscape rather than evaluating its qualities and no judgements are made in terms of suitability or utility. This is summarised in following four key concepts (Swanwick 2002):

- the emphasis is placed on landscape character;
- there is a clear division between the process of characterisation and the making of judgements to inform decisions;
- both objectivity and subjectivity occur in the process;
- there is a potential for application at different scales.

Basic concepts get specific definitions which are somewhat different from the terminology used in other systems of land(scape) classification and evaluation:

- *Character*: a distinct, recognisable and consistent pattern of elements in the landscape that makes one landscape different from another, rather than better or worse.
- *Characteristics*: elements, or combinations of elements, which make a particular contribution to a distinctive character.
- *Characterisation*: the process of identifying areas of similar character, classifying and mapping them and describing their character.
- *Elements*: individual components which make up the landscape, such as trees and hedges.

- *Features*: particularly prominent or eye-catching elements, like tree clumps, church towers, or wooded skylines.

The LCA distinguishes between landscape character types and landscape character areas. Landscape character types are distinct types of landscape that are relatively homogeneous in character. They share broadly similar combinations of geology, topography, drainage patterns, vegetation, land use and settlement patterns. However, also historic, aesthetic and perceptual aspects are included as well in the assessment. Landscape character areas are defined as single unique areas and are the discrete geographical areas of a particular landscape type. Each area has its own individual character and identity, even though it shares the same generic characteristics with other areas. This distinction is reflected in the naming of types and areas: landscape character types have generic names such as moorland plateau and river valley, but landscape character areas take on the names of specific places (Swanwick 2004). The character types and areas are defined at different, hierarchical scale levels, comparable with the hierarchical approach of the holistic classification method, but the main difference is that the scale levels are not defined by cartographic mapping scale, but rather by administrative and decision-making levels, ranging from local to national.

Although the LCA intended an integrated approach, another similar framework developed in parallel. English Heritage took the initiative for a *Historic Landscape Characterisation* (HLC) , with a focus on landscape characterisation for archaeological and historical aspects (Aldred and Fairclough 2002; Rippon 2012).

The work on landscape characterisation in the UK certainly inspired other countries in their implementation of the European Landscape Convention, in particular for inventorying their landscapes. However, most applications in landscape character assessment use specific methods developed at a national and even regional level. Consequently, assessments of landscapes between contiguous political regions rarely fit (Van Eetvelde and Antrop 2009; Mücher et al. 2003).

10.4 Landscape Monitoring

The landscape is dynamic and change is one of its fundamental characteristics. Concerning the handling of landscape change, article 6C of the European Landscape Convention refers to identification and assessment of the landscapes, including the analysis of "their characteristics and the forces and pressures transforming them" and "to take note of changes". Bunce et al. (2008) make a clear distinction between surveillance and monitoring. *Surveillance* is the recording of features at a specific location in one time frame, *monitoring* involves repeated observations allowing to detect changes. Hence, surveillance in this sense belongs to identifying the state of the landscape. Monitoring is one of the possibilities "to take note of changes". Monitoring landscapes is different from the study of their historical development, from the analysis of landscape paths and trajectories (see Chap. 7), although the past evolution helps to understand the processes and is significant for assessing the actual qualities. The purpose of monitoring is different and primarily aims to improve management decisions. Hutto and Belote (2013) used following practical and operational definition of long-term monitoring: "repeated field-based empirical measurements are collected continuously and then analysed for at least 10 years."

Many monitoring systems have been elaborated and most of them have a specific focus. A general distinction is made between passive and active monitoring. Passive monitoring aims to register any kind of changes. This is often the case when monitoring landscape changes. Active monitoring uses an experimental design to detect the effects caused by specific activities or decisions. This is the case of most ecological and land use monitoring systems.

The earliest monitoring programs related to the evolution of the biodiversity and focus on ecological processes and human impacts, which are often considered being negative. The list is long and no attempt will be made to give a complete overview. More interesting is the experienced gained so far. Long-term monitoring programs proved to have difficulties to endure. Lindenmayer and Likens (2009) list the deficiencies of long-term ecological research and monitoring programs suffer from so they fail or are ineffective:

- Mindless, lacking questions
- Poor experimental design
- Monitoring too many things poorly rather than fewer things well
- Failure to agree on what entities to monitor
- Flawed assumption that all monitoring programs can be the same
- Scientific disengagement from monitoring programs
- Poor data management
- Loss of integrity of the long-term data record
- Lack of funding
- Loss of key personnel
- Unexpected major event

Nichols and Williams (2006) made the distinction between targeted monitoring and surveillance monitoring, which, however, has a contradictory meaning compared to the definition of Bunce et al. (2008). Targeted monitoring comprises *a priori* hypotheses about system responses, which is not the case in surveillance monitoring. Targeted monitoring corresponds to what Hutto and Belote (2013) call question-driven and active monitoring, while surveillance belongs to passive monitoring. Here the purpose is to link the observed changes to particular activities using indicators describing their association. Many forms of monitoring land cover changes in agriculture and forestry attempt to do this in order to assess the effectiveness of policy decisions and measures (Parris 2003).

Adaptive monitoring has been proposed to improve the monitoring system in a changing context, allowing incorporating new questions, using new technology and data while maintaining the integrity of the core measures on the long-term

(Lindenmayer and Likens 2009). Hutto and Belote (2013) saw the improvement of monitoring programs in better formulating the basic questions and design.

The advances in landscape ecology made ecological monitoring to become 'monitoring at the landscape-scale'. This means a multi-scale approach in species and habitat monitoring and taking into consideration landscape characteristics as diversity, fragmentation and heterogeneity described by landscape metrics (see Chap. 8) (Jones 2011; O'Neill et al. 1997). Most common is using a stratified random sampling of test sites (Bunce et al. 2005; Brandt et al. 2002; Bunce 1984).

The fast and profound changes in our environment make that inventories always lack behind and it is not feasible the update them in real time. Hence, the necessity that monitoring systems should be fast in collecting, analysing and reporting data. The use of aerial photographs and remote sensing are straightforward since the resolution became satisfactory at the field/object level.

However, 'monitoring at the landscape-scale' is not a landscape monitoring. The landscape is much more than just a geographical matrix for species and habitats or economic production in agriculture and forestry. Landscape qualities also cover cultural and societal needs. When ecological monitoring provided solid methods in representative sampling and statistical analysis (Howard et al. 2004), monitoring the landscape as composed of holistic units demands more diversified approaches. This is well illustrated by the comparison of the strategic monitoring systems used in the Nordic countries, facing rather similar environments (Groom and Reed 2001). Also, the visual aspects of the landscape need to be included in landscape monitoring (Fry et al. 2009).

Photo-monitoring of the landscape uses terrestrial photography from fixed positions allowing making repeated registrations. Standardised methods have been developed to guarantee repetitive observations (Webb et al. 2010; O'Connor and Bond 2007; Dramstad et al. 2001). Terrain photographs also allow associating the view with landscape preferences (Dramstad et al. 2006). Concerning sampling the observation positions, several methods are used. Using fixed photo-points linked to stratified random sampling sites allows more comprehensive description of the test sites (Bunce et al. 2008; Dramstad et al. 2002). Alternatively, the fixed positions can be chosen based on a previous landscape classification or selected landscapes types or at frequently visited places, e.g. transects along routes and special viewpoints with special aesthetical qualities. Finally, also the positions can be chosen from historical photographs, such as old postcards, allowing 'repeat photography' (see Sect. 10.2.1) (Heikkilä 2007; Uyttenhove 2006).

References

Aalen, F. H. A., Whelan, K., & Stout, M. (Eds.). (1997). *Atlas of the Irish rural landscape* (352 pp). Cork: Cork University Press.

Ackermann, F. (1999). Airborne laser scanning – Present status and future expectations. *ISPRS Journal of Photogrammetry and Remote Sensing, 54*, 64–67.

Aitchison, C. D., & Grant, K. (1968). Terrain evaluation for engineering. In G. A. Stewart (Ed.), *Land evaluation* (pp. 125–147). Papers from the CSIRO- Symposium in co-operation with UNESCO. Canberra: Macmillan of Australia.

Aldred O., & Fairclough, G. (2002). *Historic landscape characterisation – Taking stock of the method*. The National HLC Method Review 2002, English Heritage & Somerset County Council. http://www.english-heritage.org.uk/content/publications/publicationsNew/hlc-taking-stock-of-the-method/hlc2titlepagecontents.pdf

Antrop, M. (1997). The concept of traditional landscapes as a base for landscape evaluation and planning. The example of Flanders Region. *Landscape and Urban Planning, 38*, 105–117.

Antrop, M. (2004). Landscape research in Europe: Editorial. *Belgeo, 2–3*, 199–207.

Beckett, P. H. T., & Webster, R. (1969). *Military engineering experimental esthablishment (MEXE) test report no.1123*. A review of studies on terrain evaluation 1960–1969. Oxford: Department of Agricultural Science.

Bewley, R. H., Crutchley, S. R., & Shell, C. A. (2005). New light on an ancient landscape; lidar survey in the Stonehenge World Heritage Site. *Antiquity, 79*, 636–647.

Brandt, J. J. E., Bunce, R. G. H., Howard, D. C., & Petit, S. (2002). General principles of monitoring land cover change based on two case studies in Britain and Denmark. *Landscape and Urban Planning, 62*, 37–51.

Brown, G., & Reed, P. (2009). Public participation GIS: A new method for national forest planning. *Forest Science, 55*, 166–182.

Bunce, R. G. H. (1984). *The use of simple data in the production of strategic sampling systems*. Roskilde University Centre, IALE, Proceedings of the First International Seminar on Methodology in Landscape Ecological research and Planning, theme IV (pp. 45–56).

Bunce, R. G. H., Groom, G. B., Jongman, R. H. G., & Padoa-Schioppa, E. (Eds.). (2005). *Handbook for surveillance and monitoring of European habitats*, *Alterra-rapport 1219* (107 pp). Wageningen: Alterra.

Bunce, R. G. H., Metzger, J., Jongman, R.H.G., Brandt, J., de Blust, G., Elena-Rossello, R., Groom, G.B., Halada, L., Hofer, G., Howard, D.C., Kovář, P., Mücher, C.A., Padoa-Schioppa, E., ., Paelinx, D., Palo, A., Perez-Soba, M., Ramos, I.L., Roche, P., Skånes, H., Wrbka, T. (2008). A standardized procedure for surveillance and monitoring European habitats and provision of spatial data, Landscape Ecology, 23, 11-25.

Burrough, P. A. (1986). *Principles of geographical information systems for land resources assessment* (193pp). Oxford: Oxford University Press.

Burrough, P. A., Buitenhuis, A., & de Veer, A. A. (1982). *Het informatiesysteem Landschapsbeeld*. Wageningen: Pudoc.

Butlin, R. A. (1993). *Historical Geography. Through the gates of space and time* (306 pp). London: E. Arnold.

Castells, M. (2000). *The rise of the network society*. Oxford: Blackwell.

Challis, K. (2006). Airborne laser altimetry in alluviated landscapes. *Archaeological Prospection, 13*, 103–127.

Challis, K., Kokalj, Z., Kincey, M., Moscrop, D., & Howard, A. J. (2008). Airhorne lidar and historic environment. *Antiquity, 82*, 1055–1064.

Christian, C. S., & Stewart, G. A. (1968). *Methodology of integrated surveys*. In *Proceedings of the conference on aerial surveys and integrated studies* (pp. 233–280). Toulouse: UNESCO.

Claval, P. (2005). Reading the rural landscapes. *Landscape and Urban Planning, 70*(1–2), 9–19.

Corbett, J. (2009). *Good practices in participatory mapping* (p. 55). Rome: International Fund for Agricultural Development (IFAD).

Council of Europe. (2000). *European landscape convention*. Firenze, 20.10.2000 http://conventions.coe.int/Treaty/en/Treaties/Html/176.htm

Craig, W. J., Harris, T. M., & Weiner, D. (2002). Community participation and geographic information systems. In W. J. Craig, T. M. Harris, & D. Weiner (Eds.), *Community participation and geographic information systems* (pp. 3–16). London: Taylor and Francis.

Crutchley, S. (2009). Shedding light on the past: Using airborne LIDAR to understand ancient landscapes. In O. Bender, N. Evelpidou, A. Krek, & A. Vassilopoulos (Eds.), *Geoinformation* *technologies for geocultural landscapes, European perspectives* (pp. 87–106). London: CRC Press.

Davis, J. C. (1986). *Statistics and data analysis in geology*. New York: John Wiley & Sons.

De Veer, A., & Burrough, P. (1978). Physiographic landscape mapping in the Netherlands. *Landscape Planning, 5*, 45–62.

Delafontaine, M., Nolf, G., Van de Weghe, N., Antrop, M., et al. (2009). Assessment of sliver polygons in geographical vector data. *International Journal of Geographical Information Science, 23*, 719.

Devereux, B., Amable, G., & Crow, P. (2008). Visualization of LiDAR terrain models for archaeological feature detection. *Antiquity, 82*, 470–479.

Dramstad, W., & Sogge, C. (Eds.) (2003, October 7–9). Agricultural impacts on landscapes: Developing indicators for policy analysis. In *Proceedings from the NIJOS/OECD Expert Meeting on Agricultural Landscape Indicators* in Oslo, Norway. NIJOS Report 7, 350 pp.

Dramstad, W. E., Fry, G., Fjellstad, W. J., Skar, B., Helliksen, W., Sollund, M.-L. B., Tveit, M. S., Geelmuyden, A. K., & Framstad, E. (2001). Integrating landscape-based values – Norwegian monitoring of agricultural landscapes. *Landscape and Urban Planning, 57*(3–4), 257–268.

Dramstad, W. E., Fjellstad, W. J., Strand, G.-H., Mathiesen, H. F., Engan, G., & Stokland, J. N. (2002). Development and implementation of the Norwegian monitoring programme for agricultural landscapes. *Journal of Environmental Management, 64*, 49–63.

Dramstad, W. E., Tveit, M. S., Fjellstad, W. J., & Fry, G. L. A. (2006). Relationships between visual landscape preferences and map-based indicators of landscape structure. *Landscape and Urban Planning, 78*(4), 465–474.

Drosos, V., & Farmakis, D. (2006). Airborne laser scanning and DTM generation. In: E. Manolas (Ed.), *Naxos international conference on sustainable* management *and development of mountainous and Island areas* (pp. 206–218). Greece.

Eastman, J. R., Kyem, P. A. K., Toledano, J., & Jin, W. (1993). GIS and decision making. *UNITAR explorations in GIS technology* (vol. 4, 112 pp). Geneva: UNITAR.

Emanuelsson, U. (2009). *The rural landscapes of Europe. How man has shaped European nature* (p. 383). The Swedish Research Council Formas.

English Heritage. (2009). *Aerial survey and investigation English heritage*. Available at http://www.english-heritage.org.uk/server/show/nav.8730 (1-09-2009).

Fagerholm, N., & Käyhkö, N. (2009). Participatory mapping and geographical patterns of the social landscape values of rural communities in Zanzibar. *Tanzania, Fennia, 187*(1), 43–60.

FAO. (1976). *A framework for land evaluation* (Vol. 32). Rome: FAO Soils Bulletin.

Fernandes da Silva, P. C., & Cripps J. C. (2011). Geo-environmental Terrain assessments based on remote sensing tools: A review of applications to hazard mapping and control. In E. Broniewicz (Ed.), *Environmental management in practice*. InTech, ISBN: 978-953-307-358-3. Available from: https://www.intechopen.com/books/howtoreference/environmental-management-in-practice/geo-environmental-terrain-assessments-based-on-remote-sensing-tools-a-review-of-applications-to-haza

Forman, R., & Godron, M. (1986). *Landscape ecology* (p. 619). New York: Wiley.

Fry, G., Tveit, M. S., Ode, A., & Velarde, M. D. (2009). The ecology of visual landscapes: Exploring the conceptual common ground of visual and ecological landscape indicators. *Ecological Indicators, 9*(5), 933–947.

Gallagher, J., & Josephs, R. (2008). Using LiDAR to detect cultural resources in a forested environment: An example from Isle ROYALE National Park, Michigan, USA. *Archaeological Prospection, 15*, 187–206.

Gheyle, W., Dossche, R., Bourgeois, J., Stichelbaut, B., & Van Eetvelde, V. (2014). Integrating *archaeology and landscape analysis for the cultural heritage management of a world war* I militarised landscape. The German field defences in Antwerp. *Landscape Research, 39*(5), 502–522.

Gould, P., & White, R. (1974). *Mental maps. Pelican geography and environmental studies* (p. 204). New York: Penguin Books.

Granö, J. G. (1929). Reine Geographie. Eine methodologische Studie beleuchtet mit Beispielen aus Finnland und Estland. *Helsinki, Helsingfors, Acta Geographica, 2*(2), 202 pp.
Granö, J. G. (1952). *Régions géographiques et une méthode pour les délimiter. Compte Rendu du XVIè Congrès International de Géographie*. Lisbonne 1949, 11 pp.
Granö, O., & Paasi, A. (Eds.). (1997). *Pure geography* (J. G. Granö, M. Hicks, Trans.) (19e1 pp). Baltimore/London: The John Hopkins University Press.
Groom, G., & Reed, T. (Eds.). (2001). *Strategic landscape monitoring for the Nordic countries, TemaNord*. Nordic Council of Ministers: Copenhagen.
Groom, G., Wascher, D., Potschin, M., & Haines-Young, R. (2006). Landscape character assessments and fellow travellers across. In: R. G. H. Bunce & R. H. G. Jongman (Eds.), *Landscape ecology in the mediterranean: Inside and outside approaches*. Proceedings of the European IALE Conference, Faro, Portugal, 29 March–2 April 2005 (pp. 221–231). IALE Publication Series 3.
Harmon, J. M., Leone, M. P., Prince, S. D., & Snyder, M. (2006). Lidar for archaeological landscape analysis: A case study of two Eighteenth-century Maryland plantation sites. *American Antiquity, 71*, 649–670.
Heikkilä, T. (2007). *Visual monitoring of Finnish landscapes*, *Photographic documentation of changes in cultural landscapes* (157 p). Helsinki: University of Art and Design.
Hidding, M. C., & Teunissen, A. T. J. (2002). Beyond fragmentation: New concepts for urban-rural development. *Landscape and Urban Planning, 58*(2–4), 297–308.
Hillier, B., & Hanson, J. (1984). *The social logic of space*. Cambridge: Cambridge University Press.
Howard, J., & Mitchell, C. (1980). Phyto-geomorphic classification of the landscape. *Geoforum, 11*(2), 85–106.
Howard, D. C., Petit, S., & Bunce, R. G. H. (2004). Monitoring multi-functional landscapes at a national scale – Guidelines drawn up from the Countryside Survey of Great Britain. In J. Brandt & H. Vejre (Eds.), *Multifunctional landscapes. Theory, values and history* (Vol. Vol. II, pp. 3–18). Southampton: WIT Press.
Hutto, R. L., & Belote, R. T. (2013). Distinguishing four types of monitoring based on the questions they address. *Forest Ecology and Management, 289*, 183–189.
Joly, D., Brossard, T., Cavailhes, J., Hilal, M., Tourneux, F. P., Tritz, C., & Wavresky, P. (2009). A quantitative approach to the visual evaluation of landscape. *Annals of the Association of American Geographers, 99*(2), 292–308.
Jones, J. P. G. (2011). Monitoring species abundance and distribution at the landscape scale. *Journal of Applied Ecology, 48*, 9–13.
Jongman, R. H. G., & Bunce, R. G. H. (2000). Landscape classification, scales and biodiversity in Europe. In U. Mander & R. H. G. Jongman (Eds.), *Consequences of land use changes* (pp. 11–38). Southampton: Wit Press.
Kasai, M., Ikeda, M., Asahina, T., & Fujisawa, K. (2009). LiDAR-derived DEM evaluation of deep-seated landslides in a steep and rocky region of Japan, LiDAR-derived DEM evaluation of deep-seated landslides in a steep and rocky region of Japan. *Geomorphology, 113*, 57–69.
Kilchenmann, A. (1971). Statistich-analytische Landschaftsforschung. *Geoforum, 7*, 39–52.
Kilchenmann, A. (1973). Die Merkmalanayse für Nominaldaten: eine Methode zur Analyse von Qualitativen geographischen Daten. *Geoforum, 15*, 33–45.
Kokalj, A., Zaksek, K., & Ostir, K. (2011). Application of sky-view factor for the visualisation of historic landscape features in lidar-derived relief models. *Antiquity, 85*(2011), 263–273.
Kolen, J., Renes, H., & Hermans, R. (Eds.). (2015). *Landscape biographies. Geographical, historical and archaeological perspectives on the production and transmission of landscapes*. Amsterdam: Amsterdam University Press, Landscape and Heritage Studies.
Kwakernaak, C. (1984). Information applied in ecological land classification. In J. Brandt & P. Agger (Eds.), *Proceedings of the first international IALE seminar on methodology in landscape ecological research and planning. theme III: Methodology of data analysis* (pp. 59–66). Roskilde: Roskilde University Centre.

Lambin, E. F., & Geist, H. J. (Eds.). (2006). *Local processes and global impacts*, *Global change – The IGBP series* (222 pp). Berlin: Springer.
Lebeau, R. (1979). *Les grands types de structures agraires dans le monde* (162 pp). Paris: Masson/troisième édition.
Lindenmayer, D. B., & Likens, G. E. (2009). Adaptive monitoring: A new paradigm for long-term research and monitoring. *Trends in Ecology & Evolution, 24*(9), 482–486.
Lipsky, Z. (1995). The changing face of the Czech rural landscape. *Landscape and Urban Planning, 31*, 39–45.
Liu, X. (2008). Airborne LiDAR for DEM generation: Some critical issues. *Progress in Physical Geography, 32*, 31–49.
Llobera, M. (2003). Extending GIS-based visual analysis: The concept of visualscapes. *InterntionalInternational Journal of Geographical Information Science, 17*(1), 25–48.
Lobet, J., Nederlandt, N., & Rosillon, F. (2006). *Mise en place d'un observatoire du paysage dans le bassin transfrontalier Semois-Semoy* (67 pp). Arlon: Ulg – Contrat de Rivière Semois.
Lohr, U. (1998). Digital elevation models by laser scanning. *The Photogrammetric Record, 16*, 105–109.
Loupa Ramos, O., Bianchi, P., Bernardo, F., & Van Eetvelde, V. (2017). What does really matter to people? Exploring contents of landscape identity at local scale. *Landscape Research*, in review.
Luginbühl, Y., Bontron, J.-C., & Cros, Z. (1994). *Méthode pour des atlas de paysages. Identfication et qualification*. Paris: Strates/CNRS-SEGESA, Ministère de l'Aménagement du Territoire, de l'Equipement et des Transports, Direction de l'Architecture et de l'Urbanisme.
Lynch, K. (1960). *The image of the city* (194 pp). Cambridge, MA/London: The MIT Press.
Mabbutt, J. (1968). Review of concepts of land classification. In A. Stewart (Ed.), *Land evaluation* (pp. 11–28). Melbourne: Macmillan of Australia.
MEEDDAT. (2008). *Méthode de l'Observatoire photographique du paysage*. Paris: Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire. http://observatoiredepaysages-caue73.fr/concrete5/files/2514/2418/4379/OPP_methode-DGALN2008.pdf
Mitchell, C. (1971). An appraisal of a hierarchy of desert land units. *Geoforum, 7*, 69–79.
Mitchell, C. (1973). *Land evaluation*. London: Longman.
Mitchell, C. W. (1991). *Terrain evaluation* (2nd ed.497p). Essex: Longman.
Mücher, C. A., Bunce, R. G. H., Jongman, R. H. G., Klijn, J. A., Koomen, A. J. M., Metzger, M. J., & Wascher, D. M. (2003). *Identification and characterisation of environments and landscapes in Europe*, *Alterra-rapport 832* (119 pp). Wageningen: Alterra.
Mutlu, M., Popescu, S. C., & Zhao, K. (2008). Sensitivity analysis of fire behavior modeling with LIDAR-derived surface fuel maps. *Forest Ecology and Management, 256*, 289–294.
Nakano, T. (1962). Landform type analysis on aerial photographs, its principle and technique. *Archives Internationales de Photogrammetrie, 14*, 149–152.
Naveh, Z., & Lieberman, A. (1994). *Landscape ecology: Theory and application* (360 pp). New York: Springer Verlag.
Neef, E. (1967). *Die theoretische Grundlagen der Landschaftslehre*. Haack Gotha: V.E.B.
Nichols, J. D., & Williams, B. K. (2006). Monitoring for conservation. *Trends in Ecology & Evolution, 21*, 668.
Nijhuis, S., van Lammeren, R., & van der Hoeven, F. (2011). *Exploring the visual landscape*, *Resarch in Urbanism Series, vol. 2* (p. 334). Amsterdam: IOS Press.
Nogué, J., & Sala, P. (2006). *Prototype Landscape Catalogue*. Olot/Barcelona: Observatori del Paisatge, 31 p.
Nogué, J. Sala, P. & Grau, J. (2016). *The Landscape Catalogues of Catalonia. Methodology*. Olot: Landscape Observatory of Catalonia, pp 142.
Nohl, W. (2001). Sustainable landscape use and aesthetic perception – Preliminary reflections on future landscape aesthetics. *Landscape and Urban Planning, 54*, 223–237.

O'Connor, P. J., & Bond, A. (2007). Maximising the effectiveness of photopoint monitoring for ecological management and restoration. *Ecological Management and Restoration, 8*(3), 228–233.

Observatoire Photographique Transfrontalier des Paysages. (2008). http://www.observatoire-paysages.pnth.eu/spip.php?page=index

Ode, Å., Tveit, M. S., & Fry, G. (2008). Capturing landscape visual character using indicators: Touching base with landscape aesthetic theory. *Landscape Research, 33*(1), 89–117.

O'Neill, R. V., Hunsaker, C. T., Jones, K. B., Riitters, K. H., Wickham, J. D., Schwartz, P. M., Goodman, I. A., Jackson, B. L., & Baillargeon, W. S. (1997). Monitoring environmental quality at the landscape level, using landscape indicators to assess biotic diversity, watershed integrity, and landscape stability. *Bioscience, 47*(8), 513–519.

Palang, H., Printsmann, A., Gyuró, E. K., Urbanc, M., Skowronek, E., & Woloszyn, W. (2006). The forgotten rural landscapes of Central and Eastern Europe. *Landscape Ecology, 21*(3), 347–357.

Palmer, J. F., Lankhorst, J. R. (1998). Evaluating visible spatial diversity in the landscape. *Landscape and Urban Planning, 43*(1–3), 65–78.

Palmieri, A., Martineo, L., Dominici, P., & Kasando, M. (2011). *Land cover and land use diversity indicators in LUCAS 2009 data*. http://ec.europa.eu/eurostat/web/lucas/publications

Parris, K. (2003). Agricultural landscape indicators in the context of the OECD work on agri-environmental indicators. In W. Dramstad & C. Sogge (Eds.), *Agricultural impacts on landscapes, developing indicators for policy analysis*. Proceedings from the NIJOS/OECD Expert Meeting on Agricultural Landscape Indicators in Oslo, Norway, 7–9 October 2002, 10.18.

Parris, K. (2004). Measuring changes in agricultural landscapes as a tool for policy makers. In J. Brandt & H. Vejre (Eds.), *Multifunctional landscapes. Theory, values and history* (Vol. Vol. I, pp. 193–218). Southampton: WIT Press.

Pedroli, B. (1983). Landscape concept and landscape and rangeland surveys in the Soviet Union. *ITC Journal, 4*, 307–321.

Pérez-Soba, M., & Wascher, D. (2005). *Landscape charater areas. Places for building a sustainable Europe*. Policy Brochure as deliverable from the EU's Accompanying Measure project European Landscape Character Assessment Initiative (ELCAI), funded under the 5th Framework Programme on Energy, Environmont and Sustainable Development (4.2.2).

Plets, G. (2013). *Heritages in the Making – Social embodiment of cultural heritage objects and places in the multicultural Altai Republic* (p. 360). Ghent: Ghent University/Faculty of Arts and Philosophy.

Powlesland, D., Lyall, J., Hopkinson, G., Donoghue, D., Beck, M., Harte, A., & Stott, D. (2006). Beneath the sand – Remote sensing, archaeology, aggregates and sustainability: A case study from Heslerton, the Vale of Pickering, North Yorkshire, UK. *Archaeological Prospection, 13*, 291–299.

Puschmann, O., & Dramstad, W. (2003). Documenting landscape change through fixed angle photography, In W. Dramstad & C. Sogge (Eds.), *Agricultural impacts on landscapes, Developing indicators for policy analysis*. Proceedings from the NIJOS/OECD Expert Meeting on Agricultural Landscape Indicators in Oslo, Norway, 7–9 October 2002, pp. 258–268.

Rackham, O. (1986). *The history of the countryside*. London: Penguin Books.

Rackham, O. (2000). Prospects for landscape history and historical ecology. *Landscapes, 2*, 3–15.

Ramirez, J. R. (2006). A new approach to relief representation. *Surveying and Land Information Science, 66*, 19–25.

Rippon, S. (2012). *Historic landscape analysis. Deciphering the countryside*, *Practical handbooks in archaeology n 16* (166 pp). York: CBA Publications.

Rossiter, D. G. (1995). Economic land evaluation: Why and how. *Soil Use and Management, 11*, 132–140.

Ruggles, C. L. N., Medyckyj-Scott, D. J., & Gruffydd, A. (1993). Multiple viewsheds analysis using GIS and its archaeological application: A case study in northern Mull. In J. Adresen,

T. Madsen, & I. Scollar (Eds.), *Computing the past: Computer applications and quantitative methods in archaeology* (pp. 125–132). Aarhus: Aarhus University Press.
Sauer, C. O. (1925). The morphology of landscape. University of California Publications in Geography, 2; reprinted in Leighly, J. (Ed.). (1974). *Land and life* (pp. 315–350). Berkely: University of California Press.
Saye, S. E., Wal, D. V. D., Pye, K., & Blott, S. J. (2005). Beach–dune morphological relationships and erosion/accretion: An investigation at five sites in England and Wales using LIDAR data. *Geomorphology, 72*, 128–155.
Sevenant, M., & Antrop, M. (2007). Settlement models, land use and visibility in rural landscapes: Two case studies in Greece. *Landscape and Urban Planning, 80*, 362–374.
Soini, K. (2001). Exploring human dimensions of multifunctional landscapes through mapping and map-making. *Landscape and Urban Planning, 57*(3–4), 225–239.
Stewart, G. A. (Ed.). (1968). *Land evaluation*. Papers from the CSIRO- symposium in co-operation with UNESCO. Canberra: Macmillan of Australia.
Swanwick, C. (2002). *Landscape character assessment. Guidance for England and Scotland*. Wetherby: The Countryside Agency/Scottisch Natural Heritage.
Swanwick, C. (2004). The assessment of countryside and landscape character in England: An overview. In: K. Bishop & A. Phillips (Eds.), *Countryside planning. New approaches to management and conservation* (pp. 109–124). London: Earthscan.
Tomlin, C. (1990). *Geographic Information Systems and Cartographic Modelling* (249 pp). Prentice-hall: Englewood Cliffs.
Troll, C. (1939). *Luftbildforschung und Landeskundige Forschung. Erdkundliches Wissen*. Schriftenreihe für Forschung und Praxis, Heft 12. Wiesbaden: F.Steiner Verlag.
Troll, C. (1963). Landschaftsökologie als geographisch-synoptische Naturbetrachtung. In *Ökologische Landschaftsforschung und vergleichende Hochgebirgsforschung. Erdkundliches Wissen*, *Schriftenreihe für Forschung und Praxis, Heft 11*. Wiesbaden: F.Steiner Verlag.
Tuan, Y.-F. (1977). *Space and place: The perspective of experience* (496 pp). Minneapolis: University of Minnesota Press.
Tveit, M. S. (2009). Indicators of visual scale as predictors of landscape preference; a comparison between groups. *Journal of Environmental Management, 90*, 2882–2888.
Tveit, M. S., Ode, Å., & And Fry, G. (2006). Key concepts in a framework for analysing visual landscape character. *Landscape Research, 31*(3), 229–225.
UNISCAPE. (2010). *Living landscape. The European landscape convention in research perspective*, 2 vols. Firenze: UNISCAPE.
Utkin, A. B., Lavrov, A. V., Costa, L., Simoes, F., & Vilar, R. (2002). Detection of small forest fires by LIDAR. *Applied Physics, 74*, 77–83.
Uyttenhove, P. (Ed.). (2006). *Recollecting Landscapes. Herfotografie, geheugen en transformatie 1904–1980-2004* (p. 383). Gent: A&S/Books.
Van Eetvelde, V., & Antrop, M. (2009). A stepwise multi-scaled landscape typology and characterisation for trans-regional integration, applied on the federal state of Belgium. *Landscape and Urban Planning, 91*(3), 160–170.
Van Hecke, E., Antrop, M., Schmitz, S., Sevenant, M., & Van Eetvelde, V. (2010). *Atlas van België: 2 Landschappen, platteland en landbouw* (74 pp). Gent: Academia Press.
Vink, A. P. A. (1980). *Landschapsecologie en landgebruik* (151pp). Utrecht: Bohn, Scheltema & Holkema.
Vinogradov, B. V. (1966). Les nouvelles méthodes d'interprétation des photographies aériennes pour la cartographie de la couverture végétale. *Technip, Paris, 2*, 93–96.
Vinogradov, B. V. (1976). Hierarchy of topological units of vegetation cover. *Biogeog. and Soil Geog. (Moscow), 4*, 133–137.
Vinogradov, B. V., Gerenschule, A. G., Isachenko, K. G., Raman, K. G., & Tseselchuk, Y. N. (1962). Basic principles of landscape mapping. *Soviet Geography: Review and Translatyion, 3*(6), 15–21.
Vos, W., & Meekes, H. (1999). Trends in European cultural landscape development: Perspectives for a sustainable future. *Landscape and Urban Planning, 46*(1–3), 3–14.

Warnock, S., & Griffiths, G. (2015). Landscape characterisation: The living landscape approach in the UK. *Landscape Research, 40*(3), 261–278.
Webb, R. H., Boyer, D. E., & Turner, R. M. (2010). *Repeat photography methods and applications in the natural sciences*. Island Press, p. 392. E-BOOK FORMAT, September 2012, $74.99, ISBN: 9781610910064.
Webster, R., & Beckett, P. (1970). Terrain classification and evaluation using air photography: A review of recent work at Oxford. *Photogrammetria, 26*, 51–75.
Wehr, U., & Lohr, U. (1999). Airborne laser scanning – An introduction and overview. *ISPRS Journal of Photogrammetry and Remote Sensing, 54*, 68–82.
Werbrouck, I., Antrop, M., Van Eetvelde, V., Stal, C., De Maeyer, P., Bats, M., Bourgeois, J., Court-Picon, M., Crombe, P., De Reu, J., De Smedt, P., Finke, P. A., Van Meirvenne, M., Verniers, J., & Zwertvaegher, A. (2011). Digital elevation model generation for historical landscape analysis based on LiDAR data, a case study in Flanders (Belgium). *Expert Systems with Applications, 38*, 8178–8185.
Zakšek, K., Ostir, K., & Kokalj, Z. (2011). Sky-View factor as a relief visualisation technique. *Remote Sensing, 3*, 398–415.
Zhou, G., & Xie, M. (2009). Coastal 3-D morphological change analysis using LiDAR series data: A case study of assateague Island national seashore. *Journal of Coastal Research, 25*, 435–447.
Zonneveld, I. S. (1972). *Land evaluation and Land(scape) science* (Vol. VII-4). Enschede: ITC-textbook.
Zonneveld, I. S. (1995). *Land ecology* (199 pp). Amsterdam: SPB Academic Publishing bv.
Zonneveld, I. S. (2005). The land unit as a black box: A Pandora's box? In: J. A. Wiens & M. R. Moss (Eds.), (1999). *Issues in landscape ecology. Studies in landscape ecology* (pp. 331–345). Cambridge: Cambridge University Press.