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Characterizing European cultural landscapes: Accounting for structure, management intensity and value of agricultural and forest landscapes

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ABSTRACT

Almost all rural areas in Europe have been shaped or altered by humans and can be considered cultural landscapes, many of which now are considered to entail valuable cultural heritage. Current dynamics in land management have put cultural landscapes under a huge pressure of agricultural intensification and land abandonment. To prevent the loss of cultural landscapes, knowledge on the location of different types of cultural landscapes is needed. In this paper, we present a characterization of European cultural landscapes based on the prevalence of three key dimensions of cultural landscapes: landscape structure, management intensity, and value and meaning. We mapped these dimensions across Europe at a 1-km resolution by combining proxies on management intensity and landscape structure with new indicators such as social media usage and registered traditional food products. We integrated the three dimensions into a continuous "cultural landscape index" that allows for a characterization of Europe's rural landscapes. The characterization identifies hotspots of cultural landscapes, where all three dimensions are present, such as in the Mediterranean. On the other hand, Eastern and Northern European cultural landscapes are mostly characterized by only one of the dimensions. Our paper can help to identify pressures to cultural landscapes and thus to target measures for the conservation of these landscapes, to link similar landscapes in different regions, and to inform policy design on the most important characteristics of cultural landscapes at a regional scale.

1. Introduction

Almost all rural areas in Europe have been shaped or altered by humans and can be regarded a cultural landscape, many of which now are considered to entail valuable cultural heritage. Across Europe cultural landscapes have diverging characteristics. For instance, the narrow, low-lying fields of the Dutch and German *Marschhufen* differ significantly from the wide-open Iberian *dehesas*, but both are considered typical cultural landscapes (for a good overview see Zimmermann, 2006). What they do have in common is that they often provide valuable cultural ecosystem services (Schaich et al., 2010; Tengberg et al., 2012). These include aesthetic appreciation (Van Zanten et al., 2014), cultural identity and a 'sense of place' to local inhabitants (Waterton, 2005), and a combination of services that attracts tourism and recreation (Van Berkel and Verburg, 2011). Moreover, cultural landscapes can be important havens of farmland biodiversity (Agnoletti, 2014; Bignal and McCracken, 1996; Plieninger and Bieling, 2013).

The term cultural landscapes was introduced as an academic concept in the late nineteenth century by Friedrich Ratzel and later adopted in the English literature by Carl Sauer, to denote all landscapes modified by human activity (Jones, 2003). As one can argue that nowadays all European landscapes are modified in some way by human activity (e.g. global warming, nature conservation) the term 'cultural' has lost its classical meaning (Phillips, 1998; Wu, 2010). However, in the 1990s the term was revived with the

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introduction of cultural landscapes into the UNESCO World Heritage Convention on the basis of their cultural heritage (Rössler, 2006). In addition to the classical definition, Jones (1991) identified two alternative interpretations of cultural landscapes: one that defines cultural landscapes as valued features threatened by change or disappearance and one where a cultural landscape is seen as subjective, focussing on the intangible values and meanings people attach to them.

Cultural landscapes are the result of the long-term, complex interactions between humans and nature and thus contain cultural heritage (Plieninger and Bieling, 2012). In this respect, the term cultural becomes a value-laden concept with the attention focused on those landscapes that are denoted as 'traditional landscapes' (Agnoletti, 2014; Antrop, 1997; Bignal and McCracken, 1996; Fischer et al., 2012; Plieninger et al., 2006). Antrop (1997) defines traditional landscapes as "those landscapes having a distinct and recognizable structure which reflects clear relations between the composing elements and having significance for natural, cultural, or aesthetical values." From a cultural geography perspective, scholars point at the origin of the landscape, somewhere between the Renaissance and the Industrial Revolution, and emphasize the low-intensity farming or livestock raising taking place in traditional landscapes (Plieninger et al., 2006). Consequently the terms 'traditional landscape' (Antrop, 1997) and 'low-intensity farmland' (Bignal and McCracken, 1996) are sometimes used interchangeably with the value-laden concept of cultural landscapes.

Cultural landscapes in Europe are threatened. Growing demand for food and progress in technology triggered a large-scale intensification of agriculture in highly productive areas. In contrast, less fertile land, or land less suitable for intensive agriculture, faces land abandonment (Estel et al., 2015; Kizos et al., 2009; Kuemmerle et al., 2008). This polarization of intensification on the one hand, and land abandonment on the other also induces a shift in the goods and services provided by cultural landscapes. Intensification increases agricultural commodity production, but often at the expense of a broad range of cultural services, including cultural heritage and identity (Plieninger and Bieling, 2012). Likewise, land abandonment can lead to a loss of the heritage embedded in the structure and composition of these landscapes (Van der Zanden, 2016b). These changes can be seen as decoupling of the links between humans and nature, or so-called social-ecological linkages (Fischer et al., 2012; Plieninger et al., 2015). To understand which cultural landscapes are at risk from these dynamics, to develop countermeasures to protect these landscapes and ensure a balance in the provisioning of different ecosystem services, and more generally, to retain social-ecological linkages in landscapes, knowledge on the location of different types of cultural landscapes is essential.

Existing spatially explicit typologies and characterizations of cultural landscapes rely mostly on biophysical factors such as topography, climate, soil, or land cover (Hazeu et al., 2010; Meeus, 1995). These biophysical factors, however, fail to characterize the social side of the coupled social-ecological systems, the 'cultural'. In this paper, we propose a new landscape characterization that explicitly incorporates this cultural aspect of the landscape by focussing on how people have altered the landscape, but also on how the landscape is perceived by people. We adopted a comprehensive understanding of the term cultural landscape by including all agricultural and forest landscapes, but at the same time also interpreting the adjective "cultural" as value laden, adopting the different approaches as outlined by Jones (1991). In this paper we chose to focus on rural landscapes, excluding urban landscapes, as they would require a different approach. With this definition we acknowledge that all landscapes have value to people, but these values tend to differ across Europe.

1.1. Characterizing cultural landscapes

Despite the diversity of cultural landscapes, three dimensions of cultural landscapes are frequently applied to describe them: (1) management intensity shows how people use the landscape (Bignal and McCracken, 1996; Plieninger et al., 2006), (2) landscape structure reveals how people use the landscape, but often also contains traces of how the landscape was cultivated in history (Van der Zanden et al., 2016a; Van der Zanden et al., 2013), and (3) 'value and meaning' is often used as an umbrella term for how landscape is perceived by people (Plieninger et al., 2015; Rössler, 2006).

In the literature, cultural landscapes are generally described as landscapes where agriculture is carried out with a low level of external inputs and by relatively small-sized (family) farms. One of the major threats to the cultural value of these landscapes is, therefore, directly related to intensification of land management. In terms of landscape structure, cultural landscapes are often characterized by smaller fields and the presence of landscape elements that reflect former management such as hedgerows or stonewalls (Van der Zanden et al., 2013). Finally, regarding the value and meaning of the landscape for people within a certain context (Plieninger et al., 2015), the cognitive aspect of the landscape "involves ways in which landscapes are perceived, understood and mentally structured by different groups in society" (Plieninger and Bieling, 2012).

These three dimensions form the backbone of the characterization developed in this paper. We mapped each dimension with two or more spatial variables across Europe. The characterization presented in this paper as well as the underlying data can be further explored through the HERCULES Knowledge Hub (http://labs.kh.hercules-landscapes.eu/landscape_typologies.html), a tool where users can alter the rules applied to map cultural landscapes to create their own characterization using our indicators.

2. Data and methods

2.1. Approach

For each of the three dimensions of cultural landscapes (management intensity, structure, and value and meaning), we derived a score between 0 and 1 for each landscape pixel of 1 km^2 in Europe (EU27 + Switzerland). High scores indicate a higher correspondence with landscapes that are commonly denoted as 'cultural landscapes'. With the score for each dimension we carried out two analyses. The first was the calculation of the average of the scores, yielding a continuous cultural landscape index score. This index shows which landscapes most likely resemble the traditional landscape as defined in the literature. A higher index score does not imply more cultural value as landscapes can have different value to different people (Jones, 1991). The emphasis in this paper in on the second analysis where a characterization based on the relative score of each dimension for each individual landscape was produced. Scores for each dimension are split into high and low classes. Three dichotomous scores for each landscape pixel resulted into eight different landscape types.

To assess the effect of the thresholds between high and low values chosen, we performed a sensitivity analysis. We divided the distribution of each dimension score with eight quantiles to be used as alternative thresholds. We generated a characterization for each possible combination of the different quantiles, resulting in $9^3 = 729$ possible different characterizations. For the final landscape characterization, we assigned the landscape type that occurred most frequently among the 729 characterizations. To quantify the sensitivity of the characterization to the threshold, we mapped how often the most frequently assigned landscape type occurred as a percentage of the total number of characterizations. The frequency of occurrence of the landscape type during the sensitivity analysis is referred to as the agreement score.

2.2. Data

To operationalize the three dimensions of cultural landscapes, we used a broad set of spatially-explicit proxies (Table 1), available for the entire study area. In case a EU27-wide dataset did not cover Switzerland, we used comparable Swiss national datasets. We used different data to map the cultural landscape dimensions in arable land, grassland, permanent crops and forest areas given the very different character of these two landscape types. To assign the data to different land cover classes, we used the most recent version of CORINE land cover at the time of analysis (i.e., CORINE 2006 for all countries except Greece, where CORINE 2000 was used) (EEA, 2012). We re-classified the CORINE map to seven classes (arable land, grassland, permanent crops, forest, urban, nature, and water) and aggregated the 100 m data to the 1-km grid using a constrained aggregation procedure in which the prevalence of the different land cover types in the original map was kept constant (Verburg et al., 2006). Urban, nature, and water were not addressed in this study, as we were interested in a characterization of agricultural and forest landscapes only. Due to the different characteristics of forests and agricultural landscapes in terms of land management and structure, the characterization was done separately for these two broad land cover classes.

2.3. Management intensity

Management intensity can be measured based on inputs (fertilizer, labor, mechanization), outputs (produced goods), or metrics based on system properties (Erb et al., 2013), and appropriate intensity measures differ for broad land uses. Since our characterization focusses on four broad land use/cover classes (arable land, pastures, permanent crops, and forests), we used multiple proxies for management intensity. Following Van der Zanden et al. (2016a), we used nitrogen input as an indicator for agricultural intensity, as it a common way of approximating management intensity in a spatially explicit way (Overmars et al., 2014; Temme and Verburg, 2011). Nitrogen input, measured as kg N/ha/yr, was derived from the Common Agricultural Policy Regionalized Impact Modeling System (CAPRI) database, where nitrogen input is available per crop type per NUTS2 administrative region (Britz, 2005). These data were spatially allocated to the 1-km grid per crop type and classified into three categories: 0–50 N kg/ha, 50–150 N kg/ha, and >150 N kg/ha per year. Extrapolation was done through country-specific regression models based on environmental and socio-economic covariates (Temme and Verburg, 2011). Grassland nitrogen input was based on livestock density (Neumann et al., 2009), assuming an annual nitrogen input of 100 kg per cow per year (Van der Hoek, 1998). We categorized these data into two classes: low (<100 N kg/ha/yr) and high (>100 N kg/ha/yr) N-input and normalized to a score between zero (high input) and one (low input). N input data for Switzerland were obtained from a Swiss national monitor (Hürdler et al., 2015), and classes were matched with the classes from CAPRI.

Nitrogen input data are not available for permanent crops. To measure the management intensity of permanent crop fields, we used the energy content output (i.e., the sum of food, feed, pruning of trees, residues of permanent crops, and straw) derived from the CAPRI model database (Paracchini et al., 2014). The energy content output (ECO) was normalized to a score between zero and one, where one refers to a low intensity and zero to a high intensity. We capped values above and below two standard deviations to eliminate the influence of extreme outliers. ECO for permanent crops in Switzerland was approximated using the average ECO from permanent crops in neighboring country Austria.

To distinguish between capital-intensive, large-scale farms and small-scale farms, we included the economic farm size as a second indicator of management intensity. This indicator represents the economic size of an agricultural holding in European Size Units (ESU = 1200 €) and was derived at NUTS-3 level as the mean over the years 2007–2009 (European Commission, 2012). Economic farm size was normalized to a score between zero and one, where one refers to small farms and zero to large farms. For Switzerland we used the averaged equivalent of ESU per Kanton for the years of 2007–2009 (Bundesamt für Statistik, 2009). For arable land, pasture, and permanent crops, a final management intensity score was calculated as the average of the indicators for nitrogen input (arable, pasture) or energy content output (permanent crops), and economic farm size.

In forested areas, we used forest harvesting intensity as the management intensity indicator. Forest harvesting intensity was measured by dividing wood felling by the net annual increment in m^3/ha/yr (Levers et al., 2014). This indicator was calculated for NUTS-0 to NUTS-3 regions (depending on the country, see Levers et al. (2014) for details). This indicator was also normalized to score between zero and one.

2.4. Landscape structure

We defined landscape structure as the spatial composition and heterogeneity of a landscape, referring to the spatial relations such as size, shape and configurations of the individual components (Turner, 1989; Van der Zanden et al., 2016a). Since the composing elements of a landscape dominated by forest are essentially different from those in agricultural landscapes, we used two different approaches for the two land cover classes.

For agricultural land (arable land, pasture, and permanent crops), we used field size and the abundance of green linear landscape elements. Green linear elements are tree lines, hedges, and dry stone walls indicating the degree of 'enclosedness' of an agricultural landscape (Van der Zanden et al., 2013). Abundance of green linear elements and enclosedness are often valued for its contribution to biodiversity and the cultural value of elements such as stone walls and hedgerows (Marshall and Moonen, 2002; Van der Zanden et al., 2013). For the EU27, the indicators were derived from the Land Use/Cover Area Frame Survey (LUCAS) 2012 micro-database (EUROSTAT, 2012). This database provides over 200,000 point observations evenly sampled throughout Europe (Gallego and Delincé, 2010). Linear elements were recorded in this field survey using a 250-m transect at each observation point. We interpolated the number of green linear elements from the LUCAS points to a 1 km grid using Ordinary Kriging with ArcGIS (Van der Zanden et al., 2013). To decrease the effects of outliers, we capped the indicator at a maximum of four linear elements per observation point and subsequently normalized the green linear elements density from zero (low density) to one (high density).

Next to enclosedness, cultural landscapes are often associated with small scale agriculture (Van Eetvelde and Antrop, 2004). To distinguish small-scale agriculture from industrial agriculture we used field size as an indicator. Field size is also recorded in the LUCAS survey. The LUCAS survey records the size of the field in which each observation was located, classified into four categories: <0.5 ha, 0.5–1 ha, 1–10 ha and >10 ha (EUROSTAT, 2012). We reclassified field sizes into the median of each class using 15 ha for the largest class. We interpolated the results to the 1-km grid using Ordinary Kriging and normalized the field size indicator from zero (large fields) to one (small fields). For Switzerland, we created a similar pattern of observation points as the LUCAS survey and mapped

Table 1
Details of indicators used for characterization.

	Indicator	Land cover	Data source	Raw data	Temporal coverage	Normalization
Manage-ment intensity	Economic farm size	Arable/Pasture/ Permanent crops	European Commission (2012)	St gross margins in ESU (1200 €)	2007–2009	Min-max normalization
	N-input	Arable/Pasture	Temme and Verburg (2011); Hürdler et al. (2015)	N-input in kg/ha	2000–2006	Min-max normalization
	Energy Content Output (ECO)	Permanent crops	Paracchini et al. (2014)	MJ/UAA(ha)/year	2006	Capped at $\mu + 2\sigma$ min-max normalization
	Harvest Intensity	Forest	Levers et al. (2014)	m^3/ha/yr of wood	2000–2010	Min-max normalization
Landscape structure	Field Size	Arable/Pasture/ Permanent crops	EUROSTAT (2012)	3 categories, in ha	2012	Ordinary Kriging Min-max normalization
	Green linear elements density (GLE)	Arable/Pasture/ Permanent crops	EUROSTAT (2012)	# of GLE intersections at 250 m transect	2012	Ordinary Kriging Capped at 4 Log normalization
	Forest age	Forest	Fuchs et al. (2015)	Forest extent 1900–2010 in 10-year time steps	1900–2010	Min-max normalization
Value and meaning	Product of Designated Origin (PDO) density	All	European Commission (2014)	# of PDOs	2014	Capped at 5 min max normalization
	Panoramio photo density	All	Panoramio (2015)	# of geotagged photos per km^2	2015	Log normalization capped at 10

the indicators using aerial images, taken in 2010–2012, as base layer.

A joint indicator for landscape structure was calculated as the average score of the normalized green linear elements and field size indicators. High values on this indicator for agricultural land depict those landscapes with small fields and/or many green linear elements. Areas with small fields often have higher abundance of green linear elements (the two layers are, weakly, collinear: Pearson's r = 0.29). Since small fields and the abundance of green linear elements both measure structural elements of cultural landscapes, we combined the two into one dimension.

Characterizing the landscape structure of forest requires a different approach. Field size and linear elements are inappropriate measures for the characterization of forest land cover. European wide data that are comparable with the data we used for agricultural lands cover is scarce. As landscape structure should reveal something about the history of the landscape, we chose to map forest persistence as a proxy for the structure of forests. While acknowledging the limitations of this proxy, forest structure and its cultural value is to some extent related to its persistence or length of the period that the forest has been covering the area. The forested area in Europe declined due to anthropogenic influences until the 19th century. In the twentieth century, however, the total area of forest increased steadily due to afforestation, nature conservation and farmland abandonment (Jepsen et al., 2015; Pereira et al., 2010). This indicator can identify relatively new forests and those forests that have been present for at least a century, a proxy for the more traditional forest. Here we assumed that more persistent forests have a structure that can be considered more traditional than that of a modern forest

Fuchs et al. (2015) composed a land cover map for each decade in the twentieth century on a 1 km grid using a wide set of old Prussian maps and modelling techniques (Fuchs et al., 2015). Using these maps, we estimated the persistence of the forests ranging from zero years (no forest in 2000) to over 110 years (forest land cover during the entire period 1900–2010). The more persistent the forest, the higher the score on the structure dimension.

2.5. Value and meaning

In this dimension we aimed to quantify and map the intangible and subjective side of the landscape from the landscape. Landscape value and meaning are well studied and often expressed as visual preferences (Van Zanten et al., 2014), opportunities for recreation (Van Berkel and Verburg, 2011), or 'sense of place' (Hausmann et al., 2015). A recurring insight from prior work is that often landscape values and meanings are related to landscape structure and management intensity. Nevertheless, they cannot be assessed in mere material site characteristics (Plieninger et al., 2015). The identification of value and meaning should therefore rely on less direct proxies than the operationalization of landscape intensity and structure to capture the intangible aspects of value and meaning (Paracchini and Capitani, 2011). We used two indicators to operationalize this dimension of our cultural landscape typology.

As a first indicator, we utilized the production of traditional food products, a typical form of cultural heritage which can be linked directly to the landscape it is produced in (Bessière, 1998; De Roest and Menghi, 2000). We used data on food products that are geographically protected by EU regulations. A Protected Designation of Origin (PDO) is an official EU certificate that requires food to be produced according to certain traditional guidelines within a bounded geographical area. Examples of PDO protected foodstuffs are Buffalo Mozzarella from Campania, blue cheese from Stilton, or Prosciutto from Parma. Such geographical food labels can provide a sense of place to tourists (Haven-Tang and Jones, 2005), but are also used to conserve or construct a local identity linked to the landscape (Ilbery et al., 2005). Following Van Berkel and Verburg (2011), we mapped all PDOs with explicit geographical denomination. Special wines are also protected with the PDO sign but the geographical boundaries of grape production are not documented and PDOs of wines were therefore excluded. Legal documents protecting the PDO specify either an administrative region or a number of places where the relevant product can be made. When the geographical denomination was a list of villages or cities, instead of an explicit region, we used a 5-km buffer around the places to define the production area (Van Berkel and Verburg, 2011). The number of PDOs per region varied between 0 and 12. Very few regions had more than four PDOs; therefore we capped this indicator to a maximum of four and normalized it between 0 (no PDOs) to 1 (many PDOs).

We based the second indicator on the density of pictures uploaded on Panoramio, a Google application through which users add geotagged landscape pictures to Google Earth. Social media data and other crowdsourced information are receiving a growing interest among researchers for eliciting landscape values (Keeler et al., 2015; Martínez Pastur et al., 2015; Richards and Friess, 2015). Twitter and Instagram have already been harnessed to reveal large scale behavior patterns of people (Dunkel, 2015; Frias-

Martinez et al., 2012; Wood et al., 2013). A recent study showed that Panoramio photo density can very well be used as a metric for aesthetic enjoyment and outdoor recreation (Van Zanten et al., in press). Over 30 million pictures have been added to Panoramio in the last six years in Europe only, and the database is growing. Although a good overview of the users of Panoramio is missing, the density of photos is assumed to be produced by both locals as well as outsiders. Moreover Panoramio does not have a clear bias towards certain regions in Europe, in contrast to other platforms such as Flickr and Instagram (Van Zanten et al., in press). We downloaded the metadata of all photos (including X and Y coordinates) with a geotag in Europe through the Panoramio REST API (Panoramio, 2015). For this purpose we developed a Python script that sends a download request for each area of 0.01 decimal degrees by 0.01 decimal degrees in Europe.[1] To control for the bias of very active users we calculated the number of unique user uploads per square kilometer as an indicator for the societal appreciation of European landscapes. Photos taken in urban areas were excluded based on the land cover base map (Section 3.2). After filtering urban photos and accounting for unique user uploads, the data comprised 4.6 million entries. We normalized the data to score the 1-km grid cells using the natural logarithm of the number of photos per pixel to a score between 0 (no photos) to 1 (many photos). Data were downloaded in January 2015. Due to the scarce data availability we limited the score for value and meaning on the average of these two indicators. This dimension shows one aspect of the supply of value and meaning (PDOs) as well as the demand in the form of appreciation by people. However we are aware that vital concepts such as sense of place, history, or inspiration are not included in the indicators.

3. Results

Since the Cultural Landscape Index (CLI) of agricultural land and forests relied on different indicators, we present the respective CLIs in separate maps. Fig. 1a shows the spatial distribution of overall CLI scores in agricultural land. This map gives a rough indication of coldspots (for example, Northern France, or Eastern Germany) and hotspots (Tuscany or Lower Normandy) of cultural landscapes (references to the geographical locations are localized on a map in the supplementary material). More generally, agricultural land with high CLIs is concentrated around the Mediterranean, while northern countries have low to medium CLIs. In some places, high values are found in narrow mountain valleys, hardly visible in the maps. The total CLI of forests in Fig. 1b shows a clear pattern: high CLIs in mountainous areas and lower scores in lowland forests. An exception to this rule can be found in Lapland, which has a high CLI despite the dominance of lowland forests.

The actual characterization, based on the dominant dimension, is shown in Fig. 2 for agricultural land. Agricultural land in Eastern Europe and western Spain are mostly characterized by low land-use intensity, while in Ireland and Brittany, landscape structure is the dominant dimension. Some landscapes, frequently occurring in the Mediterranean are characterized by a high score on all dimensions (dark red) while other landscapes, such as in eastern Germany and northern France are characterized by a low score on each dimension (light yellow). The distribution of landscape types within countries show striking regional patterns (Fig. 3). Especially in Eastern Europe countries have a similar distribution of the different landscape types. In Switzerland and Luxemburg, significant proportions of the agricultural area score low on the dimensions intensity and structure, but still provide a high value/meaning to the population. Opposite patterns (high scores for structure and intensity, but low value/meaning) are seen in parts of Eastern Europe and Portugal.

Most forest in mountainous areas is characterized by high values on all three dimensions (Fig. 4, dark red). We found persistent, but intensively harvested forest in Scandinavia and in small patches throughout Europe such as the Landes forest (France), southern Germany, Austria and Czech Republic. However the latter three examples also have a high score on value/meaning.

Our sensitivity analyses (Fig. 5a and b) indicate to what extent the threshold that distinguishes high and low scores for each dimension influence the landscape characterization outcome. We found some hotspots of 'agreement' (indicating low sensitivity to thresholds) in Ireland, northern France and Romania while landscapes such as the Po Valley, Western Poland or the valleys in Austria have only 20%–40% agreement. Areas with high agreement scores can be regarded as areas that are classified with high certainty as belonging to the category it is given in Fig. 2. Areas with a low agreement scores are landscapes that, with small adjustments of the characterization thresholds, are categorized into a different landscape type. For forests, agreement is relatively high in Scandinavia and mountainous regions, while it is lower in lowland regions, especially in Germany, France, and Poland. Large forest areas such as in Scandinavia, the Landes forest, and mountainous regions, tend to have a higher agreement score, while smaller forest patches tend to be classified with a lower certainty.

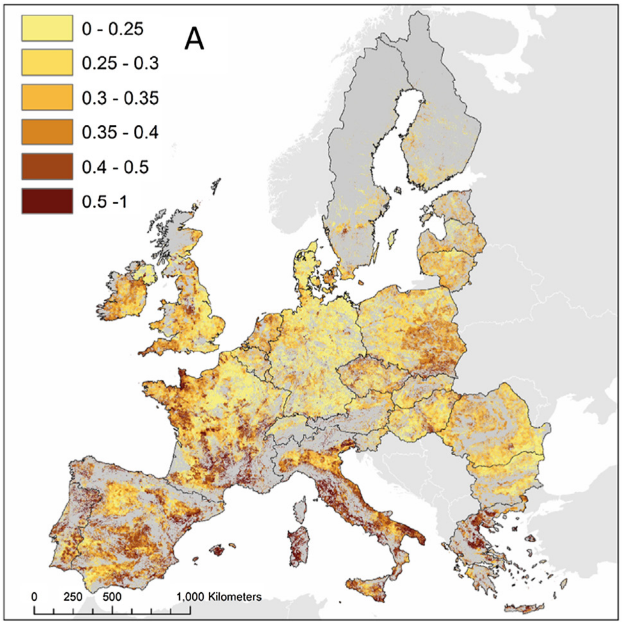
4. Discussion

Cultural landscapes provide important ecosystem services, harbor farmland biodiversity, and are cherished for their heritage throughout the world. Yet, cultural landscapes are also increasingly threatened by intensification on the one hand and abandonment on the other. While cultural landscapes have been the subject of many studies, our study is the first to map their spatial distribution across Europe. This includes an overall index showing the correspondence of a location with properties commonly associated with cultural landscapes. Although we use three key dimensions of cultural landscapes, we acknowledge that these are not universal. We provide an interactive tool where individuals can view, use and/or customize the data or depict landscapes across the EU in different ways. In addition, we characterize the dominant dimensions determining this index and the sensitivity of this characterization towards the assumptions made. Together, the different maps allow an interpretation of the diversity of conditions that characterize cultural landscapes across Europe.

4.1. Spatial patterns of cultural landscapes types

The way in which our map characterizes well-known cultural landscapes highlights the value of our maps. A good example of a well-known cultural landscape is found in Tuscany, Italy (Agnoletti, 2007), which is clearly distinguishable in our three maps, having a high CLI, a high score on all dimensions, and a relatively high agreement score. Tuscany is home to many PDOs (e.g. pecorino, prosciutto), and is a known tourist attraction. Moreover a hilly terrain and soils of low productivity have constrained agricultural intensification, which has led to the persistence of the traditional farming landscape (Agnoletti, 2007). Similarly the *bocage* landscapes of lower Normandy, named after the abundance of hedgerows, clearly stand out on all our three maps. Due to a change from collective to private farming, many hedgerows were planted here during the 18th and 19th century. Unlike many other areas in Europe, they have been conserved well there (Bonnieux and Le Goff, 1997; Schulp et al., 2014).

[1] The Python script is available upon request.



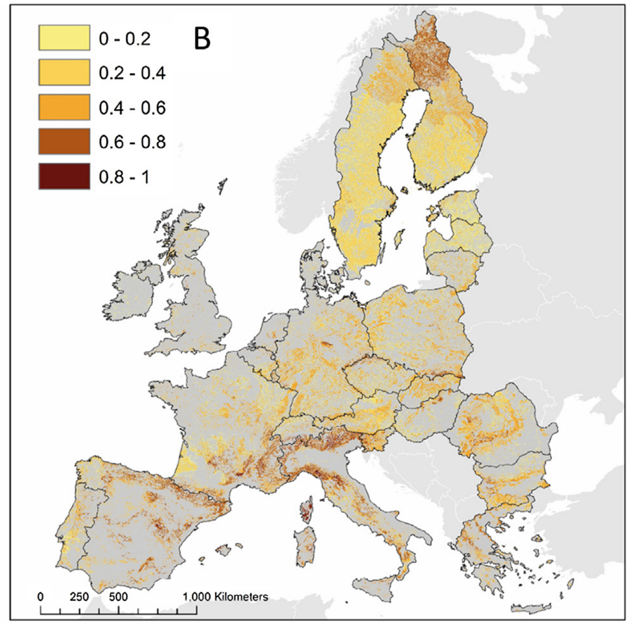


Fig. 1. Cultural Landscape Index (CLI) of European (A) agricultural land and (B) forest.

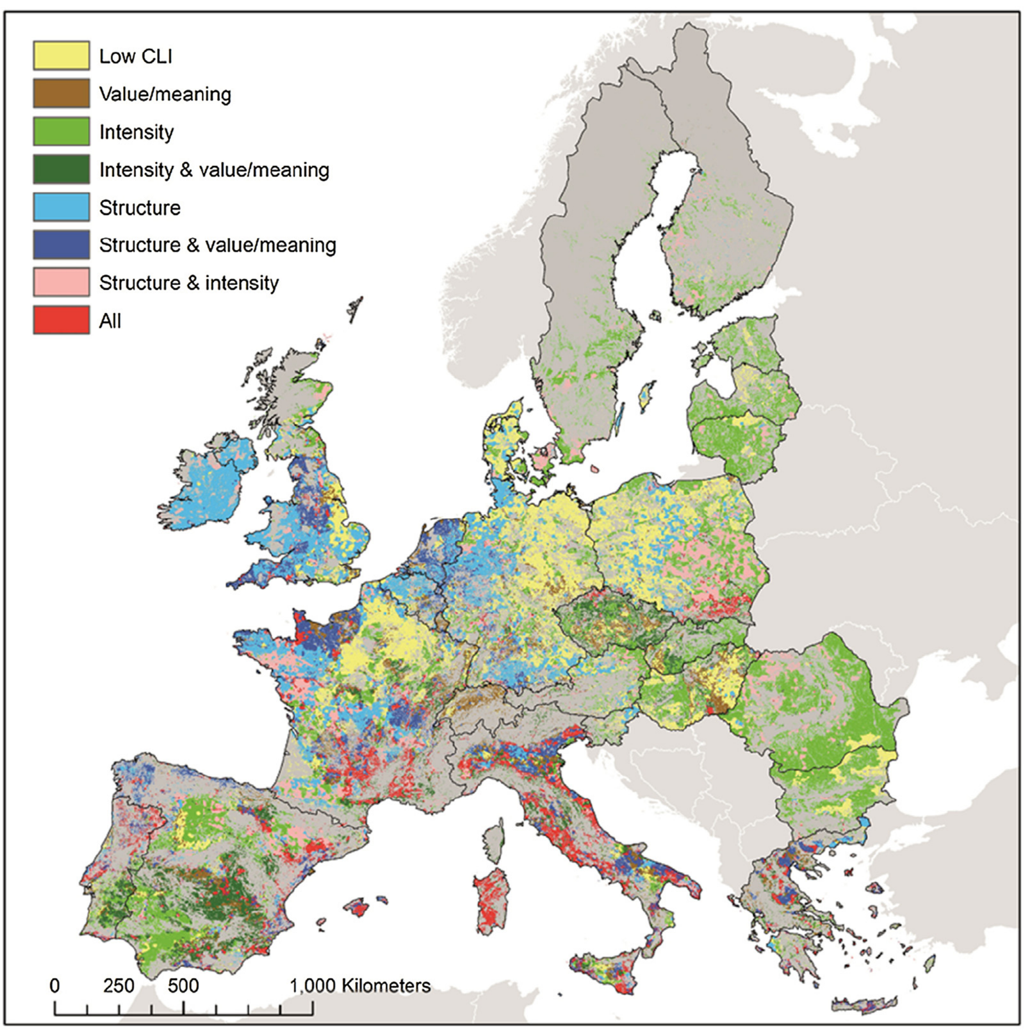


Fig. 2. Characterization of European agricultural landscapes. The map indicates which dimensions characterize cultural landscapes with a high score.

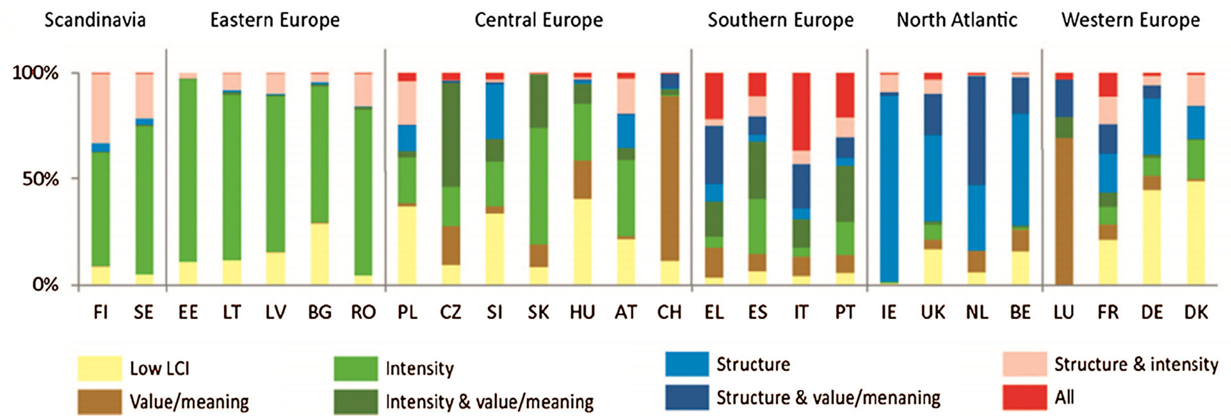


Fig. 3. Distribution (area percentage) of agricultural landscape types, by country and region.

In contrast, large parts of Eastern Europe are characterized by a low score on the structural and value and meaning dimension, but high on management intensity score. We classified 80–95% of the landscapes in Eastern Europe as large-scale and/or open landscapes. Higher scores on the other dimensions here are found in mountainous areas that are often managed with relatively low intensity. Rapid institutional and political transformations during the 20th century caused disruptive changes in the landscape, deteriorating connections once held between inhabitants and their landscape (Lieskovský et al., 2014; Palang et al., 2006). In many areas in Eastern Europe collectivization during the Soviet period generated large fields while traditional structures such as linear landscape elements were largely removed during that period (Palang, 2010). Moreover, the protection of specialized local foodstuffs is not very common in Eastern European countries, leading to a low score on the value/meaning dimension. A relatively low

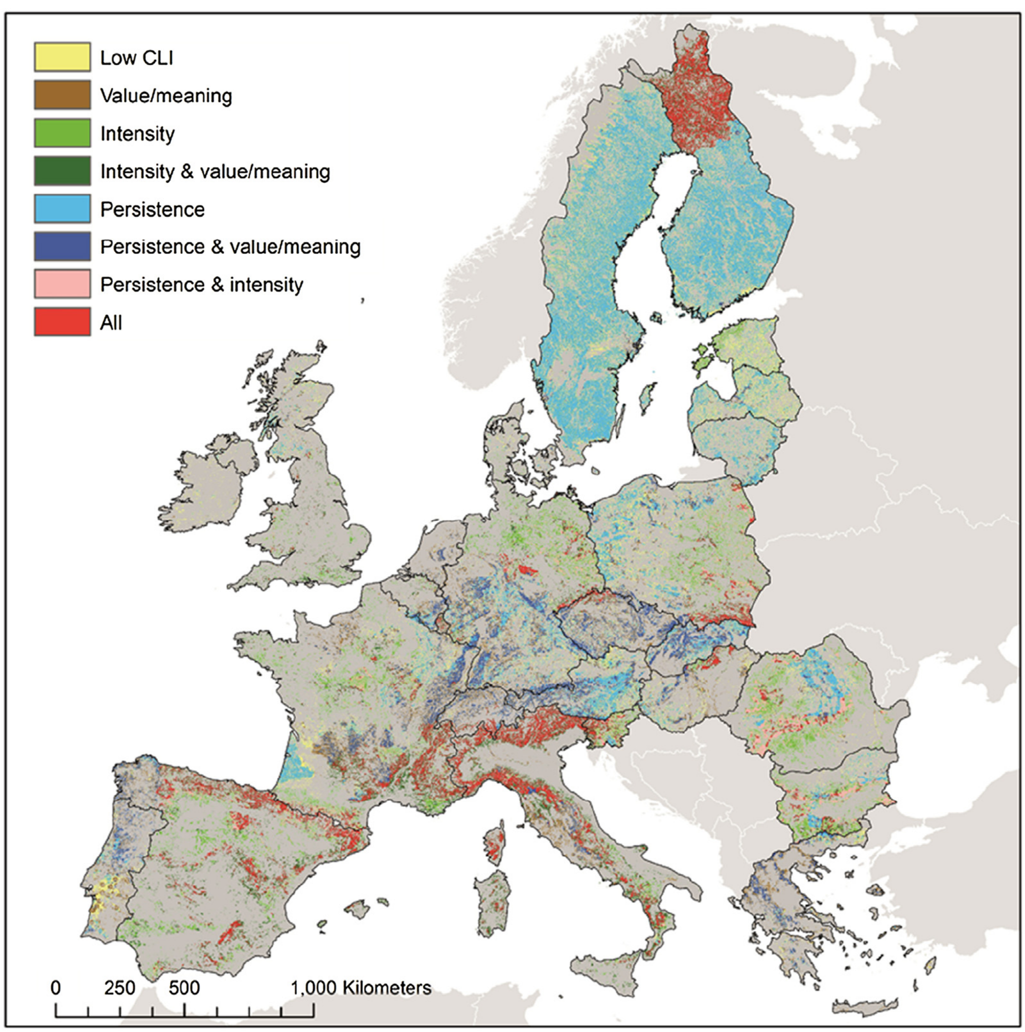


Fig. 4. Characterization of European forests. The map indicates which dimensions that characterize cultural landscapes display a high score.

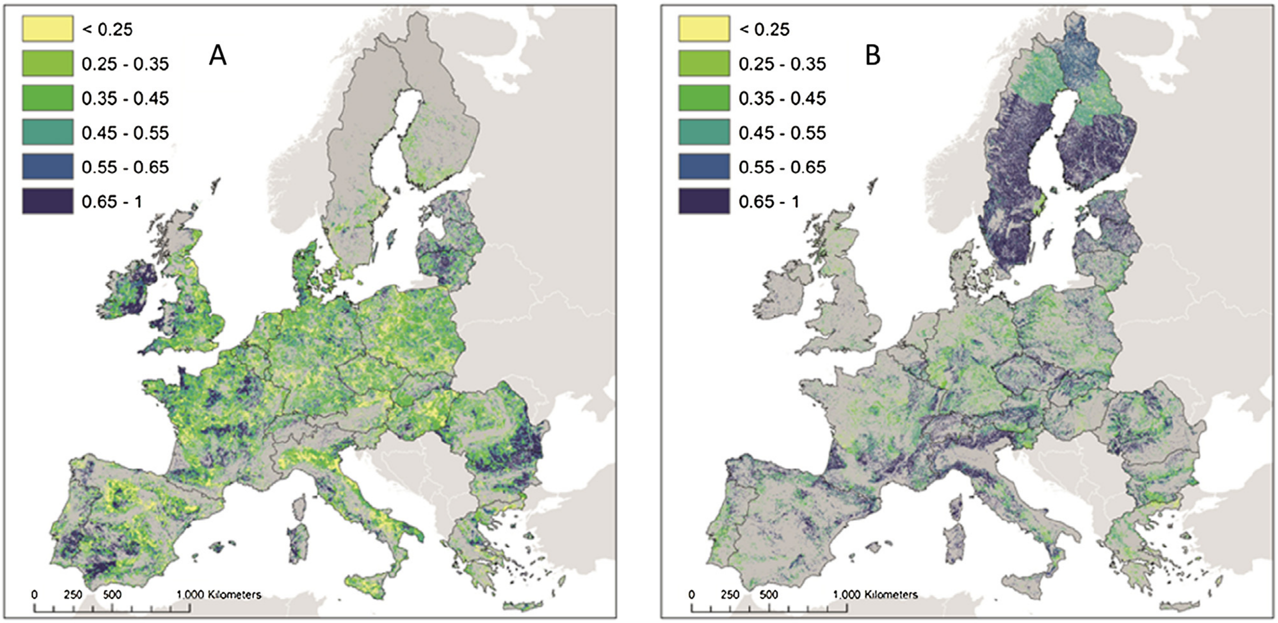


Fig. 5. Agreement score of (A) agricultural landscape characterization and (B) forest (occurrence of most frequent characterization as a fraction of total characterizations).

intensity of agricultural management is a common feature of this region. Partly this is a result of slower intensification. Furthermore, after 1989, liberalization caused decreasing agricultural yields that triggered widespread dis-intensification throughout areas east of the former Iron Curtain (Kuemmerle et al., 2008; Lieskovský et al., 2013), with fertilizer input dropped by more than 50% in a number of eastern and central European countries between 1989 and 1999 (Macours and Swinnen, 2000). This explains the large area of agricultural land, primarily characterized by low management intensity. In spite of this overall pattern, many hotspots of cultural landscapes are still found in eastern and central Europe. Some of them are clearly visible in our characterization, for example, in the south of Poland or the south of Hungary (Palang et al., 2006). Other known landscapes, such as those in Romania, are of great ecological and cultural value (Sutcliffe et al., 2013) but appear less clearly in our characterization.

A similar landscape type with low scores on the structure dimension and high scores on the intensity dimension can also be found in southern Spain and Portugal. These *dehesa* (Spain) or *montando* (Portugal) landscapes are generally regarded as a traditional landscape of high cultural significance. Spain has faced less disruptive political changes with expansive impact on land management than took place in Eastern Europe though these landscapes were subject to severe (but more gradual) changes as well. The dehesas today are largely found in those landscape less suitable for intensive agriculture (Vicente and Alés, 2006). Today this silvo-pastoral landscape system of the dehesa/montando, where animals graze within cleared oak forests (Plieninger et al., 2003), is characteristic for Southwestern Spain and Southeastern Portugal and is mainly used for non-timber forest products and meat production (Campos et al., 2013). Moreover, the typical Iberian ham, which is protected with multiple PDOs is “the main economic raison d’être for the maintenance of this landscape type” (Zimmermann, 2006).

The agreement in the forests classified with high scores on all dimensions, in mountains such as the Alps, the Pyrenees or the Carpathians is remarkably high. These forests have persisted over the last century, they show a relatively low harvesting intensity, and they are displayed prominently on Panoramio photos. Therefore these forests also have a high CLI and have high scores on all dimensions. Other forest landscapes, known for its cultural significance, such as the Black Forest in southern Germany (Plieninger and Bieling, 2012), appear as persistent and with value or meaning. These forests which are more accessible than mountainous forests, are more intensely harvested than the less accessible mountain forests. Other forest landscapes, which also show persistence, but not characterized with value and meaning are mainly found in Finland and Sweden and for instance in the Landes forest. These locations show resemblance with the even aged production forests in the typology of Hengeveld et al. (2012).

Other forests, not characterized by persistence, are more scattered throughout Europe and are largely found in lowland regions. Here afforestation occurred after the Second World War. Forests were both needed to meet increased wood demand and a desire for timber self-sufficiency (Vilén et al., 2012), and also followed contraction of agricultural land upon intensification (Nabuurs et al., 2003). Consequently, countries with a low score on the three dimensions in agricultural areas, due to intensification, also tend to have low scores in forests. Although not very stark, these relatively new forests do show some spatial overlap with regions of land abandonment (Estel et al., 2015), such as in eastern Poland.

4.2. Mapping methods for cultural landscapes

Providing a characterization of cultural landscapes in Europe is a challenging task as there is no consensus on defining and characterizing cultural landscapes. Simply mapping the diversity of landscapes in terms of composition or farming practices is insufficient to map the variety of cultural value of these landscapes. We incorporated human activities (through the intensity dimension) and appreciation though the value and meaning dimension. By adding the value and meaning dimension, we tried to incorporate the subjective and intangible aspect of the landscape as described by Jones (1991). However, we are aware of the fact that especially these indicators are all but comprehensive, but nevertheless give a reasonable indication of the dimension given the available data. Concepts that are still missing from this typology are amongst others local history or the different value to different peoples. Our overall cultural landscapes index is an expression of how close these landscapes come to the – simplified – ideal of a cultural landscape as found back in much of the literature on cultural landscapes defined by a rich landscape structure, low land-use intensity, and high values and meanings. At the same time, we acknowledge that 'ordinary' or 'everyday' landscapes that score low in all three dimensions (e.g., many peri-urban landscapes of Central Europe) are of importance for people's quality of life as well, as recognized in the European Landscape Convention (Conrad et al., 2011). The CLI map should therefore be treated with caution and should not be interpreted as a valuation of landscapes. The classification proposed should be interpreted as a characterization of landscape rather than a valuation. A higher score on the cultural landscape index therefore does not imply more value; it implies greater correspondence to what is commonly denoted as a traditional cultural landscape.

Irrespective of the methodology chosen, the data selection is a source of uncertainty as different indicators may lead to different cultural landscape characterizations. Cultural heritage may not be directly visible in a physical landscape. Quintessential aspects of cultural value and meaning, or heritage, are not fully captured in this analysis, mainly due to the fact that there are no data that can be used for a wall-to-wall European assessment. We confined ourselves to including the three dimensions of cultural landscapes commonly agreed upon in the literature, but we provided the option to customize the characterization on the Hercules Knowledge Hub (http://labs.kh.hercules-landscapes.eu/landscape_typologies.html) to allow other users to adjust the characterization to their needs.

In contrast to the general notion of landscapes being composed of multiple land cover types we chose to separate forests from agricultural landscapes in this study since the data were significantly different for these two broad lands cover classes. Therefore, some of the integrity of landscapes as mosaics of agriculture and forest, often expressed at resolutions below the one used in this study, are not captured.

The data layers for the intensity and structure are all derived from well-established datasets that were previously used in several European scale studies (Overmars et al., 2014; Van der Zanden et al., 2016a; Van der Zanden et al., 2013).The only dataset that was created particularly for this study is the Panoramio photo density. The usage of social media and big data for the purpose of approximating landscape preferences is not entirely new (Casalegno et al., 2013), but a European wide photo density map never has been produced for this purpose. The map reveals some interesting patterns and strongly suggests preferences for certain type of landscapes, such as a clear preference for mountainous areas and landscapes close to water bodies. As the high density of photos along the Camino de Santiago shows, care should be taken in interpretation as result of the potential biases related to these data. Panoramio only shows where users have taken photos and subsequently uploaded them on the web. Social media users are by no means representative for the entire population (Boyd and Crawford, 2012). However, the combination of Panoramio with the PDO data reduced potential biases. With current trends in big data research and the use of crowd-sourced information for landscape preference and valuation (Dunkel; Goossen, 2010; Wood et al., 2013), the data used in the characterization could be improved to include different aspects of cultural landscapes.

5. Conclusions and applications

In this study, we used three dimensions of cultural landscapes commonly identified as important Plieninger et al. (2015) in order to map cultural landscapes on the European scale. By using these dimensions, we were able to identify known hotpots of cultural landscapes (such as Tuscany, the Dehesas or the bocage in Normandy), less known hotspots such as mountainous forests, or coldspots of cultural landscapes such as the landscapes of industrial agriculture northern France. High scores on all three dimensions were mainly found in southern European countries and in local hotspots elsewhere such as southeastern Poland. Landscapes with lower scores on at least two of the three dimensions were found in Northern France, Eastern Germany, Bulgaria and Romania. Furthermore, the characterization proposed in this paper can be used as a framework for local or regional case studies. By doing so this paper addresses the aims of the European Landscape Convention "to promote landscape protection, management and planning, and to organize European co-operation on landscape issues" (Council of Europe, 2000). Our map of cultural landscapes includes the first characterization including proxies to measure people's perception. This may enhance the protection of valuable cultural landscape while it simultaneously caters for European co-operation as similarities between landscapes across borders become apparent.

Our characterization can also be used to monitor change in cultural landscapes. Most cultural landscapes face severe threats due to both intensification and extreme de-intensification or abandonment. By updating this characterization with regular time intervals it becomes a monitor for the current status of the different cultural landscapes of Europe, since it especially focusses on the management of the landscapes. This creates a framework to identify and classify threats and opportunities to and for cultural landscapes throughout Europe.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landusepol.2016.12.001.

References

Agnoletti, M., 2007. The degradation of traditional landscape in a mountain area of Tuscany during the 19th and 20th centuries: implications for biodiversity and sustainable management. For. Ecol. Manage. 249, 5–17.

Agnoletti, M., 2014. Rural landscape, nature conservation and culture: some notes on research trends and management approaches from a (southern) European perspective. Landsc. Urban Plann. 126, 66–73.

Antrop, M., 1997. The concept of traditional landscapes as a base for landscape evaluation and planning: the example of Flanders Region. Landsc. Urban Plann. 38, 105–117.

Bessière, J., 1998. Local development and heritage: traditional food and cuisine as tourist attractions in rural areas. Sociologia Ruralis 38, 21–34.

Bignal, E.M., McCracken, D.I., 1996. Low-Intensity farming systems in the conservation of the countryside. J. Appl. Ecol. 33, 413–424.

Bonnieux, F., Le Goff, P., 1997. Valuing the benefits of landscape restoration: a case study of the cotentin in Lower-Normandy, France. J. Environ. Manage. 50, 321–333.

Boyd, D., Crawford, K., 2012. Critical questions for big data. Inf. Commun. Soc. 15, 662–679.

Britz, W., 2005. CAPRI Modelling System Documentation (Common Agricultural Policy Regional Impact Analysis). Bonn.

Bundesamt für Statistik, 2009. Landwirtschaftliche Strukturerhebung, in: Switzerland (Ed.).

Campos, P., Huntsinger, L., Oviedo, J.L., Starrs, P.F., 2013. Mediterranean Oak Woodland Working Landscapes: Dehesas of Spain and Ranchlands of California. Springer, New York.

Casalegno, S., Inger, R., Desilvey, C., Gaston, K.J., 2013. Spatial covariance between aesthetic value & other ecosystem services. PLoS One 8, e68437.

Conrad, E., Christie, M., Fazey, I., 2011. Is research keeping up with changes in landscape policy? A review of the literature. J. Environ. Manage. 92, 2097–2108.

Council of Europe, 2000. The European Landscape Convention. Council of Europe, Strassbourg.
De Roest, K., Menghi, A., 2000. Reconsidering 'Traditional' food: the case of parmigiano reggiano cheese. Sociologia Ruralis 40, 439–451.
Dunkel, A., 2015. Visualizing the perceived environment using crowdsourced photo geodata. Landsc. Urban Plann. 142, 173–186.
EEA, 2012. Corine Land Cover 2006 Raster Data. European Environment Agency (EEA).
EUROSTAT, 2012. LUCAS Microdata 2012 http://ec.europa.eu/eurostat/web/lucas/data/primary-data/2012 (Accessed 27 January 2015).
Erb, K.-H., Haberl, H., Jepsen, M.R., Kuemmerle, T., Lindner, M., Müller, D., Verburg, P.H., Reenberg, A., 2013. A conceptual framework for analysing and measuring land-use intensity. Curr. Opin. Environ. Sustain. 5, 464–470.
Estel, S., Kuemmerle, T., Alcantara, C., Levers, C., Prishchepov, A., Hostert, P., 2015. Mapping farmland abandonment and recultivation across Europe using MODIS NDVI time series. Remote Sens. Environ. 163, 312–325.
European Commission, 2012. In: Commission, E. (Ed.), Farm Accountancy Data Network – Public Database. DG Agricultural & Rural Development, Brussels.
European Commission, 2014. DOOR, http://ec.europa.eu/agriculture/quality/door/list.html (Accessed 14 October 2014).
Fischer, J., Hartel, T., Kuemmerle, T., 2012. Conservation policy in traditional farming landscapes. Conserv. Lett. 5, 167–175.
Frias-Martinez, V., Soto, V., Hohwald, H., Frias-Martinez, E., 2012. Characterizing urban landscapes using geolocated tweets, proceedings of the 2012 ASE/IEEE international conference on social computing and 2012 ASE/IEEE international conference on privacy, security, risk and trust. IEEE Comput. Soc., 239–248.
Fuchs, R., Herold, M., Verburg, P.H., Clevers, J.G.P.W., Eberle, J., 2015. Gross changes in reconstructions of historic land cover/use for Europe between 1900 and 2010. Global Change Biol. 21, 299–313.
Gallego, J., Delincé, J., 2010. The European Land Use and Cover Area-Frame Statistical Survey, Agricultural Survey Methods. John Wiley & Sons, Ltd, pp. 149–168.
Goossen, C.M., 2010. Gathering Online Landscape Preferences Voluntarily with a Destination Recommendation System. Wageningen, The Netherlands.
Hürdler, J., Prasuhn, V., Spiess, E., 2015. Abschätzung diffuser Stickstoff- und Phosphoreinträge in die Oberflächengewässer der Schweiz MODIFFUS 3.0. Bericht im Auftrag des BAFU. Agroscope, Zürich-Reckenholz, 115 S.
Hausmann, A., Slotow, R.O.B., Burns, J.K., Di Minin, E., 2015. The ecosystem service of sense of place: benefits for human well-being and biodiversity conservation. Environ. Conserv., 1–11.
Haven-Tang, C., Jones, E., 2005. Using local food and drink to differentiate tourism destinations through a sense of place. J. Culin. Sci. Technol. 4, 69–86.
Hazeu, G., Elbersen, B., Andersen, E., Baruth, B., van Diepen, K., Metzger, M., 2010. A biophysical typology in agri-environmental modelling. In: Brouwer, F.M., Ittersum, M.K. (Eds.), Environmental and Agricultural Modelling. Springer, Netherlands, pp. 159–187.
Hengeveld, G.M., Nabuurs, G.-J., Didion, M., van den Wyngaert, I., Clerkx, A.P.P.M., Schelhaas, M.-J., 2012. A forest management map of european forests. Ecol. Soc. 17.
Ilbery, B., Morris, C., Buller, H., Maye, D., Kneafsey, M., 2005. Product, process and place: an examination of food marketing and labelling schemes in europe and north america. Eur. Urban Reg. Stud. 12, 116–132.
Jepsen, M.R., Kuemmerle, T., Müller, D., Erb, K., Verburg, P.H., Haberl, H., Vesterager, J.P., Andrič, M., Antrop, M., Austrheim, G., Björn, I., Bondeau, A., Bürgi, M., Bryson, J., Caspar, G., Cassar, L.F., Conrad, E., Chromý, P., Daugirdas, V., Van Eetvelde, V., Elena-Rosselló, R., Gimmi, U., Izakovicova, Z., Jančák, V., Jansson, U., Kladnik, D., Kozak, J., Konkoly-Gyuró, E., Krausmann, F., Mander, Ü., McDonagh, J., Pärn, J., Niedertscheider, M., Nikodemus, O., Ostapowicz, K., Pérez-Soba, M., Pinto-Correia, T., Ribokas, G., Rounsevell, M., Schistou, D., Schmit, C., Terkenli, T.S., Tretvik, A.M., Trzepacz, P., Vadineanu, A., Walz, A., Zhllima, E., Reenberg, A., 2015. Transitions in European land-management regimes between 1800 and 2010. Land Use Policy 49, 53–64.
Jones, M., 1991. The elusive reality of landscape. Concepts and approaches in landscape research. Norsk Geografisk Tidsskrift – Nor. J. Geogr. 45, 229–244.
Jones, M., 2003. The concept of cultural landscape: discourse and narratives. In: Palang, H., Fry, G. (Eds.), Landscape Interfaces. Springer, Netherlands, pp. 21–51.
Keeler, B.L., Wood, S.A., Polasky, S., Kling, C., Filstrup, C.T., Downing, J.A., 2015. Recreational demand for clean water: evidence from geotagged photographs by visitors to lakes. Front. Ecol. Environ. 13, 76–81.
Kizos, T., Dalaka, A., Petanidou, T., 2009. Farmers' attitudes and landscape change: evidence from the abandonment of terraced cultivations on Lesvos Greece. Agric. Hum. Values 27, 199–212.
Kuemmerle, T., Hostert, P., Radeloff, V.C., van der Linden, S., Perzanowski, K., Kruhlov, I., 2008. Cross-border comparison of post-socialist farmland abandonment in the carpathians. Ecosystems 11, 614–628.
Levers, C., Verkerk, P.J., Müller, D., Verburg, P.H., Butsic, V., Leitão, P.J., Lindner, M., Kuemmerle, T., 2014. Drivers of forest harvesting intensity patterns in Europe. For. Ecol. Manage. 315, 160–172.
Lieskovský, J., Kanka, R., Bezák, P., Štefunková, D., Petrovič, F., Dobrovodská, M., 2013. Driving forces behind vineyard abandonment in Slovakia following the move to a market-oriented economy. Land Use Policy 32, 356–365.
Lieskovský, J., Kenderessy, P., Špulerová, J., Lieskovský, T., Koleda, P., Kienast, F., Gimmi, U., 2014. Factors affecting the persistence of traditional agricultural landscapes in Slovakia during the collectivization of agriculture. Landsc. Ecol. 29, 867–877.
Macours, K., Swinnen, J.F.M., 2000. Causes of output decline in economic transition: the case of central and eastern european agriculture. J. Comp. Econ. 28, 172–206.
Marshall, E.J.P., Moonen, A.C., 2002. Field margins in northern Europe: their functions and interactions with agriculture. Agric. Ecosyst. Environ. 89, 5–21.
Martínez Pastur, G., Peri, P., Lencinas, M., García-Llorente, M., Martín-López, B., 2015. Spatial patterns of cultural ecosystem services provision in Southern Patagonia. Landsc. Ecol, 1–17.
Meeus, J.H.A., 1995. Pan-European landscapes. Landsc. Urban Plann. 31, 57–79.
Nabuurs, G.-J., Schelhaas, M.-J., Mohren, G.M.J., Field, C.B., 2003. Temporal evolution of the European forest sector carbon sink from 1950 to 1999. Global Change Biol. 9, 152–160.
Neumann, K., Elbersen, B.S., Verburg, P.H., Staritsky, I., Pérez-Soba, M., de Vries, W., Rienks, W.A., 2009. Modelling the spatial distribution of livestock in Europe. Landsc. Ecol. 24, 1207–1222.
Overmars, K.P., Schulp, C.J.E., Alkemade, R., Verburg, P.H., Temme, A.J.A.M., Omtzigt, N., Schaminée, J.H.J., 2014. Developing a methodology for a species-based and spatially explicit indicator for biodiversity on agricultural land in the EU. Ecol. Indic. 37, 186–198.
Palang, H., Printsmann, A., Gyuró, É.K., Urbanc, M., Skowronek, E., Woloszyn, W., 2006. The forgotten rural landscapes of Central and Eastern Europe. Landsc. Ecol. 21, 347–357.
Palang, H., 2010. Time boundaries and landscape change: collective farms 1947–1994. Eur. Countrys. 2.
Panoramio, 2015. Panoramio API (Accessed 11 January 2015).
Paracchini, M.L., Capitani, C., 2011. Implementaion of a EU wide indicator for the rural-agrarian landscape. In: JRC Scientific and Technical Reports. Joint Research Centre of the European Commission.
Paracchini, M.L., Rega, C., Bulgheroni, C., Leip, A., 2014. Energy Content Output (ECO) index. In: Scenarios Comparison Visions of Land Use Transitions. VOLANTE.
Pereira, H.M., Leadley, P.W., Proença, V., Alkemade, R., Scharlemann, J.P.W., Fernandez-Manjarrés, J.F., Araújo, M.B., Balvanera, P., Biggs, R., Cheung, W.W.L., Chini, L., Cooper, H.D., Gilman, E.L., Guénette, S., Hurtt, G.C., Huntington, H.P., Mace, G.M., Oberdorff, T., Revenga, C., Rodrigues, P., Scholes, R.J., Sumaila, U.R., Walpole, M., 2010. Scenarios for global biodiversity in the 21st century. Science 330, 1496–1501.
Phillips, A., 1998. The nature of cultural landscapes — a nature conservation perspective. Landsc. Res. 23, 21–38.
Plieninger, T., Bieling, C., 2012. Resilience and the Cultural Landscape: Understanding and Managing Change in Human-Shaped Environments. Cambridge University Press.
Plieninger, T., Bieling, C., 2013. Resilience-based perspectives to guiding high nature value farmland through socio-economic change. Ecol. Soc. 18, 20.
Plieninger, T., Pulido, F.J., Konold, W., 2003. Effects of land-use history on size structure of holm oak stands in Spanish dehesas: implications for conservation and restoration. Environ. Conserv. 30, 61–70.
Plieninger, T., Höchtl, F., Spek, T., 2006. Traditional land-use and nature conservation in European rural landscapes. Environ. Sci. Policy 9, 317–321.
Plieninger, T., Kizos, T., Bieling, C., Le DÛ-Blayo, L., Budniok, M.-A., Bürgi, M., Crumley, C.L., Girod, G., Howard, P., Kolen, J., Kuemmerle, T., Milcinski, G., Palang, H., Trommler, K., Verburg, P.H., 2015. Exploring ecosystem-change and society through a landscape lens: recent progress in European landscape research. Ecol. Soc. 20.
Rössler, M., 2006. World heritage cultural landscapes: a UNESCO flagship programme 1992–2006. Landsc. Res. 31, 333–353.
Richards, D.R., Friess, D.A., 2015. A rapid indicator of cultural ecosystem service usage at a fine spatial scale: content analysis of social media photographs. Ecol. Indic. 53, 187–195.
Schaich, H., Bieling, C., Plieninger, T., 2010. Linking ecosystem services with cultural landscape research. GAIA – Ecol. Perspect. Sci. Soc. 19, 269–277.
Schulp, C.J.E., Lautenbach, S., Verburg, P.H., 2014. Quantifying and mapping ecosystem services: demand and supply of pollination in the European Union. Ecol. Indic. 36, 131–141.
Sutcliffe, L.M., Paulini, I., Jones, G., Marggraf, R., Page, N., 2013. Pastoral commons use in Romania and the role of the Common Agricultural Policy. Int. J. Commons 7, 58–72.
Temme, A.J.A.M., Verburg, P.H., 2011. Mapping and modelling of changes in agricultural intensity in Europe. Agric. Ecosyst. Environ. 140, 46–56.
Tengberg, A., Fredholm, S., Eliasson, I., Knez, I., Saltzman, K., Wetterberg, O., 2012. Cultural ecosystem services provided by landscapes: assessment of heritage values and identity. Ecosyst. Serv. 2, 14–26.
Turner, M.G., 1989. Landscape ecology: the effect of pattern on process. Annu. Rev. Ecol. Syst. 20, 171–197.
Van Berkel, D.B., Verburg, P.H., 2011. Sensitising rural policy: assessing spatial variation in rural development options for Europe. Land Use Policy 28, 447–459.
Van Eetvelde, V., Antrop, M., 2004. Analyzing structural and functional changes of traditional landscapes—two examples from Southern France. Landsc. Urban Plann. 67, 79–95.
Van Zanten, B.T., Verburg, P.H., Koetse, M.J., van Beukering, P.J., 2014. Preferences for European agrarian landscapes: a meta-analysis of case studies. Landsc. Urban Plann. 132, 89–101.
Van Zanten, B.T., Van Berkel, D.B., Meentemeyer, R.K., Smith, J.W., Tieskens, K.F., Verburg, P.H., 2016. Continental scale quantification of landscape values using

social media data. Proceedings of the National Academy of Sciences in the United States of America (in press).
Van der Hoek, K.W., 1998. Nitrogen efficiency in global animal production. Environ. Pollut. 102, 127–132.
Van der Zanden, E.H., Verburg, P.H., Mücher, C.A., 2013. Modelling the spatial distribution of linear landscape elements in Europe. Ecol. Indic. 27, 125–136.
Van der Zanden, E.H., Levers, C., Verburg, P.H., Kuemmerle, T., 2016a. Representing composition, spatial structure and management intensity of European agricultural landscapes: a new typology. Landsc. Urban Plann. 150, 36–49.
Van der Zanden, E.H., 2016b. Agricultural Landscapes in Europe: Spatial Structure, Land Management and Consequences of Agricultural Abandonment. Vrije Universiteit, Amsterdam.
Verburg, P.H., Schulp, C.J.E., Witte, N., Veldkamp, A., 2006. Downscaling of land use change scenarios to assess the dynamics of European landscapes. Agric. Ecosyst. Environ. 114, 39–56.
Vicente, Á., Alés, R., 2006. Long term persistence of dehesas. Evidences from history. Agrofor. Syst. 67, 19–28.
Vilén, T., Gunia, K., Verkerk, P.J., Seidl, R., Schelhaas, M.J., Lindner, M., Bellassen, V., 2012. Reconstructed forest age structure in Europe 1950–2010. For. Ecol. Manage. 286, 203–218.
Waterton, E., 2005. Whose sense of place? Reconciling archaeological perspectives with community values: cultural landscapes in England. Int. J. Herit. Stud. 11, 309–325.
Wood, S.A., Guerry, A.D., Silver, J.M., Lacayo, M., 2013. Using social media to quantify nature-based tourism and recreation. Sci. Rep. 3, 2976.
Wu, J., 2010. Landscape of culture and culture of landscape: does landscape ecology need culture? Landsc. Ecol. 25, 1147–1150.
Zimmermann, R.C., 2006. Recording rural landscapes and their cultural associations: some initial results and impressions. Environ. Sci. Policy 9, 360–369.