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Sustainable futures for Europe's HERitage in CULtural landscapES: Tools for understanding, managing, and protecting landscape functions and values

GA no. 603447

D5.2 EU scale analysis of future cultural landscape dynamics

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Work package	WP 5 Fine- and broad-scale modelling of future landscapes			
Deliverable nature	Report (R)			
Dissemination level (Confidentiality)	Public (PU)			
Estimated indicated person-months	15			
Date of delivery	Contractual	31 May 2015	Actual	31 May 2015
Version	0.1			
Total number of pages	24			
Keywords	Land use change,			

Executive summary

HERCULES Work Package 5 makes a model-based assessment of processes of change in cultural landscapes. This deliverable evaluates potential future threats to cultural landscapes at a European scale. It is assumed that processes like globalization, demography, and changes in affluence result in a polarization of land use, with urbanization and intensification as well as abandonment threatening the character and functioning of European cultural landscapes. In this deliverable, we analyze how cultural landscapes are expected to change by 2040 under four scenarios.

The scenarios are structured along two axes, one ranging from local development to global development, while the second axis indicates the level of government intervention. Land use and land cover changes under the scenarios were simulated with a coupled set of macro-economic and land use allocation models. Next, these changes were summarized into fourteen trajectories that represent well-known and significant land change trends in Europe, like (peri)urbanization, intensification and extensification of agriculture and forestry, and land abandonment with subsequent rewilding. Cultural landscapes were mapped based on a "Landscape Character Index" (LCI), which is derived from landscape patterns, landscape structure and intensity of land use, and cultural significance. These three variables are commonly considered important features of cultural landscapes. An overlay of the LCI map and the cultural landscape map was made to assess which trajectories were most important for the future of European cultural landscapes.

Between 15% and 30% of the cultural landscapes is expected to face land change up to 2040. Land abandonment and rewilding are expected to affect large areas of European cultural landscapes over the coming 25 years. Urbanization, peri-urbanization, and intensification are a less important and less widespread threat. Stable cultural landscapes are mainly the more varied, but also more remote and less productive areas, which are less competitive on a globalized market. Scenarios with regionally focused development and policies targeted at maintaining the variety of landscapes in Europe partly mitigate the abandonment of cultural landscapes. Abandonment and rewilding of cultural landscapes can result in loss of landscape quality, provision of ecosystem services including support for recreation, and changes in biodiversity.

While there are trade-offs with ecosystem services being enhanced upon abandonment of cultural landscapes, loss of landscape quality and loss of the other, intangible, values of cultural landscapes cannot be easily compensated and are likely to be irreversible.

As agreed during the 2nd consortium meeting, this deliverable focuses on EU scale analysis and provides a large-scale overview of threats to cultural landscapes. However, local variation of management change will have a strong impact on the landscape. These processes are driven by the large-scale drivers analysed here, but also by farm and farmer characteristics such as age, motivation for farming, and local demographic variation. The latter are not captured in this analysis. Deliverable 5.3 will elaborate the impact of these drivers on a selection of cultural landscape case studies and elaborate on European scale impacts.

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1. Introduction

Landscape change is an inherent property of cultural landscapes. Past changes have been decisive for the appearance of the landscape today following long term driving forces (Dearing et al., 2010; van der Leeuw et al., 2011), while European cultural landscapes are changing at present as a result of changes in society, technology, and global trade. Traditional European cultural landscapes are often characterized by low inputs of nutrients, mechanization and pesticides, while their appearance and functioning depends on labour intensive management practices. This is often no longer economically feasible, making these landscapes vulnerable to lose economic competitiveness (Vos and Meekes, 1999). Such changes in economic competitiveness can result in land use and landscape changes that affect the landscape character and functioning.

Current changes in cultural landscapes range from land abandonment in some parts of the landscape to agricultural intensification elsewhere. These two processes together cause a "polarization of land use" (Gellrich and Zimmermann, 2007; Kuemmerle et al., 2008; Navarro and Pereira, 2012; Verburg et al., 2010). Further threats and opportunities for cultural landscapes include tourism and urban sprawl (Vos and Meekes, 1999). The speed of landscape changes in cultural landscapes is believed to be increasing, and new landscapes emerging are considered less diverse than traditional landscapes (Van Eetvelde and Antrop, 2004), and are considered to have lost coherence and identity (Antrop, 2005).

The future of cultural landscapes will build upon past changes that have led to the current state. However, the direction and rate of driving forces of landscape and land use change can entail different future trajectories (Zimmermann, 2006). This depends on the cultural landscape in question, and on external factors including global markets, population dynamics, and climate change.

HERCULES WP5 studies future changes in cultural landscapes, both at the EU scale and in a selection of case studies. In order to assess the future of cultural landscapes, the use of scenarios of possible changes is necessary, because scenarios allow plausible futures of complex systems with uncertain outcomes to be addressed (Zurek and Henrichs, 2007). This deliverable provides a European-scale framework to these analyses, by providing a summary of expected land change trajectories and its impacts in cultural landscapes at European scale. As agreed during the Amsterdam consortium meeting in September 2014, this deliverable focuses on European scale landscape changes. In Deliverable 5.3, case study scale analyses of landscape change will be presented that takes full stock of the stakeholder interaction in the case studies.

2. Methods

To quantify threats and opportunities to cultural landscapes across Europe, we compared a map of European cultural landscapes with projected land changes in four scenarios over the coming decades. This chapter describes the scenarios (section 2.1), land change trajectories that were analysed for their impact on cultural landscapes (section 2.2), the map of European cultural landscapes (section 2.3), and the analyses performed (section 2.4).

2.1. Scenarios

An analysis of future land use changes in Europe up to 2040 has been done in the VOLANTE FP7 project. VOLANTE used a set of explorative scenarios based on SRES as reference scenarios (Figure 1) and additionally explored a range of policy options, which disentangle and highlight the impact of, for example, restrictions on urban sprawl or strongly enhanced nature protection. The reference scenarios cover a broad range of plausible future developments and therefore provide a suitable framework for analyzing changes in European cultural landscapes. In this deliverable, we focus on the main, reference, scenarios (Figure 1). The scenarios are structured along two axes, one ranging from local development to global development, while the second axis indicates the level of government intervention. The four resulting scenarios are:

- *"V-A1 represents a globalised world with strong economic growth, high growth of food and feed demand, weak regulation on land use change, declining tropical forest areas, a fully liberalized CAP, and phased-out bioenergy mandates.*
- *V-A2 represents a fragmented world with modest economic growth, high population growth, high growth of food and feed demand, weak regulation on land use change, declining tropical forest areas, no change in the CAP, and phased-out bioenergy mandates.*
- *V-B1 represents a sustainable world with modest economic growth, slow growth of food and feed demand, strong regulation on land use change, protected tropical forest areas, a liberalized CAP, and modest bioenergy demand.*
- *V-B2 represents a fragmented world with modest economic growth, modest growth of food and feed demand, some regulation on land use change, some protection of tropical forest areas, no change in the CAP, and modest bioenergy demand." (From (Lotze-Campen et al., 2013)).*

Global population in 2040 ranges between 8.5 billion people in the V-A1 and V-B1 scenarios, and 10.3 billion people in the V-A2 scenario. The scenarios do include differences in climate change. Low emissions with climate change of ca. +2°C in 2100 are included in V-B1 and V-B2. Medium emissions with ca. +3°C are assumed in V-A1 while V-A2 assumes a high level of emissions with ca. +4°C in 2100.

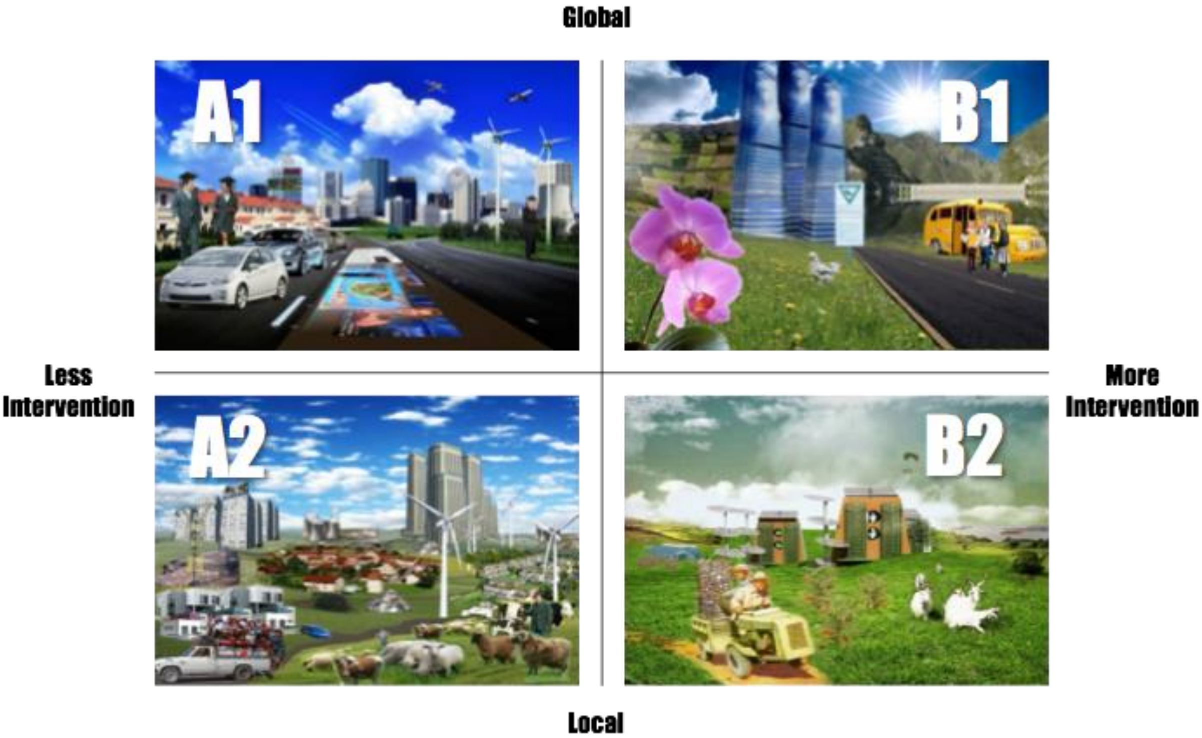

Figure 1: VOLANTE Scenario setup

2.2. Land use change trajectories

Land use and land cover changes under the four scenarios were simulated with a coupled set of macro-economic and land use allocation models. First, population growth, trade patterns, food and bioenergy demands and global scale land use regulations were simulated using the combined models ReMIND/MAGPIE (Lotze-Campen et al., 2008; Luderer et al., 2013). With these outputs, the global equilibrium model LEITAP/MAGNET was used to simulate global changes in land use, agricultural production and consumption patterns, and regional sub-sector specific changes in bilateral trade flows while future trends in forest production were simulated with the global forestry model EFI-GTM. These outputs were fed into the agricultural economic model CAPRI (Britz et al., 2011) with which region and product specific yields and fertilizer use were simulated, and into the forest resource projection model EFISCEN (Schelhaas et al., 2007). Outcomes of these models are typically at the national or sub-national level. With the Dyna-CLUE model, these outputs were disaggregated into land cover and land management maps at 1km resolution (Temme and Verburg, 2011; Verburg et al., 2012; Verburg and Overmars, 2009). Dyna-CLUE simulates competition between land uses, combined with spatial allocation rules that define location suitability for land use types, conversions between land use types, impact of spatial policies, and neighbourhood characteristics (Verburg et al., 2010). Regrowth of natural vegetation was simulated as a function of the local growing conditions, and pressures from human population density, grazing and management (Verburg and Overmars, 2009). The model uses a 1-year timestep, 1 km spatial resolution and distinguishes 17 land use types, based on a spatially and thematically aggregated version of the CLC2000 land cover map (EEA, 2000; Schulp et al., 2014c; Verburg and Overmars, 2009).

Next, land use intensity was mapped. In arable land nitrogen application rates were used as an indicator. This was simulated by the CAPRI model and disaggregated to 1km resolution following the approach described by Temme and Verburg (2011). For pastures, livestock numbers simulated with CAPRI were disaggregated based on grazing probability maps (Neumann et al., 2009). Forest intensity was mapped based on wood removels which were downscaled based on tree species maps and harvest likelihood maps (Brus et al., 2011; Verkerk et al., 2011).

Land use and land cover changes were summarized into fourteen land change trajectories that represent well-known and significant land change trends in Europe (Sturck et al., 2015) (Table 1).

Table 1: Land change processes considered (From (Sturck et al., 2015)).

Land change trajectory	*Short description*	*Classification rules*
Stability	No change in land cover nor land management intensity	All grid cells covered by a dynamic land cover category (built-up area, cropland (incl. permanent crops), pasture, (semi-)natural land), and forest) in the reference year, for which neither land cover nor management intensity category changed in the scenarios.
Intensification and de-intensification	Change in land management intensity	Increase or decrease in (a) fertilizer use on cropland (b) grazing intensity on pastures (c) wood removals in forests. All grid cells which had a higher (lower) intensity category than the reference year were considered intensifying (de-intensifying). Changes in wood removals of more than 25% compared to the reference year were considered intensifying or de-intensifying.
Expansion and decline	Land cover conversions	All grid cells covered by any dynamic land cover category (see stability), that converted to another land cover category in the scenarios
Land abandonment	Conversion of agriculture to green space	Conversion of agriculture (i.e., cropland and pasture) in the reference year to green space (i.e., forest or (semi-)natural vegetation) in the scenarios
Recultivation of green space	Conversion of green space to agriculture	All grid cells covered by green space (i.e., forest or (semi-)natural vegetation) in the reference year, that converted to agriculture in the scenarios
Recultivation of pasture	Conversion of pasture to cropland	All grid cells covered by pasture in the reference year, which land cover converted to cropland in the scenarios
Polarization of rural land	Parallel land abandonment and intensification in remaining agriculture patches	Land abandonment and agricultural intensification extracted based on land masks which reflect extent of land abandonment and average intensification within a radius of 15km
Urban growth	Growth of built-up area which adds to an urban core	Urban cores were derived from DGUR (degree of urbanization typology) available from Eurostat (2001), and merged with the extent of built-up area in the reference year to distinguish urban agglomerations from other built-up areas. DGUR used information on minimum population and population density to define urban cores. Expansion of built-up area was only identified as urban growth if it led to the expansion of an urban core in immediate adjacency.
Peri-urban growth	Growth of built-up area located in the rural-urban fringe	The rural-urban fringe captured an area between the outskirts of an urban agglomeration and the countryside. We varied the size of the rural-urban fringe with respect to the size of the urban cores by using a diameter of twice the radius of the urban core to delineate the extent of the rural-urban fringe. When an urban core expanded in a scenario, its associated rural-urban fringe expanded proportionally. New built-up area located within the expanding rural-urban fringe in a scenario was addressed as peri-urban growth.
Expansion of wild areas	Conversion of agriculture and intensively managed forest to a more natural vegetation cover, adding to contiguous patches of nature	Wild areas were defined as contiguous patches of nature larger than 1000 km^2. Nature could comprise all land cover which was not covered by built-up area, agriculture, pastures, and intensively managed forests. Nature in adjacency to built-up area or agriculture was not considered eligible as a part of wild area. Only patches showing net growth of wild area were considered. Pixels which contributed to their growth were considered expansion of wild areas.
Contraction of wild areas	Conversion of wild areas to built-up area, agriculture or high intensity forest	Wild areas (see Expansion of wild areas) were identified for the reference year. Pixels which were part of wild areas in the reference year and converted to agriculture, intensive forestry, or built-up area during the scenario were considered as contraction of wild areas.

Each land use trajectory was characterized by (1) decreasing or increasing human impact on the landscape, and (2) a scale of the impact, ranging from local to regional scale (Sturck et al., 2015). For example, while agricultural intensification denotes increasing human impact and can occur on a local scale, re-wilding includes decreasing human impacts and by definition occurs on a larges spatial scale given that it contributes to the expansion of large nature patches. Figure 2 displays hotspots of land use change trajectories in the four scenarios.

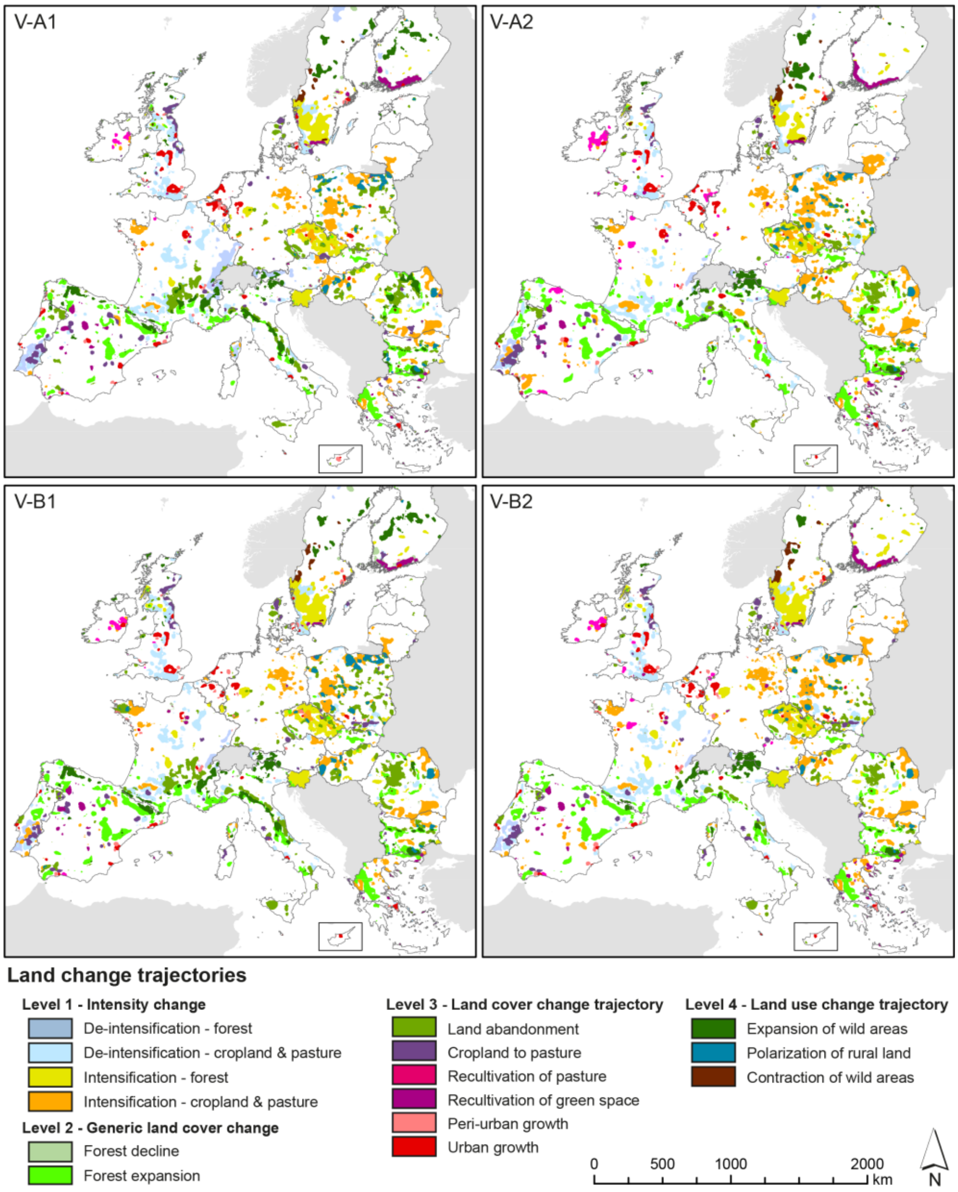

Figure 2: Hotspots of land change

2.3. Mapping cultural landscapes

Commonly, landscape patterns, landscape structure and intensity of land use, and cultural significance are considered important features of cultural landscapes (Plieninger et al., 2015; Tieskens et al., 2015; 2014). Whereas an industrial landscape has large geometrically shaped field where heavy machinery can find its way for high intensity agriculture, more traditional landscapes are situated on smaller patches and with chaotic forms and ample landscape elements, while intensity is mostly low (Van Eetvelde and Antrop, 2004). The third and last dimension is less tangible than the previous two and encompasses the cultural significance of the landscapes. Based on maps of landscape patterns, landscape structure and intensity of land use, and cultural significance, we mapped a European scale "Landscape Character Index" (Hereafter abbreviated as LCI).

First, each dimension was mapped individually. Landscape structure in agricultural landscapes was quantified using a map of the density of green linear elements, as derived by upscaling LUCAS observations (van der Zanden et al., 2013). Additionally, field size map was used (Kuemmerle et al., 2013b). Both maps were normalized to a zero-one range and the average value was calculated. Forest age, quantified using a time series of land cover maps ranging from 1900 to 2000, was normalized to a zero-one range and used as an indicator for landscape structure in forests (Tieskens et al., 2015). The landscape structure maps of forests and agricultural land were subsequently merged into a wall-to-wall map.

For pastures and arable land, the intensity maps as described in section 2.2 for the year 2000 were applied as indicators for land use intensity. This indicator is not available for permanent crops or forest. Therefore, for permanent crops the sum of food, feed, pruning, residues, and straw as derived from the CAPRI model is used as an indicator (Paracchini and Capitani, 2012). For forest, harvesting intensity is used (Levers et al., 2014). Land use intensity maps for individual land use types were normalized to a zero-one range, where zero denotes a low intensity and one a high intensity, and merge into a single map.

To quantify the cultural significance of landscapes, we used a spatially explicit database of food products with a Protected Designation of Origin (PDO) (Tieskens et al., 2015). A PDO is either linked to an administrative region, or to a (number of) village(s). The number of PDOs per region was counted, or the production region for each PDO was defined as a 5km radius around the villages. The number of PDOs per region varied between 0 and 12. This was normalized into a zero-one index by dividing by 12.

To combine the individual maps of the three dimensions into a single LCI map, an average value of the landscape structure, land use intensity, and cultural significance maps was calculated (Tieskens et al., 2015) (Figure 3). This was done under the assumption that the dimensions individually contribute to the landscape character and can compensate each other. For example, the Achterhoek region in the East of the Netherlands is seen as a characteristic cultural landscape due to its distinct structure with small fields and many green linear elements unless the high land use intensity compared to other European regions.

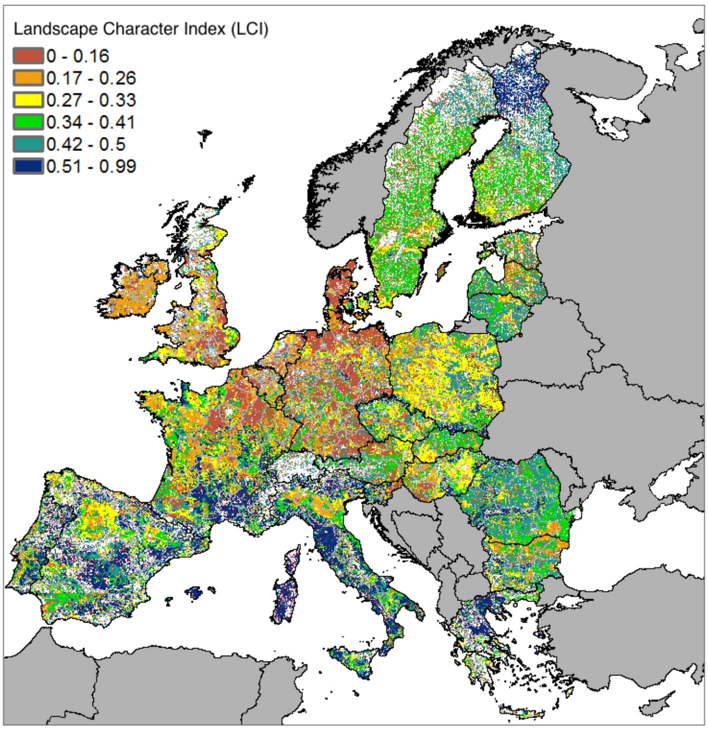

Figure 3: Landscape Character Index (LCI) of European landscapes. Countries in grey are not considered. Areas in white have "no data" value due to missing input data.

2.4. Analyses

The land change trajectory maps for the scenarios described in Section 2.2 were systematically compared with the LCI map (Section 2.3). First, local occurrence densities of land change trajectories were calculated. Based on a 10,000-point sample distributed weighted by area across the LCI classes, correlations between LCI levels and land change trajectory occurrence was calculated. Second, for each land change trajectory, we quantified if it was over- or underrepresented in areas with a high LCI. A high LCI was defined as LCI values >66%. Areas within and outside each trajectory and high-LCI areas were calculated. Expected areas upon equal distribution were calculated by:

*Expected area = (Area with high LCI * area within land change trajectory) / total area*

Next, the ratio between the observed area and the expected area was calculated. For visualization purposes, ratios were calculated separately for underrepresented and overrepresented trajectories where underrepresented trajectories were multiplied by -1. Also, one was subtracted from the ratios to have zero as a central value.

Finally, for the land change trajectories that were most heavily impacting landscapes with a high LCI, a visual comparison between locations of land change and locations of landscapes with a high LCI was done. Areas with a hotspot of each land change trajectory (defined as locations undergoing the land change trajectory in each scenario) and locations where the land change trajectory occurred in three or less scenarios were identified and overlayed with the map indicating areas with a high LCI. The levels of the underlying dimensions (landscape structure, intensity, and cultural significance) were checked and interpreted visually.

3. Results

3.1. Threats and opportunities to cultural landscapes

Overall, between 900 000 (V-A2) and 1135 000 (V-B1) km^2 land is expected to change between 2000 and 2040. This is not equally distributed over the levels of the LCI. **Figure 4** shows that in areas with a high LCI between 15% (V-A2) and 30% (other scenarios) is undergoing land change. Areas with a high LCI are dominantly forest (60%) and approx. 40% agricultural land. In areas with a low LCI, 24% (V-A2) to 27% (V-B1 and V-B2) of the area is affected by land change. In all scenarios except V-A2, areas with a high LCI are somewhat more changing than areas with a low LCI. In terms of area, forest intensification is the most important land change trajectory in all scenarios but V-A2.

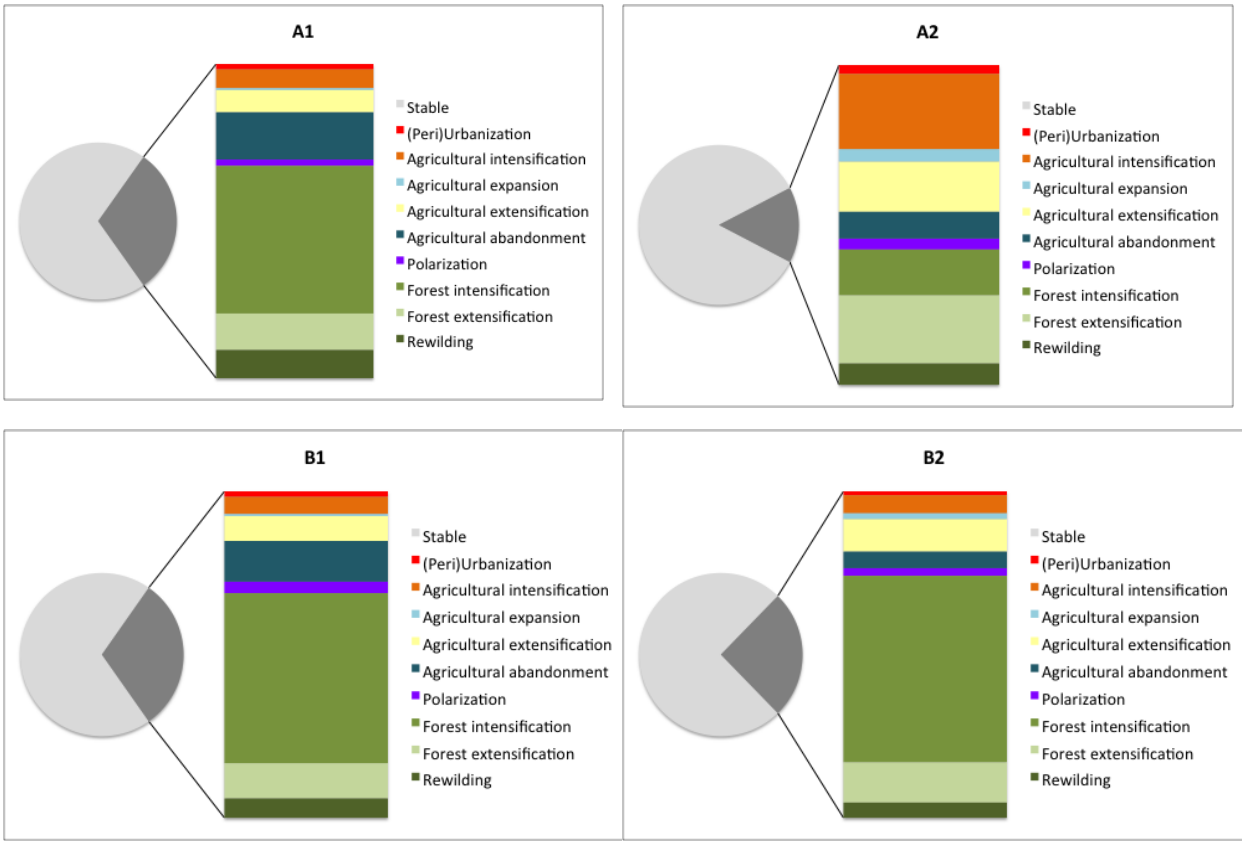

Figure 4: Overview of land change trajectories in all scenarios.

This is also demonstrated with Table 2. There is a clear negative correlation between the LCI and the occurrence of not-changing land, but for V-A2 the relation is less strong than for the other land change trajectories. Table 2 furthermore indicates that (peri)urbanization and intensification of arable land occur more frequently on areas with a low LCI, while land abandonment and rewilding occur more frequently on areas with a high LCI. For polarization, there are pronounced differences between the scenarios. The "regulation" scenarios (V-A2 and V-B2) show now differences across LCI levels, while the V-A1 and V-A2 scenarios have opposite effects.

Table 2: Correlation between LCI and occurrence density of land change trajectory. "ns" indicates non significant correlations ($p<0.05$).

Correlation	V-A1	V-A2	V-B1	V-B2
Urbanization	-0.47	-0.53	-0.39	-0.46
Periurbanization	-0.33	ns	-0.47	-0.48
Pasture intensification	ns	ns	ns	ns
Cropland intensification	-0.33	-0.27	-0.37	-0.33
Recultivation Pasture	-0.50	-0.21	-0.22	ns
Recultivation Nature	-0.70	-0.67	-0.76	-0.70
Contraction Wild Areas	-0.30	-0.31	-0.30	-0.30
Polarization	-0.27	0.25	ns	ns
Pasture extensification	0.34	0.37	0.37	0.37
Cropland extensification	-0.50	ns	-0.44	-0.48
Cropland to pasture	ns	0.37	0.41	0.45
Land abandonment	0.37	0.46	0.20	0.37
Rewilding	0.49	0.36	0.46	0.41
Forest intensification	0.39	-0.34	0.37	0.32
Forest extensification	0.42	0.42	0.42	0.42
Stable	-0.64	-0.30	-0.63	-0.63

Figure 5 shows the factor by which each land change trajectory is under- or overrepresented in areas with a high LCI compared to what could be expected under an equal distribution. Most land change trajectories are either underrepresented or overrepresented in all scenarios. While forest extensification, rewilding, and pasture intensification are overrepresented in all scenarios, polarization, contraction of wild areas, recultivation of nature, cropland intensification and (peri)urbanization are underrepresented in all scenarios. Forest intensification is overrrepresented in all scenarios except V-A2 and cropland-pasture conversion and pasture extensification are overrepresented in all scenarios except V-A1.

In terms of area, forest intensification is the dominant process, affecting 2.2% (V-A2) to 14.7% (V-A1) of the area with a high LCI (Figure 4). Land abandonment and rewilding together affect 2.3% (V-A2) to 7.5% (A1) of the area with a high LCI. Agricultural intensification is widespread in V-A2 where it affects 3.6% of the area.

The most important land change trajectories in areas with a high LCI are ***Forest extensification, Forest intensification, Rewilding,*** and ***Cropland to pasture conversion***. Additionally, land abandonment (all scenarios except V-A2) and agricultural intensification (V-A2) can affect large areas.

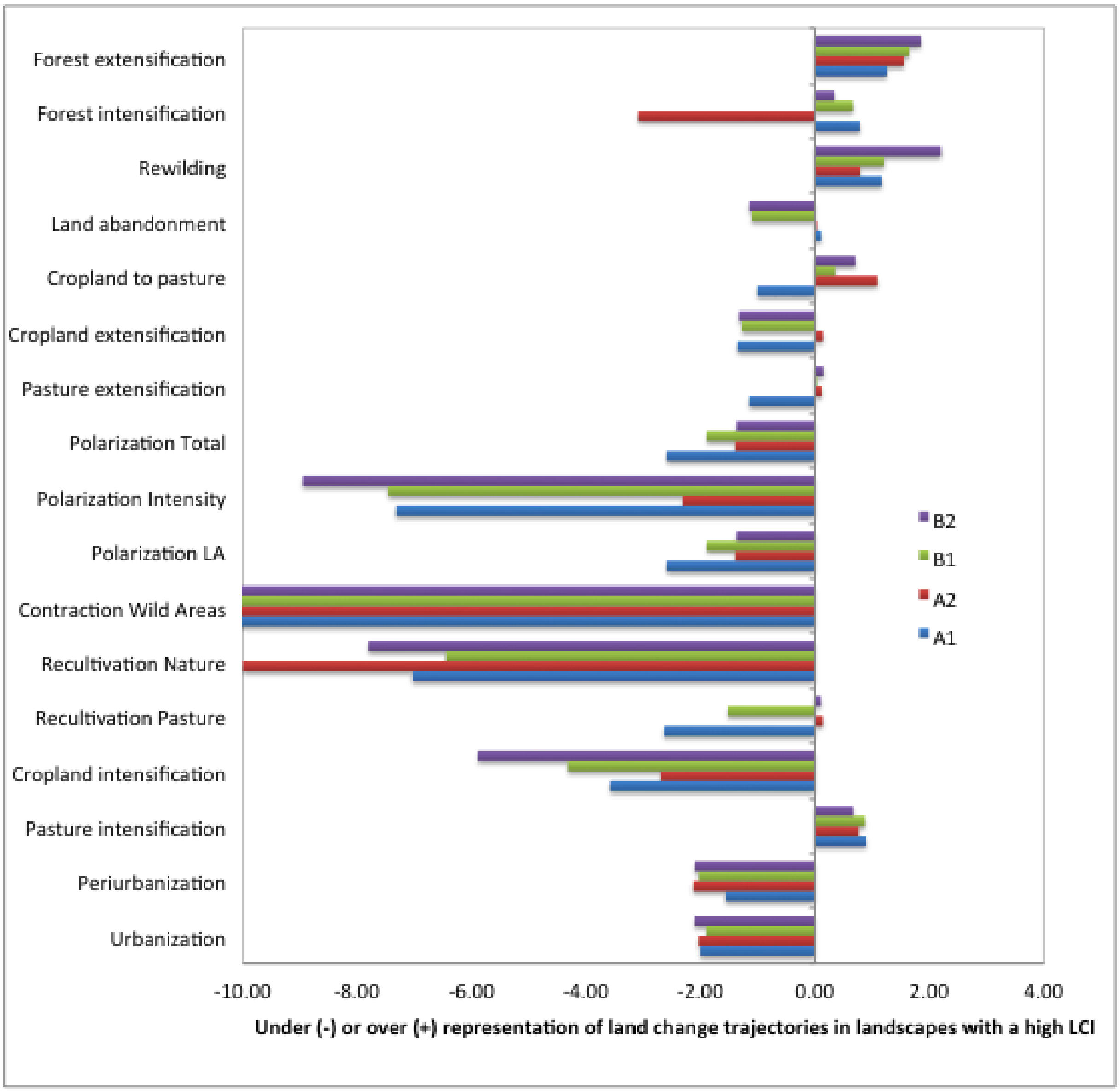

Figure 5: Under- or overrepresentation of each land change trajectory in landscapes with a high LCI.

3.2. Spatial distribution of threats and opportunities of cultural landscapes

Figure 6 shows where the major land change trajectories affect landscapes with a high LCI in all four scenarios, or in at least one of the scenarios. Forest extensification affects landscapes in the Alps, Pyrennees, Portugal and Finland in all scenarios. Additional impact is seen in Southern Spain in a few of the scenarios. In all these regions except the southern half of Portugal, these areas include many relatively old forests (high scores on "structure" dimension) and are already relatively extensive.

Forest intensification occurs in the same areas, but is wider spread through Spain, France, and Italy. The hotspots of forest intensification (occurring in all four scenarios) are also including many relatively old forests while the areas where forest intensification occurs in fewer scenarios are of moderate age. Forest intensification occurs both on already intensive areas as well on currently extensive forests.

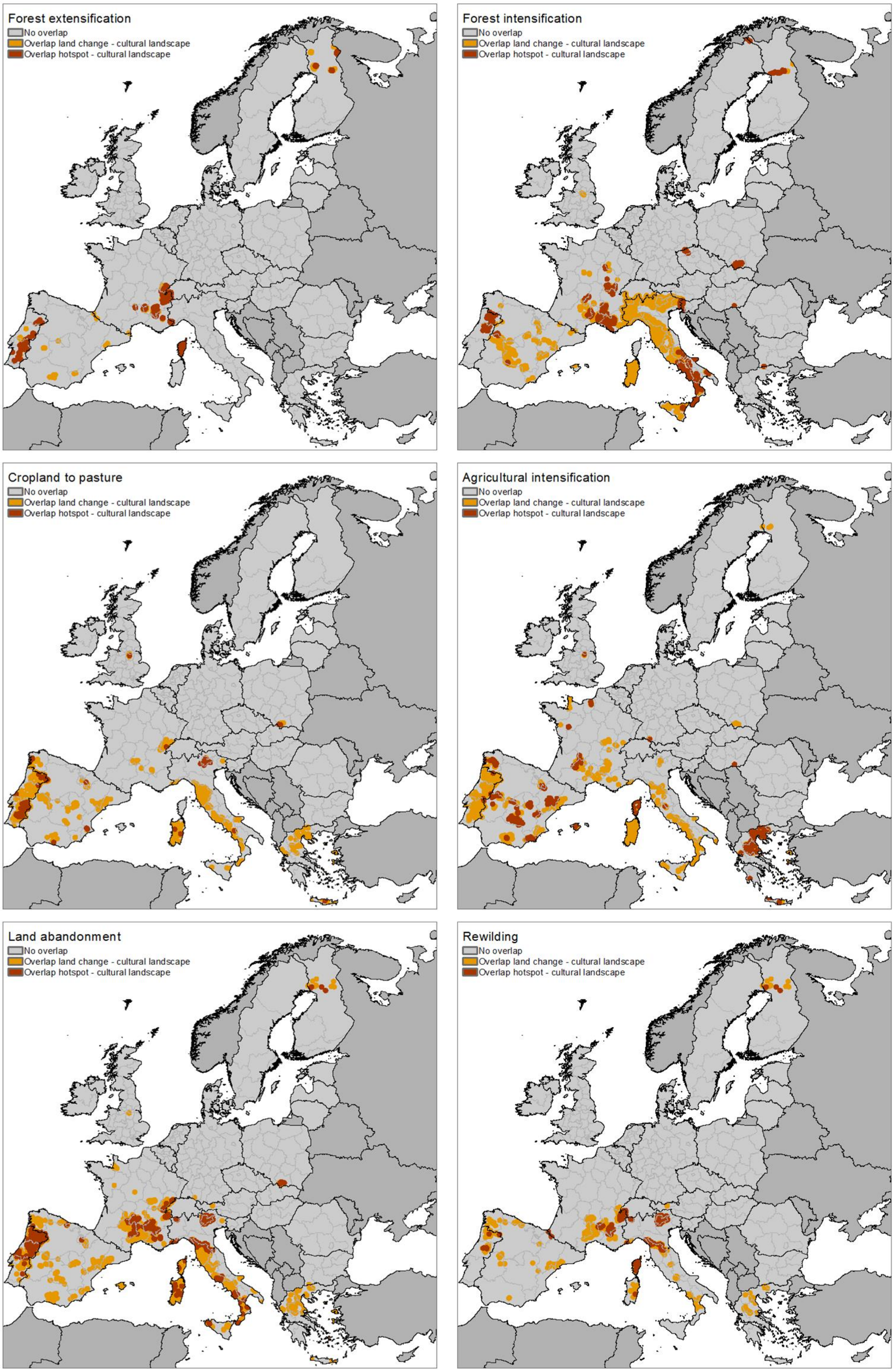

Figure 6: Overlap between land change trajectories and areas with a high LCI. A filter highlighting a 25km radius around land change –high-LCI-landscape overlap was applied for the sake of clarity.

Rewilding affects cultural landscapes throughout the southern European maintain ranges (Alps, Apennines, Pyrennees) and Portugal and Greece, while land abandonment affects cultural landscapes in large parts of Portugal, southeastern France, and Italy in all scenarios. Cultural landscapes in almost the whole of Spain are possibly affected by land abandonment in a few of the scenarios. The cultural landscapes facing abandonment or rewilding are currently extensively managed landscapes that are relatively important sources of products with PDO designation. These land change trajectories do not show clear impact on cultural landscapes with a distinct landscape structure.

Cropland-to-pasture conversions occur on cultural landscapes in Portugal and on the Mediterranean islands in all four scenarios while in few scenarios cultural landscapes in large parts of Spain, France, Italy, and Greece are affected. Cropland-to-pasture conversions are common on relatively extensively managed areas.

Agricultural intensification is expected to affect cultural landscapes in Spain and Greece in all scenarios. Additional impacts in the V-A2 scenario are simulated in Spain, Southern France, Portugal, and Italy. These areas are currently characterized by relatively extensive management and include hotspots for products with a PDO designation.

4. Discussion

4.1. Threats to cultural landscapes

Forestry changes are assumed to respond to increases in demand for wood for material and biomass energy. Increased felling (i.e., increased intensity) is expected throughout the EU, except in Southwest Europe, where increases are more marginal (Tucker et al., 2013). Strongest increases are expected in V-A2, given the strong population and GDP growth. Changes in the forest sector are mainly expressed as changes in intensity, less so by changes in area. The increasing demand for wood is, therefore, realized through changes in harvest intensity (Lotze-Campen et al., 2013). Forest expansion is to a large extent through land abandonment and not yet taken into production, while also forest area is kept for biodiversity conservation (UNECE FAO Forestry and Timber Section, 2011).

Over the past decades, abandonment of agricultural land was concentrated in areas with moderate to strong biophysical constraints to agricultural production, such as dry regions or areas with other climatic constraints, soils with low or very high soil organic matter content or low clay content, and in specific countries, which is likely a proxy for institutional drivers for land abandonment (BIO et al., 2014; Hart et al., 2012; Hatna and Bakker, 2011; Van Vliet et al., 2015). These areas are currently often covered with extensive arable or mixed farming systems (Hart et al., 2012) and are likely to have a high LCI.

In the future, the same areas are believed to remain vulnerable to abandonment. Most drivers for abandonment, including the institutional drivers and increasing exposure to global markets, are believed to remain or intensify. The highest levels of abandonment are expected for scenarios that assume global competition in agriculture and low CAP support for extensive farming. This is consistent with other European scale land use predictions (van der Zanden et al., 2015). Interaction with marginal local conditions might further increase abandonment (BIO et al., 2014; Keenleyside and Tucker, 2010). This is clearly reflected in the spatial pattern of abandonment. Policies included in the V-A2 scenario including CAP and LFA measures seem to have the capacity to reduce this abandonment in many cultural landscapes, which is consistent with findings of Keenleyside and Tucker (2010). Additionally, protection from global markets might be beneficial for these areas.

In this analysis, land abandonment is simulated as one single, relatively small-scale process. In reality, land abandonment can emerge as *(a) Actual abandonment*, where the farmland is not used at all; *(b) hidden abandonment*, where the land is only used with a very low level of management, generally just enough to meet requirements to be able to claim direct payments from the CAP; or *(c) transitional abandonment* areas that can move in and out of agricultural use depending on market prices for certain commodities (Hart et al., 2012). Depending on local-scale variation of drivers for abandonment including e.g. farmers attitude and local demographical dynamics (Van Vliet et al., 2015), the abandonment simulated in this analysis might work out in one of these three ways. This would require a more detailed, local-scale analysis.

Although rewilding is highly variable across the scenarios in extent and location (Sturck et al., 2015), this land change trajectory is consistently overrepresented in landscapes with a high

LCI (Figure 6, Table 2). Rewilding is stimulated by land abandonment, that allows for regrowth of nature. Consequently, more rewilding occurs in scenarios with more abandonment, being the scenarios that assume global competition in agriculture and low CAP support for extensive farming. Rewilding is spatially constrained to areas closer to existing large-scale nature patches. These are often remote areas, which are marginal for agriculture due to, among others, the marginal location.

Pasture expansion due to conversion from cropland mainly occurs along fringes of agricultural area (Sturck et al., 2015) on the more marginal croplands where crop production is not competitive.

Agricultural intensification in cultural landscapes is seen in the same regions as forest intensification in Spain and France. Over the recent past, a trend towards increased specialization and input intensification has been observed. This was to a large extent explained by institutional factors and additionally by suitable biophysical conditions and accessibility (Kuemmerle et al., 2013a; Van Vliet et al., 2015). These factors tend to exclude factors explaining the presence of cultural landscapes. Future scenarios of land use change in Europe often expect a further polarization of land use, with further intensification on already intensive areas, which mainly excludes cultural landscapes. Given increasing food and energy crop production demand, particularly in the “market” scenarios (A1 and A2; Figure 1), increasing production is seen anyway and is also expected to influence cultural landscapes. Cultural landscapes undergoing intensification in all scenarios (hotspots, Figure 6) tend to be on more accessible, less marginal locations. Visual comparison of the LCI map (Figure 3) with a map of capacity for development of intensive agriculture (Van Berkel and Verburg, 2011) indicates that most landscapes with a high LCI have low to intermediate capacities for intensification.

Just as for abandonment, there is a wide variety in management practices captured within the “agricultural intensification” trajectories. These can include intensification of fertilizers, livestock density, pesticides, or labor. These differences have different impacts on the landscape and are driven by additional drivers of land change, including farm and farmer characteristics (Van Vliet et al., 2015).

Urbanization is largest in Western Europe, with urban sprawl being common in Belgium and the Netherlands. Peri-urban growth is widespread in Western Europe, Spain, Portugal and Greece. In western Europe, LCIs are commonly relatively low (Figure 3). Agricultural areas in western Europe are among the most intensive (Overmars et al., 2014), while also landscape elements that provide structure to the landscape tend to have disappeared in these areas that are highly accessible (van der Zanden et al., 2013). In Western Europe, there are small, scattered patches of landscapes with a high LCI while the large extents are in more remote areas in southern and eastern Europe, which are, because of that location, less prone to urban and peri-urban expansion. Only along the Mediterranean, there is some overlap between landscapes with a high LCI and urban or peri-urban expansion. This is likely to include building development to support increasing tourism.

Polarization as a single land change trajectory is not clearly affecting cultural landscapes. Landscapes with a high LCI are affected by polarization on a large scale than quantified in this study, where the landscapes with a high LCI overlap with the more marginal areas that face abandonment and subsequent rewilding (Figure 6). The related intensifying areas are more found in Northern and Western Europe (Kuemmerle et al., 2013a; Sturck et al., 2015).

4.2. Impacts of land change on cultural landscapes

Cultural landscapes are valued as living environment, aesthetically pleasing countryside, heritage, recreational landscapes (Plieninger et al., 2006), host unique biodiversity (Donald et al., 2002), and are assumed to be important areas for providing ecosystem services (Schulp et al., 2014b). Provision of these services and public goods is dependent on continuation of specific land use and management practices that support the values currently provided by the landscape. The land change trajectories mapped here will affect the status of these public goods.

Land abandonment can emerge in very different ways (Hart et al., 2012) but will result in decreasing intensity or discontinuation of landscape management. For example, maintenance of structuring elements likes terraces or hedges can be abandoned (Deckers et al., 2005; Kizos and Koulouri, 2006), or spontaneous regrowth of natural vegetation can occur. Given that inhabitants often appreciate varied landscapes with elements like hedges, this can lead to loss of landscape character and visual appreciation of the landscape (Kienast et al., 2012; Paracchini et al., 2014; Van Berkel et al., 2011; Van Berkel and Verburg, 2014; Van Zanten et al., 2014). Also, upon abandonment the accessibility of the landscape to recreants decreases, limiting the actual availability of land to recreate.

With respect to ecosystem services, very varied impacts of abandonment are to be expected. Land abandonment is supposed to be associated with increase in biomass, which is beneficial for sequestration of carbon in soil and vegetation (Schulp et al., 2008), although for soil organic carbon stocks effects are mixed (Gabarrón-Galeote et al., 2015; Post and Kwon, 2000). Capacity to retain water and regulate floods is often believed to increase upon abandonment, while for erosion control effects are very mixed and strongly dependent on management (Van der Zanden et al., 2015). Pollinator communities are favoured by abandonment (Barral et al., 2015), but given the associated abandonment of crop production this does not favour the actual supply of the service (Schulp et al., 2014a; Serna-Chavez et al., 2014).

For biodiversity, rather a change of species communities could be expected than a general increase or decrease of diversity. Generally, species adapted to open habitats disappear while species related to closed habitats are favoured (Van der Zanden et al., 2015). The possibility of development of large-scale natural areas or wilderness is often seen as an asset (Keenleyside and Tucker, 2010; Navarro and Pereira, 2012; Van der Zanden et al., 2015) but in these cases trade-offs with loss of landscape character would need to be considered.

Although urbanization and peri-urbanization affect only small parts of cultural landscapes, the impact of these changes on the landscape is strong. Both biodiversity and potential ecosystem service supply are strongly influenced (Bennett et al., 2009; Tucker et al., 2013), but also the environmental pressure on the surrounding landscape increases due to increased population density and increased accessibility (e.g., (Boithias et al., 2013)).

For the areas that face intensification, the exact type and amount of impact is difficult to forecast. Intensification can involve scale enlargement that negatively affects landscape character, increased use of pesticides and fertilizer that can impact biodiversity or ecosystem services, or can involve increased mechanization.

5. Conclusions and recommendations

This deliverable provides a large-scale overview of threats to cultural landscapes in Europe. While it is often assumed that cultural landscapes are threatened by urban sprawl and polarization of land use, this analysis showed that mainly land abandonment and subsequent rewilding is expected to affect cultural landscapes. Urbanization does affect cultural landscapes along the Mediterranean coasts while there is some intensification on cultural landscapes. Nevertheless, these land use trajectories are underrepresented on cultural landscapes compared to other landscapes.

Abandonment and rewilding of cultural landscapes can result in loss of landscape quality, provision of ecosystem services including support for recreation, and changes in biodiversity. While there are trade-offs with ecosystem services being enhanced upon abandonment of cultural landscapes, loss of landscape quality and loss of the other, intangible, values of cultural landscapes cannot be easily compensated and are likely to be irreversible.

These expected changes are for a large part scenario dependent. While few cultural landscapes face the threat of abandonment in all scenarios, the analysis showed that scenarios with CAP support and protection from global markets can limit loss of cultural landscapes.

The scenarios used in this analysis do include some of the major policies affecting land use change in the European Union, like the Habitat and Bird Directive (Natura2000 areas) and the Common Agricultural Policy. Several other policies that could influence land use decisions are not included. The Water Framework Directive for example might place additional restrictions on land take or specific land use conversions at specific locations while the Biodiversity Strategy can reduce land take and gross land use change, especially in protected areas (BIO et al., 2014; Schulp et al., 2014c). Additionally, several recent changes in EU policy context demonstrate an increasing attention for land use and land functions, particularly in the agriculture and energy sectors. These policies are not targeted at cultural landscapes, but could result in either additional pressures or in protection of these landscapes.

The analysis presented in this deliverable provides a large-scale overview of threats to cultural landscapes. However, the scale of the analysis poses several limitations. The trajectories of change do indicate if and where a certain change is occurring, while the strength or the type of change is not further specified. Especially for intensification and extensification the exact way the management changes will have a strong impact on the landscape. For example, small increases in fertilizer or pesticide inputs to agricultural land have completely different impacts on the landscape character than scale enlargement. These processes are driven by the large-scale drivers analysed here, but also by farm and farmer characteristics such as age, motivation for farming, presence of a successor, or general attitude (Van Vliet et al., 2015), and local demographic variation. The latter are not captured in this analysis. Deliverable 5.3 will elaborate the impact of these drivers on a selection of cultural landscapes, and elaborate on European scale impacts.

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