HERCULES

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

GA no. 603447

D4.2 Indicator database and report describing the input data, methodology, and data quality for each indicator

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Executive summary

HERCULES seeks to assess and synthesizes the existing knowledge on the dynamics, drivers, patterns, and outcomes of cultural landscape transformations. A central task in this context is the development of a new cultural landscape typology, focusing explicitly on cultural heritage. This typology serves four major goals: (1) to capture the diversity of Europe's cultural landscapes; (2) to support targeting policy efforts protecting and investing in cultural landscapes; (3) to provide spatial context for HERCULES case studies as well as other local studies of landscape change; and (4) to provide a platform for empowering local communities through publically available information on the occurrence of cultural landscape types.

The development of this typology takes place in work package (WP) 4. In Deliverable D4.1, we laid out a framework for this typology, in line with the cultural landscape approach put forward in Deliverable 1.1, which is based on capturing the major characteristics of cultural landscapes along three main dimensions: (1) landscape structure and management intensity, (2) landscape history, and (3) landscape value and heritage. In this deliverable, we document the datasets needed to define and map our cultural landscapes typology.

Once a cultural landscapes typology and map of cultural landscape distribution has been developed, this map will form the basis to assess how cultural landscapes have been transformed in terms of land use change. This deliverable thus also documents the indicators needed for assessment of the impacts of land use change, pertaining to land conversions (e.g., farmland abandonment or urban expansion) and changes in management intensity (e.g., changes in fertilizer application or livestock stocking densities). The resulting typology and change trajectories will be presented in D4.3. Our cultural landscape typology will also form the basis for a model-based assessment of cultural landscape futures, across a range of scenarios and at multiple levels, connecting EU-level dynamics with local decision-making by landowners and managers in WP5.

All layers documented here will be made available via the HERCULES Knowledge Hub upon publication of the papers that document these layers.

Table of contents

Background

Project context

The project Sustainable Futures for Europe's Heritage in Cultural Landscapes (HERCULES, www.hercules-landscapes.eu) brings together landscape scientists and practitioners across Europe with the overall goal to empower public and private actors to protect and sustainably manage cultural landscapes. This is necessary because cultural landscapes across Europe are changing rapidly due to a variety of socio-economic, institutional, and environmental drivers. This ongoing transformation of cultural landscapes puts at risk the significant cultural, socio-economic, historical, natural and archaeological value and heritage that these landscapes contain.

In order to achieve this overarching goal, HERCULES assesses and synthesizes the existing knowledge on the dynamics, drivers, patterns, and outcomes of cultural landscape transformations. Based on these insights, new management tools for landscape observation and modelling are developed and opportunities and threats relating to cultural landscape change are distilled. HERCULES is inherently multiscalar, combining a top-down, European-wide perspective with in-depth, local-scale analyses from nine study landscapes. These case study regions were selected in order to ensure a balanced representation of environmental and land-use gradients within Europe – from Uppland in Sweden to the Sierra de Guadarrama foothills in Spain and from South West Devon in England to the Greek island of Lesvos. The study-landscapes also serve as laboratories to test and apply the insights, technologies, and strategies developed throughout the project.

Finally, the HERCULES project seeks to provide a strong and unified vision of 'pathways' towards protecting heritage in cultural landscapes, which provide policy makers and practitioners with up-to-date information to guide effective decision-making. To do so, HERCULES builds on the development and application of innovative technologies and tools for assessing cultural landscapes and transformations they are experiencing. The strong involvement of small and medium-sized enterprises and non-governmental organizations in HERCULES here provides a prototype for the empowerment of these institutions in landscape planning and management.

In sum, HERCULES has five key objectives:

- Objective 1: To synthesize existing knowledge on drivers, patterns, and outcomes of persistence and change in Europe's cultural landscapes
- Objective 2: To perform targeted case studies to develop in-depth insights on dynamics and values of cultural landscapes
- Objective 3: To develop a typology of cultural landscapes and scale-up case study insights using observations and landscape modelling
- Objective 4: To develop visions for re-coupling social and ecological components in cultural landscapes and translate them into policy and management options
- Objective 5: To design and implement a community-based Knowledge HUB for Good Landscape Practice and test it with land users, agencies, small and medium-sized enterprises, and citizen associations

European-wide assessment of cultural landscapes transformation

Two work packages (WPs) in HERCULES focus on the pan-European scale, providing spatially explicit and area-wide information on past and future changes in cultural landscapes. WP4 concentrates on the past, specifically the time period 1990 to now, to assess and map the current distribution of cultural landscapes across Europe. A central element of WP4 is therefore the development of a cultural landscapes typology. This considers the insights gained from the meta-analyses and review of cultural landscape drivers, patterns, and outcomes (WP1) as well as the case study work (WP2 and WP3). A second central goal of WP4 is to map the distribution of these typical cultural landscapes, and thus to generate, gather, and homogenize the indicators pertaining to land cover, land management, landscape structure, land-use history, and cultural heritage needed for doing so. Lastly, WP4 uses land-use indicators from remote sensing, ground surveys, and agricultural and forestry statistics to reconstruct recent (1990-now) dynamics in cultural landscapes and to detect hotspots and coldspots (i.e., areas of stability) of cultural landscape loss.

The outcomes of WP4, specifically the typology of cultural landscapes and the map of cultural landscape distribution, will then form the basis to study how cultural landscapes may change in the future in WP5. This WP implements a model-based assessment of cultural landscape change at multiple levels, connecting EU-level dynamics with local decision-making by landowners and managers. At the core of this assessment is the systematic exploration of alternative socio-economic and development pathways scenarios as well as the study of the potential impact of a range of policy options to steer cultural landscapes into desired development pathways.

WP4 has three deliverables. A first deliverable (D4.1) documents the process of the development of a cultural landscape typology, which included both quantitative and qualitative, expert-based elements. This deliverable has been finalized and is available via the HERCULES website. A second deliverable (D4.2, this deliverable) describes an indicator database gathered in order to map the typology developed in D4.1 across Europe and to analyse recent changes in cultural landscapes in Europe at the 1x1 km² grid level. Finally, a third deliverable (D4.3) will report on the mapping of the current distribution of cultural landscapes in Europe and recent changes therein. Deliverable 4.3 is due in month 32.

The HERCULES typology of cultural landscapes

Knowledge about the current spatial patterns of cultural landscapes in Europe is important for understanding how recent land use changes, socio-economic transformation, or environmental change is affecting them, and thus to develop policies that are effective in protecting and managing the cultural, historical, and archaeological value of these landscapes. Moreover, a typology may provide a useful template within which to develop and employ effective policies to navigate cultural landscapes into desired futures. Yet, to date there is no European typology or map of heritage landscapes.

A central goal of WP4 is to develop and map a typology of cultural landscapes focusing explicitly on cultural heritage. For this typology, we set out four specific goals: (1) to capture the diversity of Europe's cultural landscapes; (2) to support targeting policy efforts protecting and investing in cultural landscapes; (3) to provide spatial context for HERCULES case studies as well as other local studies of landscape change; and (4) to provide a platform for

empowering local communities through publically available information on the occurrence of cultural landscape types.

In Deliverable D4.1, we laid out a framework for this new typology of European cultural landscapes. This framework was developed and structured to be in line with the HERCULES 'cultural landscape research approach' documented in detail in Deliverable D1.1. At the same time, our typology is based upon, and draws from, the multitude of local to national cultural landscape maps that have been developed largely independently from each other – in particular regarding the indicators used to map these cultural landscapes (see deliverable D4.1 for an overview of national landscape typologies and maps).

While a continental-scale European typology of cultural landscapes provides many scale advantages over a mere assemblage of local and national typologies, which are often incomparable in thematic focus, temporal and spatial extent and resolution, generating a broad-scale typology is challenging due to data limitations. The indicators desirable for mapping cultural landscapes are often not available for the entire EU-27 territory or, if available, are aggregated to the level of coarse administrative units. Developing and mapping a European typology therefore requires working with proxy variables of (a) characteristics of cultural landscapes or (b) more direct drivers and agents of change in cultural landscapes (see Deliverable D4.1 for a more detailed discussion of this).

Cultural landscapes are often appreciated for their richness in history and the preservation of cultural traditions, as many valuable cultural ecosystem services are directly linked to these traditions (Plieninger et al., 2006; Schaich et al., 2010; Tengberg et al., 2012). Examples include aesthetic appreciation for mosaic landscape, provision of a cultural identity and a 'sense of place' to local inhabitants or a combination of services that attracts tourism and recreation. Moreover, complex, heterogeneous, and low-intensity agricultural systems are typically rich in farmland biodiversity, which is increasingly threatened throughout the EU (Bignal and McCracken, 1996; Agnoletti, 2014; Agnoletti, 2007; Plieninger and Bieling, 2013; Plieninger et al., 2006). The European landscape typology, defined in HERCULES, is designed to emphasize the above mentioned cultural values and associated ecosystem services and biodiversity by focusing on what we call the 'traditionality' of cultural landscapes. Although traditionality is not synonymous with value or meaning, landscapes defined as traditional are often associated with high value and meaning (Plieninger et al. 2015).

The concept of a traditional landscape captures people's imagination. However, the concept can become problematic when looking at broader spatial scales such as the European-wide scale. Due the diverse histories of European countries and regions Europe consists of a great diversity of landscapes, of which many can be regarded as traditional. For example, the German and Dutch *marschhufen* differ significantly from the Iberian *dehesas*, although both are being well regarded as typical traditional landscapes (for a more detailed overview see Zimmermann, 2006 and Meeus, 1993). What these landscapes have in common is that they all provide cultural heritage and/or local identity (Agnoletti, 2014; Plieninger and Bieling, 2013; Plieninger and Bieling, 2012; Antrop, 2005). This common ground definition, however, appears tautological, since it is exactly the heritage and identification that we want to conceptualize and synthesize. The identification of traditional landscapes and thus cultural heritage should therefore rely on other more quantitatively measurable characteristics. For this purpose, i.e. the identification of 'traditionality', we use three dimensions of cultural landscapes: (1) landscape structure and intensity (Antrop, 2005; van der Zanden et al., 2013),

(2) land-use history (Plieninger et al., 2006; Bignal and McCracken, 1996), and (3) cultural value (Altieri, 2004). For each dimension we generate an index ranging from 0 to 1. The closer a value is to 1, the more traditional the landscape is within the scale of the specific dimension, the closer the value of the respective indicator is to zero, the less traditional a landscape is rated. The scores of all three dimensions are summed to reveal the final score of 'traditionality' of a landscape, ultimately allowing for the identification of typical traditional landscapes across Europe. Ultimately, this will allow identifying different types of traditional landscapes and as such different types of cultural heritage. The identified cultural landscape type will then be compared to land-use/cover change indicators, pertaining to both land conversions and management intensity changes, in order to reveal local hotspots of cultural landscape transformations as well as regions of cultural landscape stability (Fig. 1).

In this deliverable, we document the indicators gathered to map the dimensions of the proposed typology – 'Landscape structure and intensity' and 'Landscape history' – as well as the indicators that will be used to map land-use changes within cultural landscape in Europe, pertaining to changes in the area-extent of broad land-use classes and the management intensity within these classes. Table 1 provides a summary of the indicators gathered and documented. The indicators used to describe the third dimension of our typology, 'Landscape value', will be documented in Deliverable 4.4.

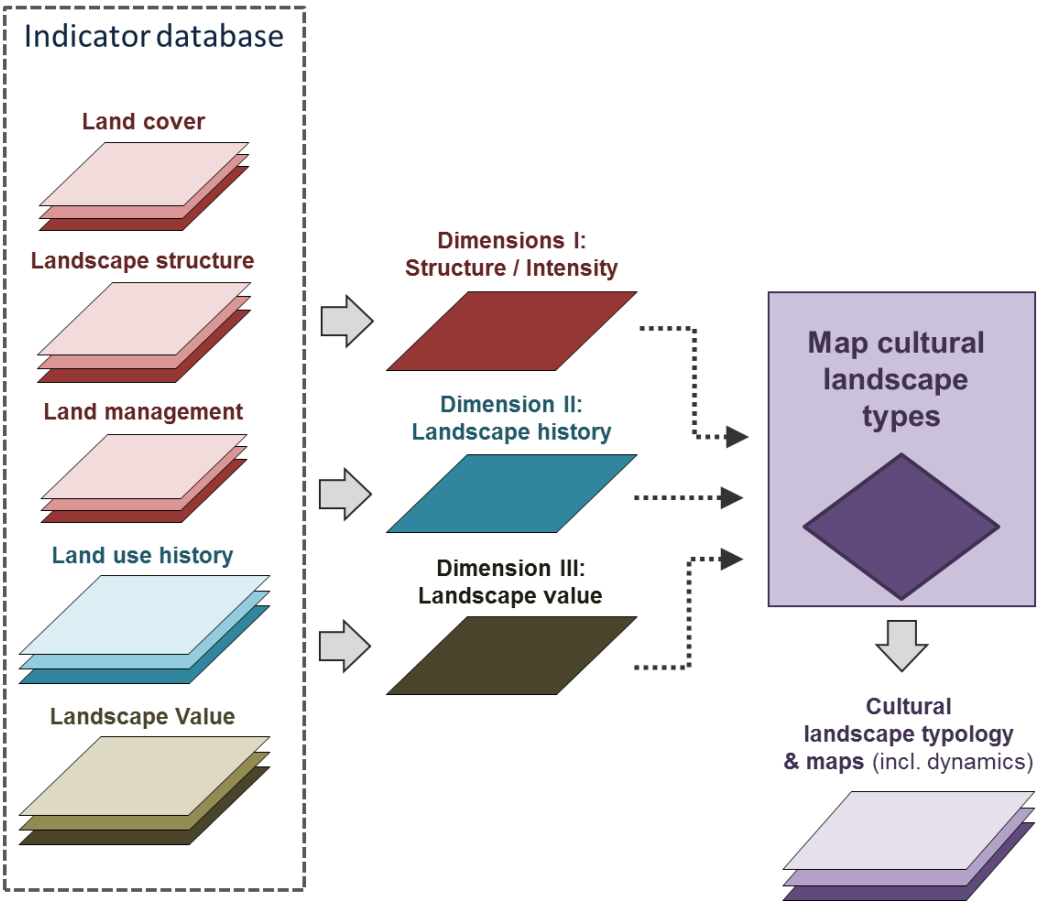

Fig. 1: Overview of characterizing and mapping cultural landscapes applied in WP4. This deliverable documents the indicators gathered to map Dimensions I: Landscape structure and intensity and Dimension II: Landscape history of our typology.

Table 1: Overview of indicators gathered to (a) map dimensions I (Landscape structure and intensity) and II (Landscape history) for our typology and (b) to assess land use changes and how they may affect cultural landscapes, pertaining to area changes in broad land-use classes and management intensity changes within these classes.

	Indicator	Name of Dataset	Short description	Time period covered	Used in typology generation?	Used for assessing land-use change?
Land cover and use extents	Land Cover 2006	CORINE Land-Cover (categorical)	The CORINE land cover/use map at a resolution of 100m, generated from Landsat TM/ETM+ satellite imagery from the European Environmental Agency	2006	YES	NO
	Land conversions				NO	YES
	Farmland Abandonment	Abandonment map (binary)	Farmland abandonment mapped from MODIS satellite image time series	2000-2012	NO	YES
	Protected areas	CDDA (binary)	Nationally designated areas (CDDA) from the European Environmental Agency	1990-2012	NO	NO
Landscape structure	Field Size Pattern	Field Size (ha)	Field size map generated from the LUCAS ground survey data	2012	YES	NO
	Green Elements	Landscape elements (#)	Landscape elements (e.g., ditches, tree rows, etc.) map generated from the LUCAS ground survey data	2012	YES	NO

Table 1 cont.

	Indicator	Name of Dataset	Short description	Time period covered	Used in typology generation?	Used for assessing land-use change?
Land-scape history	Land Use History	Land use age (# years)	Persistent land use age derived from a historical landscape reconstruction	1900 - 2010	YES	NO
Landscape value	Traditional foodstuffs	DOOR database (#)	Number of protected designation of origin food products per region	2014	YES	NO
	Panoramio	Panoramio (#)	Number of unique user uploaded geotagged photo in Google service Panoramio.	2014	YES	NO

The maps of the input indicators for creating our cultural landscape typology, and the resulting cultural landscapes map itself, will be made publically available via the HERCULES Knowledge Hub. Through open access to the cartographic layers, our typology can be explored by landscape practitioners, researchers and the interested public. The Knowledge Hub will also allow to alter the typology, if necessary, to adapt it to a wide range of uses. As such, the typology might become a useful tool for landscape practitioners aiming at planning and conserving cultural heritage on landscapes.

Individual indicators

CORINE Land-Cover 2006

Description

For the typology we used the CORINE land-cover data of 2006. Due to data gaps for Greece in the 2006 assessment, we supplemented this data set with data from the year 2000. The CORINE land-cover classification was reclassified into the classification scheme that is used within the Dyna-CLUE simulations. The $100m^2$ CORINE data were aggregated to a $1km^2$ grid cell resolution using the dominant land use for each pixel (majority vote). The aggregation was then adjusted so that the total area of each land-cover class remained the same as in the original $100m^2$ map.

Input data

- CORINE land-cover for the years 2000 and 2006 (http://www.eea.europa.eu/data-and-maps/data#b_start=0&c11=landuse)

Validation

CORINE land cover data for the year 2000 was validated (the thematic accuracy of CORINE land cover 2000, EEA Technical report No 7/2006).

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References

- CORINE land-cover for the years 2000 and 2006 (http://www.eea.europa.eu/data-and-maps/data#b_start=0&c11=landuse).

Time period	Spatial extent	Resolution	Version
2000, 2006	EU-27(+CH)	$1km^2$	V1.0

Map: CORINE land-cover data, reclassified into Dyna-CLUE classification scheme.

Land conversions

Description

Patterns and changes of broad land-cover/use categories provide information about land-change trajectories and about the anthropogenic use of the natural environment. Within HERCULES, we use a harmonised dataset on the spatial extent of broad land-cover/use categories as well as changes therein in Europe on a 1 km^2 grid for the time steps 1990, 2000, and 2006, generated by the Institute for Social Ecology, Alpen-Adria university Klagenfurt in Vienna. This dataset was generated using CORINE land-cover maps, sub-national forest data, and CAPRI data on biomass production in NUTS2 regions related to cropping, grazing, and forestry. From this harmonized datasets, we derived information on the extent of (i) built-up and infrastructure, (ii) cropland (arable, permanent, and fallow), (iii) forests and other wooded land, as well as (iv) grazing land (e.g., meadows, pastures).

First, the share of all non-forest and non-farmland (i.e., cropland and pasture) areas for each 1 km^2 pixel was calculated by excluding built-up area, unproductive and wetland areas, and wilderness areas. Second, cropland area demand was estimated using cropland statistics from the CAPRI database. Third, forest area demand was estimated using national statistics from the State of European Forests (SoEF) database that were allocated to regional-scale administrative units (NUTS3 to NUTS1) using weights based on regional statistics for the year 2000. Fourth, the remaining land was used to allocate grazing areas for which statistics were taken from the CAPRI database.

Input data

- CORINE land-cover for the years 1990, 2000, and 2006 (http://www.eea.europa.eu/data-and-maps/data#b_start=0&c11=landuse)
- Wilderness Quality Index (EEA 2012, http://www.eea.europa.eu/data-and-maps/figures/wilderness-quality-index).
- CAPRI biomass and spatial extent of 12 major crop types and fallow cropland (http://www.capri-model.org/dokuwiki/doku.php?id=start)
- Spatial extent of forest and other wooded land (SoEF, Forest Europe et al. 2011)
- Pan-European forest cover map (Gunia et al 2012, www.efi.int/portal/virtual_library/information_services/mapping_services/forest_map_of_europe)

Validation

CORINE land cover data for the year 2000 was validated (the thematic accuracy of Corine land cover 2000, EEA Technical report No 7/2006).

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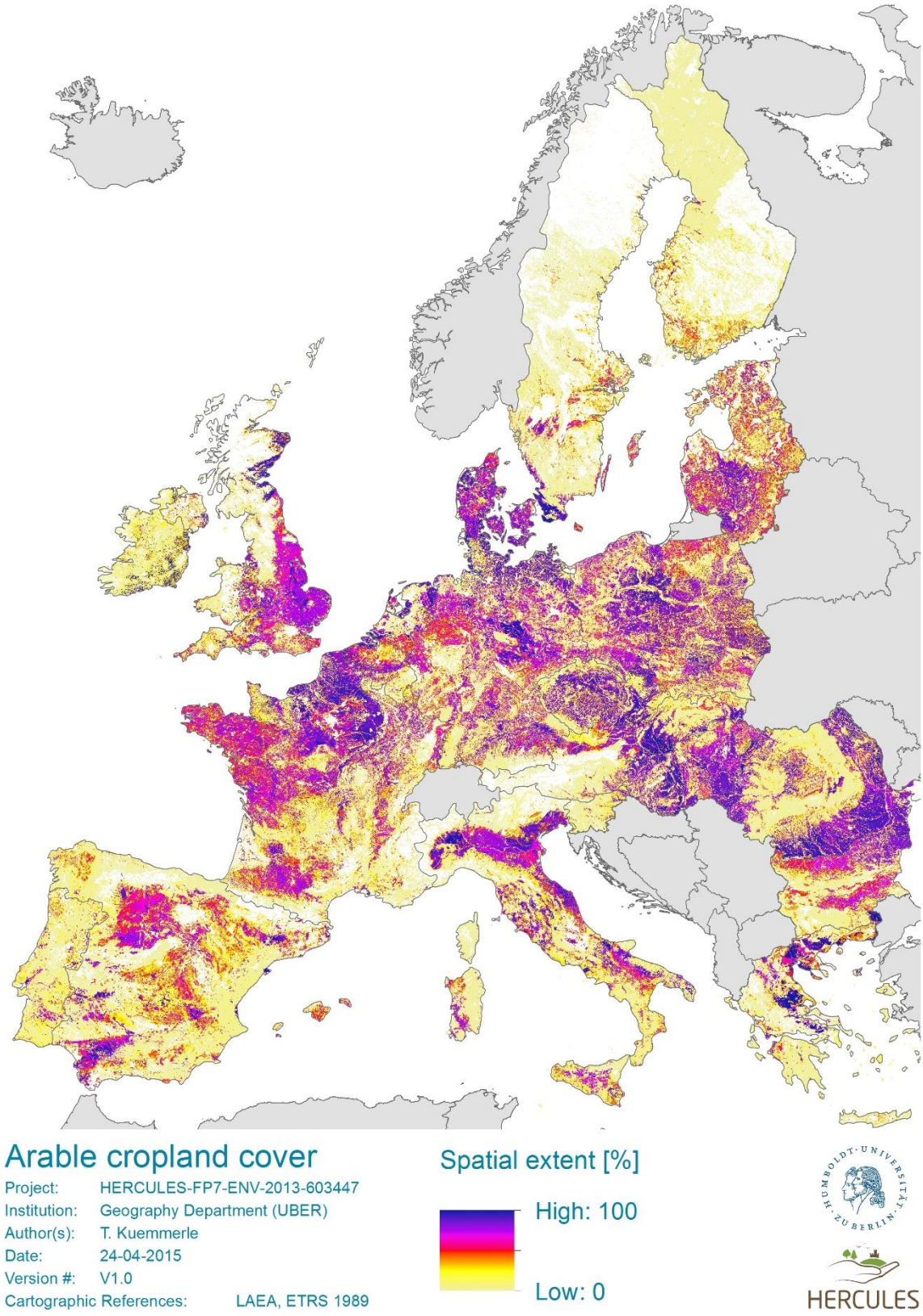
References

- Plutzar, C., Kroisleitner, C., Haberl, H., Fetzel, T., Bulgheroni, C., Beringer, T., Hostert, P., Kastner, T., Kuemmerle, T., Lauk, C., Levers, C., Lindner, M., Moser, D., Müller, D., Niedertscheider, M., Paracchini, M.L., Schaphoff, S., Verburg, P.H., Verkerk, P.J. Erb, K.-H. (*under review*). Changes in the spatial patterns of human appropriation of net primary production (HANPP) in Europe 1990-2006.

Time period	**Spatial extent**	**Resolution**	**Version**
1990, 2000, 2006	EU-27	1km²	V1.0

Map: Data is shown for the arable cropland extent in the year 2000. Data for the entire study period and for all other land-cover/use categories is available in the data repository.



Farmland abandonment

Description

Farmland abandonment is the dominant land-use change in the European Union, as a consequence of increasing yields on productive lands, conservation policies, and increasing imports of agricultural products from outside the EU. Within HERCULES, we provide the first map of farmland abandonment across the EU-27 between 2000 and 2012. The map is based on 8-day MODIS NDVI time series and an extensive training dataset from the LUCAS database and high-resolution imagery from Google-Earth.

The product provides for each individual year (i.e., 2000, 2001 etc.) information on whether farmland is actively used or left fallow – thus, over the entire time span several pieces of information can be extracted: (1) the overall fallow frequency of agricultural land, (b) the process of farmland abandonment, when periods of active farmland are followed by multiple years of fallow, (c) the re-cultivation process, when land that was left fallow for several years becomes actively farmed again.

Input data

- Moderate Resolution Image Spectroradiometer (MODIS) 8-day NDVI time series data from 2000 to 2012
- Land Use/Cover area Frame Statistical Survey (LUCAS) database (Eurostat, data 2009), http://epp.eurostat.ec.europa.eu/portal/page/portal/lucas/data/lucas_primary_data_2009). For more details, see also Jacques and Gallego (2010): The European land use and cover area-frame statistical survey. Agricultural survey methods. (ed. R.Benedetti, et al.), pp. 151-168. John Wiley & Sons

Validation

The map was validated using an extensive validation dataset and came from several sources: (a) ground observations from the LUCAS surveys, (b) Landsat dense time series as well as high-resolution imagery from Quickbird, IKONOS and WorldView (mostly available from Google Earth), (c) MODIS NDVI profiles. For each of the yearly classification of active and fallow farmland, an individual point dataset was gathered, on average ~2000 points per year. Based on these points, an error matrix was generated and overall accuracies were calculated. On average, the yearly classifications reached accuracies of ~90%. For more details to the validation please refer to Estel et al. (2015).

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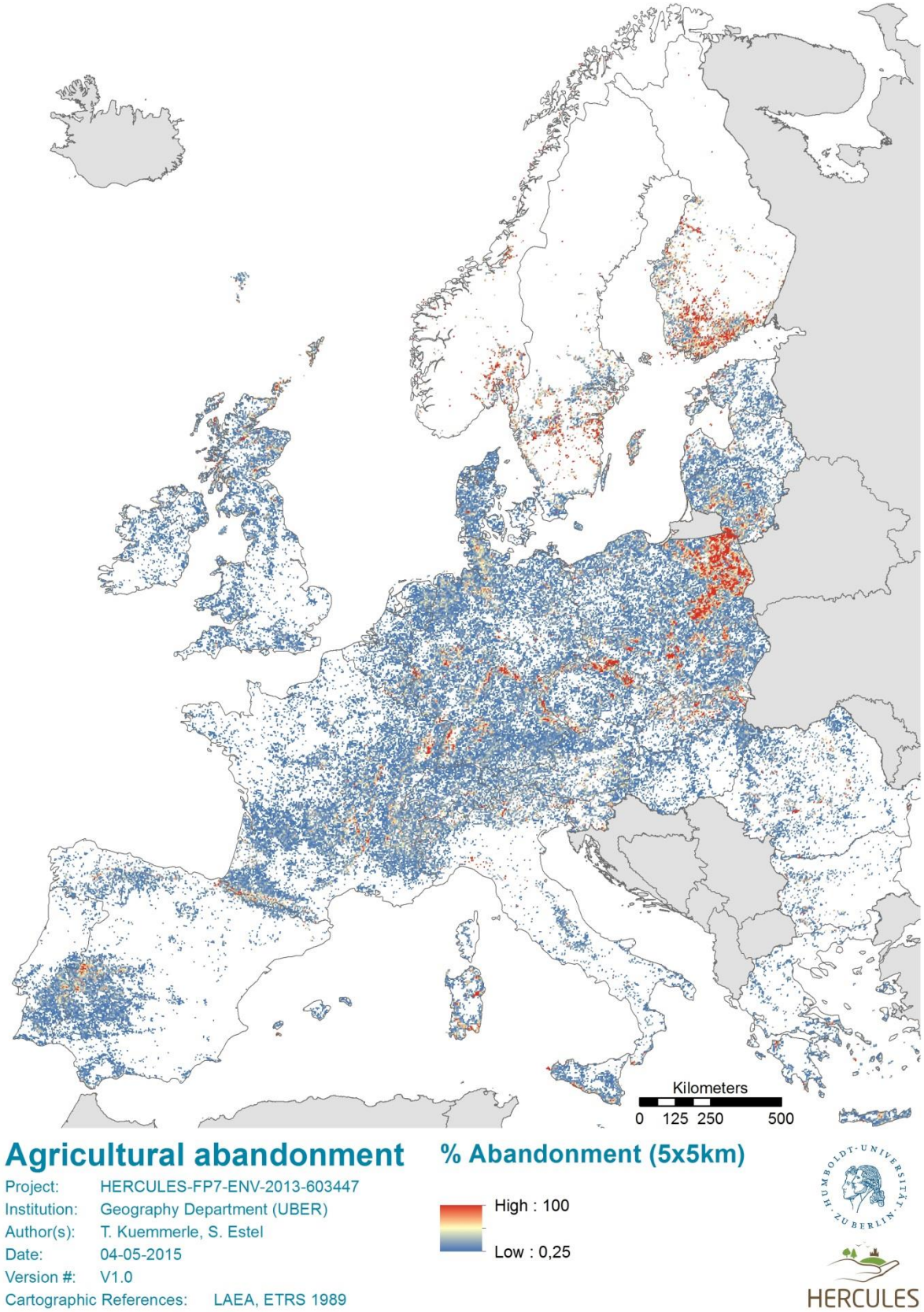
References

- 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 Sensing of Environment, in press.

Time period	Spatial extent	Resolution	Version
2000-2012	EU-27 + NO & CH (original analysis covers entire Continental Europe to the Ural mountains)	237m	V1.0

Map: Farmland abandonment for the period 2000-2012. Abandonment rates are summarized at the 5x5 km^2 grid for visualization purposes, but are available in the original resolution.



Protected areas

Description

This indicator provides information on the location of areas under protection status. We gathered data from the European Environment Agency (EEA) on areas that are nationally designated protected areas (CDDA; in total 85,319 sites) or belong to the Natura2000 network (in total 15,021 sites). We only used records for which the year of establishment of the protected area was documented. Ultimately, we used 83,024 records of the CDDA database and the full Natura2000 database

Since Natura2000 data is only available for 2006 and 2012, we created three different outputs:

1. CDDA protected areas for 1990, 2000, 2006, 2010, and 2012
2. Natura2000 protected areas for 2006 and 2012
3. CDDA+Natura2000 protected areas for 2006 and 2012

To do so, we converted the native vector data format of the final CDDA and Natura2000 databases into raster layers with a resolution of 1km².

Input data

- CDDA: EEA 2012 (http://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-6)
- Natura2000 sites: EEA 2013 (http://www.eea.europa.eu/data-and-maps/data/natura-4)

Validation

none

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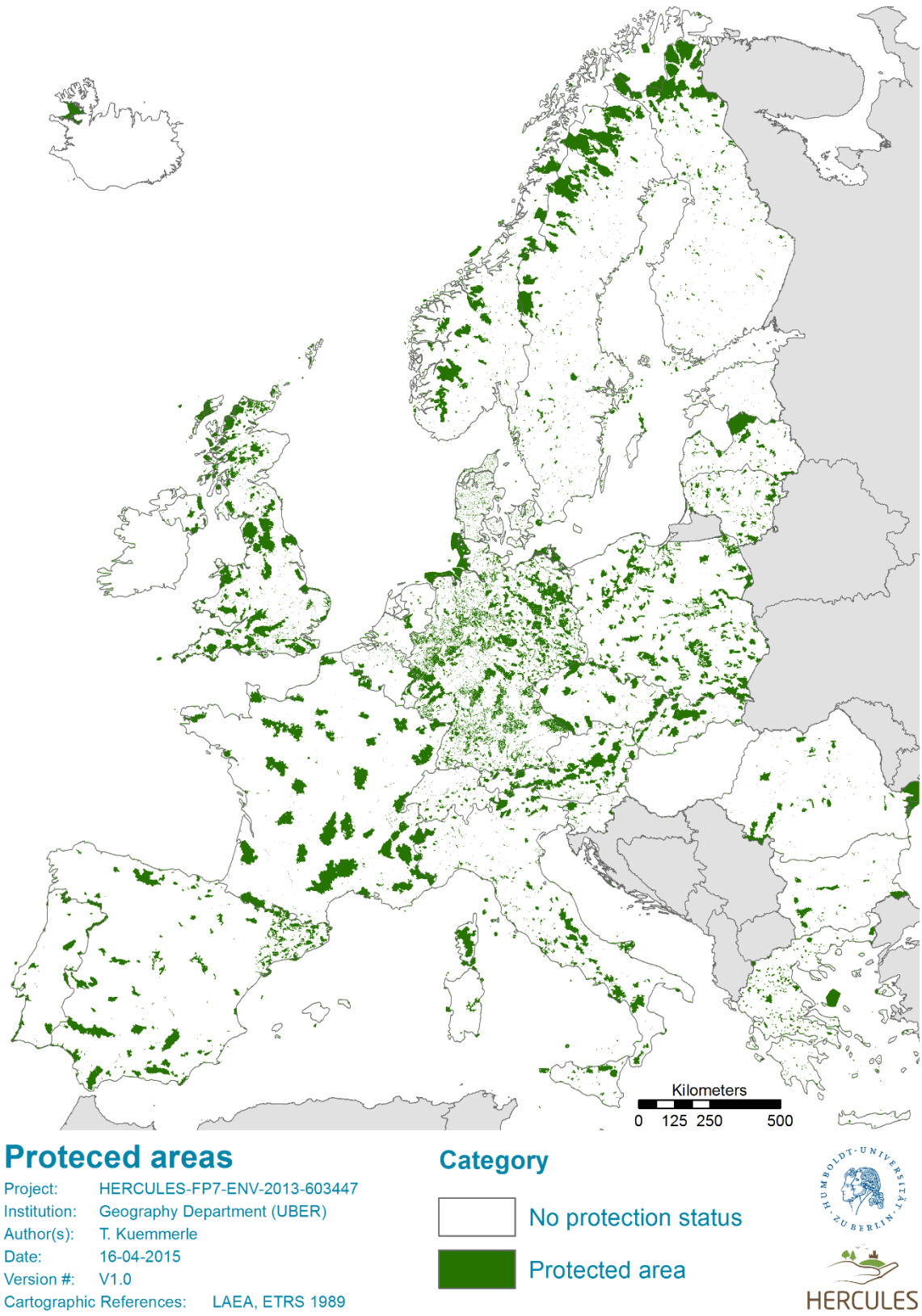
References

none

Time period	Spatial extent	Resolution	Version
1990, 2000, 2006, 2010, 2012	EU-27	1km²	V1.0

Map: Data is shown for the year 2000 for areas with CDDA protection status. Data for the entire study period is available in the data repository.



Field size pattern

Description

Agricultural field size is an indicator that can help describing capital intensity in land management, such as the degree of mechanization. Here we provide a map of field size categories across the EU-27. The mapping of field size pattern consisted of three steps: (1) extraction of field size information from the LUCAS database (Land Use/Cover area Frame Statistical Survey, www.lucas-europa.info). This resulted in a dataset of ~235,000 points. (2) Assignment of a categorical value of field size for each point falling into an agricultural database. The categories were a) <0.5ha, b) 0.5-1ha, c) 1-10ha, d) >10ha. For interpolation we used a mean value for each category and a value of 15ha for category 4. (3) Interpolating the areas between the points using an Ordinary Kriging approach. Kriging derives a semi-variogram that describes the autocorrelation between points; the final prediction map was produced by minimizing the error of the predicted values. For the generation of the Field Size Pattern indicator, a K-mean variogram mode with 50 observations as search radius was used.

Input data

- Land Use/Cover area Frame Statistical Survey (LUCAS) database (Eurostat, data 2009 & 2012), http://ec.europa.eu/eurostat/web/lucas/data/primary-data/2012). For more details, see also Jacques and Gallego (2010): The European land use and cover area-frame statistical survey. Agricultural survey methods. (ed. R.Benedetti, et al.), pp. 151-168. John Wiley & Sons.

Validation

This indicator was validated with ground truth data digitized from high-resolution images. An addition could also be to compare the field size map to the cadastre data, which are being collected for the WP1 case studies. This factsheet will be updated accordingly.

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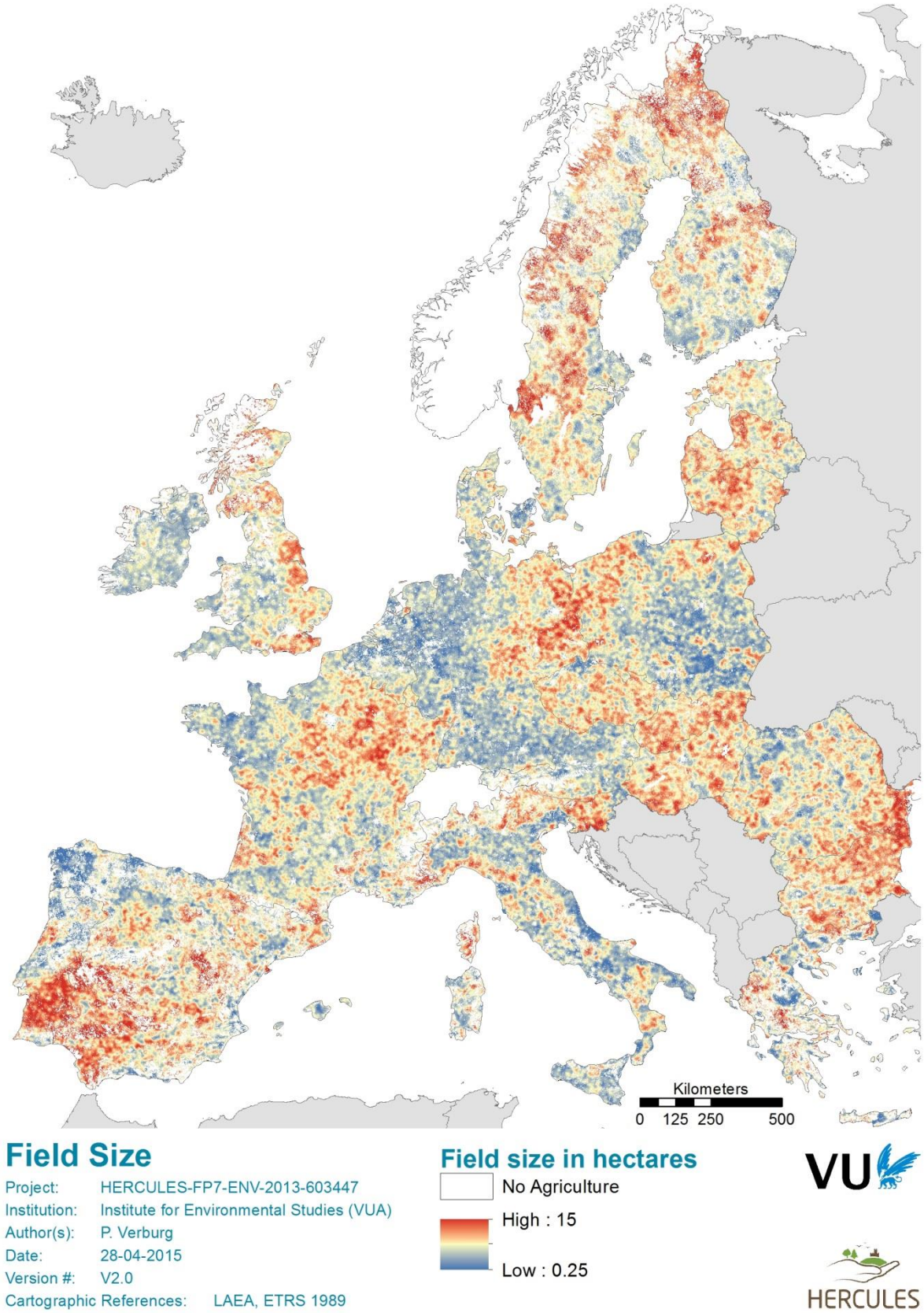
References

- A manuscript detailing this indicator is in preparation.
- The field size map and the methodology to derive it are also described in: Kuemmerle, T.; Erb, K.; Meyfroidt, P.; Müller, D.; Verburg, P.H.; Estel, S.; Haberl, H.; Hostert, P.; Jepsen, M.R.; Kastner, T.; Levers, C.; Lindner, M.; Plutzar, C.; Verkerk, P.J.; van der Zanden, E.H.; Reenberg, A. (2013): Challenges and opportunities in mapping land use intensity globally. Current Opinion in Environmental Sustainability, 5, 484-493.

Time period	Spatial extent	Resolution	Version
2009, 2012	EU-27	1km²	V2.0

Map: Ordinary Kriging of 2012 LUCAS data on field size



Landscape elements

Description

Ditches, hedgerows, lines of trees and field margins are often referred to as linear landscape elements and have important ecological functions within agricultural landscapes. While traditional cultural landscapes often contain several of these elements, intensively managed landscapes are often characterized by their homogeneity in which most of these elements are missing. Thus, spatial information of linear landscape elements can be used as an indicator for the degree of management intensity of a landscape, and the distribution of linear elements can help to describe the ecological infrastructure in a landscape.

Within HERCULES, we provide a wall-to-wall coverage for the entire EU-27 of green vegetation elements, ditches and grassland. The input for this dataset came from the LUCAS database (Land Use/Cover area Frame Statistical Survey), of which we extracted linear features. Specifically, the LUCAS database contains transect information, which was conducted by a surveyor walking along 250m-transects from a starting point recording the sequence of land-cover types along these transects as well as the number of crossings with linear landscape features. For the present dataset, we considered features of minimum 1m width and minimum 20m length.

Input data

- Land Use/Cover area Frame Statistical Survey (LUCAS) database (Eurostat, data 2009), http://epp.eurostat.ec.europa.eu/portal/page/portal/lucas/data/lucas_primary_data_2009).For more details, see also Jacques and Gallego (2010): The European land use and cover area-frame statistical survey. Agricultural survey methods. (ed. R.Benedetti, et al.), pp. 151-168. John Wiley & SonsGDP: as used in Van Eupen et al. 2012 (Land Use Policy 29: 473-482)
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- Travel time to cities/ports: Accessibility analysis based on GISCO database infrastructure. For more details, please see Van Eupen et al. (2012) Land Use Policy 29: 473-482
- Natura2000 sites: EEA 2011 (http://www.eea.europa.eu/data-and-maps/data/natura-1)
- European Council 2006. LEADER Local Action Groups Map. Obtained: DG for Agriculture and Rural Development
- Less Favoured Areas: EEA 2011 (http://www.eea.europa.eu/data-and-maps/figures/less-favoured-areas/)
- European Soil Database. Joint Research Centre (JRC) of the EU 2006
- PESERA Soil Erosion (http://eusoils.jrc.ec.europa.eu/ESDB_Archive/pesera/pesera_data.html)
- CGIAR SRTM and GTOPO30 global terrain data. Terrain ruggedness was calculated following Riley et al. (1999). Intermountain J. Sciences 5: 23-27
- WorldClim (http://www.worldclim.org/current) for precipitation data.
- Daily Wind speed (10m above ground): European Centre for Medium-Range Weather Forecasts (http://data-portal.ecmwf.int/data/d/interim_full_daily)
- CORINE land cover maps (www.eea.europa.eu/publications/COR0-landcover) for information on land use (Mosaic and agricultural land use, agroforestry)
- CAPRI-DynaSpat crop type information for 2011 (http://afoludata.jrc.ec.europa.eu)
- Livestock (Herbivores and monogastrics): For more information please see Neumann et al. (2009). Landscape Ecology 24: 1207-1222

Validation

The resulting dataset was validated based on a stratified random sample of 150 plots of 10 km^2 size across agricultural areas. Within each sample plot, 10 Eastward transects of 250m length were evaluated in accordance with the LUCAS sampling procedures by interpreting high-resolution imagery in Google Earth.

As validation, a comparison was made between the average element count per sampling square and the average model outcomes for the same area. An average of 10 transects was used instead of individual transects in order to produce a regionally representative value. The validation was restricted to green

lines (i.e., tree lines or hedgerows) because of the problematic detection of grass margins and ditches from aerial photographs and revealed an Europe-wide correlation with LUCAS point data of r = 0.55 and r = 0.14 to r = 0.77 for different European regions (Western, Eastern, Southern Europe and Scandinavia).

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References

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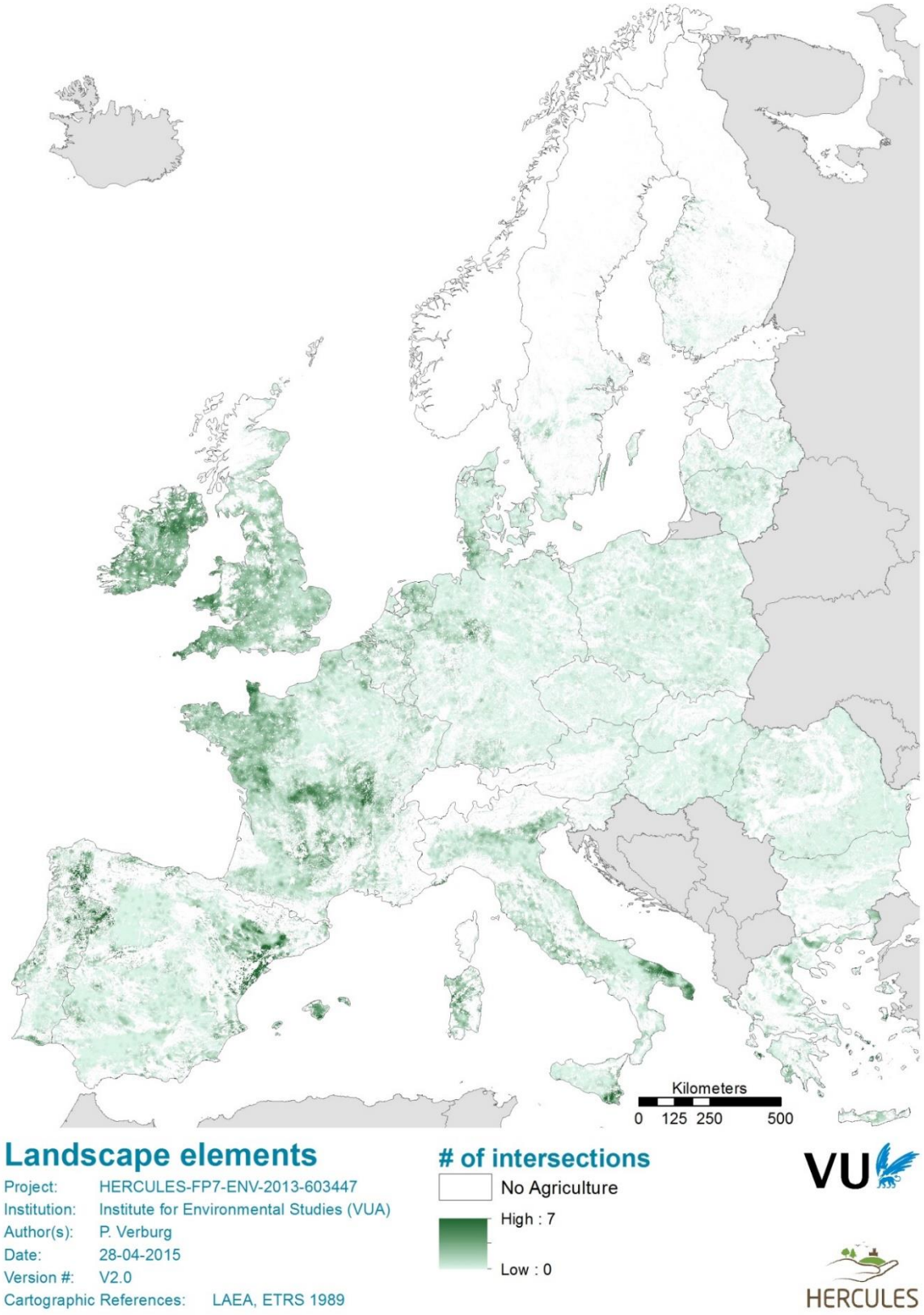
Time period	**Spatial extent**	**Resolution**	**Version**
2009, 2012	EU-27	1km²	V2.0

Map: Map shows Ordinary Kriging results of LUCAS 2012 green linear elements



Fertilizer application

Description

This indicator is based on information on nitrogen input and can be used to describe management intensity. Input data on nitrogen application came from Farm Structure Surveys (FSS) and were available at the NUTS-3 level. These data were disaggregated using local stocking densities and crop information from the LUCAS database. For croplands, crop information at the LUCAS point locations was assigned to the crop-specific nitrogen application rate from the FSS data. Nitrogen application rates were then classified into three classes *low* (<50 kg/ha), *medium* (50-150 kg/ha) and *high* rates (>150 kg/ha). Using the point locations, nitrogen classes were then modelled using multinomial regression and a set of environmental and socio-economic factors (see input data section below for more information on the regression factors) – thereby fitting an individual model for each of the EU-27 countries separately to account for differences in the relationship between agricultural intensity and the location factors between the countries. Using the results of the regression, a prediction map was calculated for each of the three intensity rates.

For grassland, LUCAS grassland observations were linked to a nitrogen input using local stocking densities of cattle. Stocking densities were derived from the livestock maps of Neumann et al. (2009), which we classified into *intensive* grassland with > 50 kg N/ha and *extensive* grasslands with < 50 kg N/ha. Similar to the crop-estimation, we fitted country-specific logistic regression models and used the results in order to downscale the areas of the different intensity classes to individual locations within the administrative units.

Input data

- CLC 2000 & 2006 land cover data (www.eea.europa.eu/data-and-maps/)
- Farm Structure Survey (FSS) from Eurostat, containing Nitrogen input levels per crop type, (http://epp.eurostat.ec.europa.eu/portal/page/portal/farm_structure_survey/data/Database)
- Land Use/Cover area Frame Statistical Survey (LUCAS) (Jacques and Gallego 2010, The European land use and cover area-frame statistical survey. Agricultural survey methods. (ed. R. Benedetti, et al.), pp. 151-168. John Wiley & Sons, see also www.lucas-europa.info)
- Livestock density maps (for details: Neumann et al. (2009). Landscape. Ecology 24:1207-1222)
- Factors, describing the biophysical (e.g., topography, temperature, soil depth) and socio-economic characteristics for each country (e.g., accessibility, travel time, rural population density), that were used in the regression analyses. For more detail on each individual factor please see Temme & Verburg (2011). Agriculture, Ecosystems. & Environment 140: 46-56

Validation

The intensity classes were validated in their agreement with CORINE2000 irrigation classes.

Contact

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References

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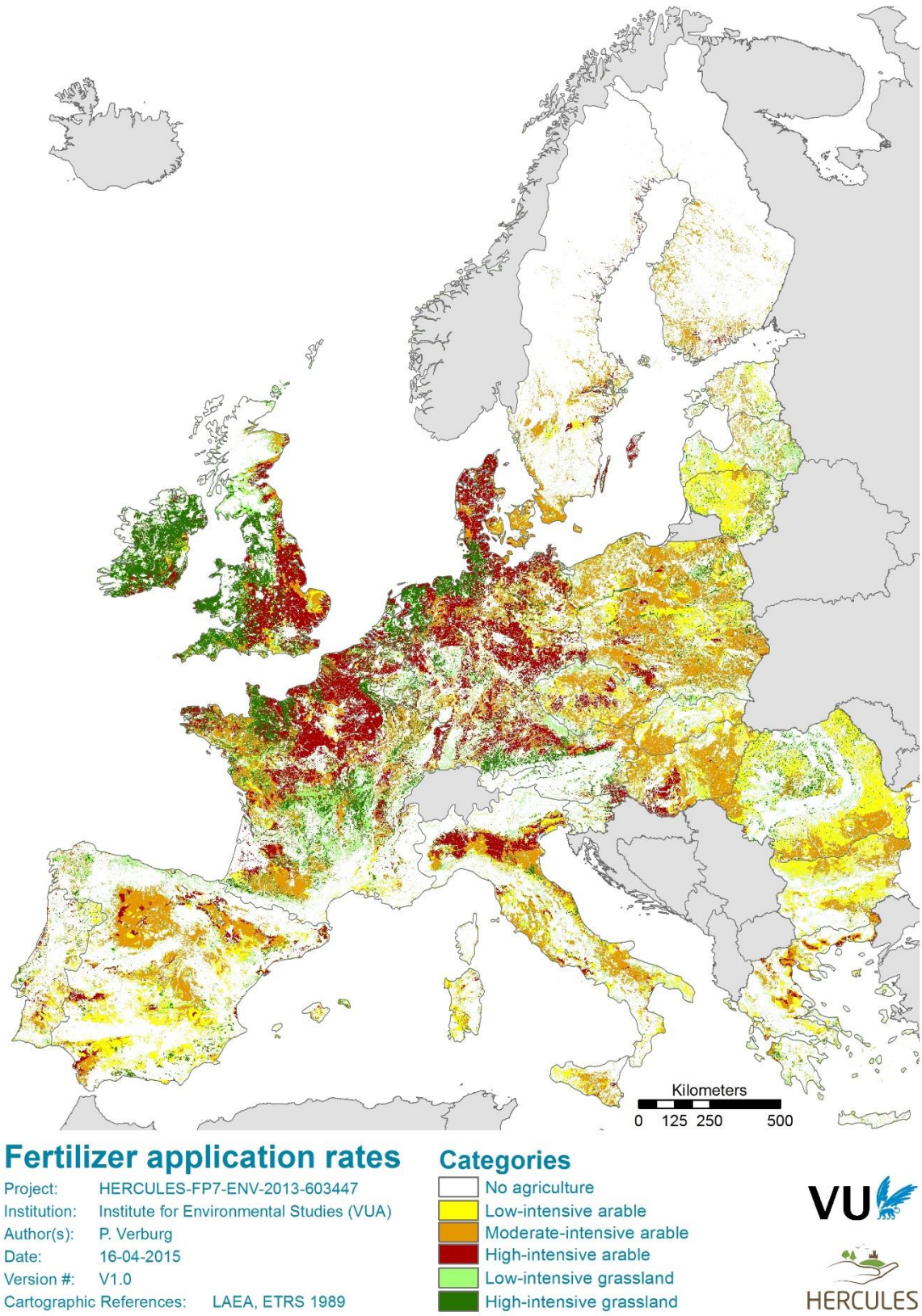
Time period	Spatial extent	Resolution	Version
1990, 2000, 2006	EU-27	1km²	V1.0

Map: Data is shown for the year 2000. Data for the entire study period is available in the data repository.



Economic farm size

Description

Besides the actual size of agricultural holdings or fields (often measured in hectares), economic conditions can be an effective measure to classify agricultural holdings. This indicator uses estimations on the standard gross margin (SGM) of agricultural production for agricultural holdings to reveal its overall economic size.

This data set was generated from the Farm Accounting Data Network (FADN) of the European Commission using the indicator "economic size" that is measured in European Size Units (ESU). One ESU is equivalent to 1,200€. The obtained data was collected for individual farms and aggregated to the NUTS 3 administrative unit level.

Due to data gaps (e.g., different EU accession dates, missing values for certain years and regions), we only used information for the years 2007 to 2009 to calculate this indicator since these years had the highest number of administrative units for which data was collected and revealed the lowest amount of data gaps. We calculated the arithmetic mean value for the three target years thereby omitting NA values.

Input data

- FADN data (http://ec.europa.eu/agriculture/rica/)

Validation

none

Contact

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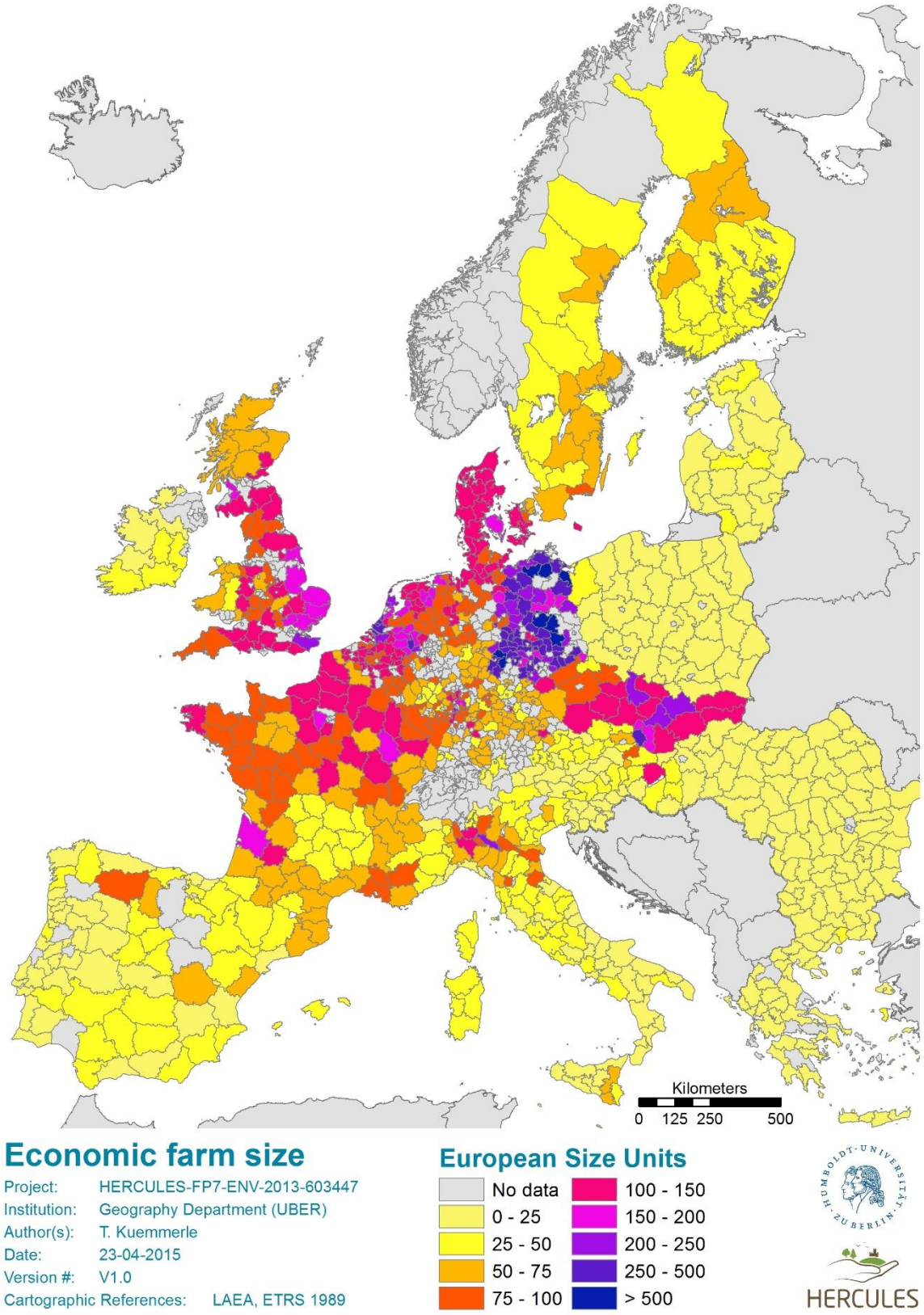
References

none

Time period	Spatial extent	Resolution	Version
2007-2009	EU-27	NUTS 3	V1.0

Map: Data is shown as the mean value between 2007 and2009.



Yields in agriculture

Description

Yields are among the most important measures to characterize the output intensity of an agricultural holding. Yields relate the amount of agricultural production to the area that was cultivated to produce the amount of agricultural products and is measured in energy content output

The total Energy Content Output is the sum of the following components: food, feed, pruning of trees, residues of permanent crops, and straw. The results presented here were derived from the disaggregation at HSMU (homogeneous soil mapping units) level of the results at NUTS2 level elaborated by the CAPRI model.

Input data

- CORINE land-cover for the years 1990, 2000, and 2006 (http://www.eea.europa.eu/data-and-maps/data#b_start=0&c11=landuse)
- CAPRI data base (Leip et al 2008; Britz and Leip 2009)
- CAPRI-Dynaspat database ((http://www.ilr.uni-bonn.de/agpo/rsrch/dynaspat/dynaspat_e.htm)

Validation

none

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References

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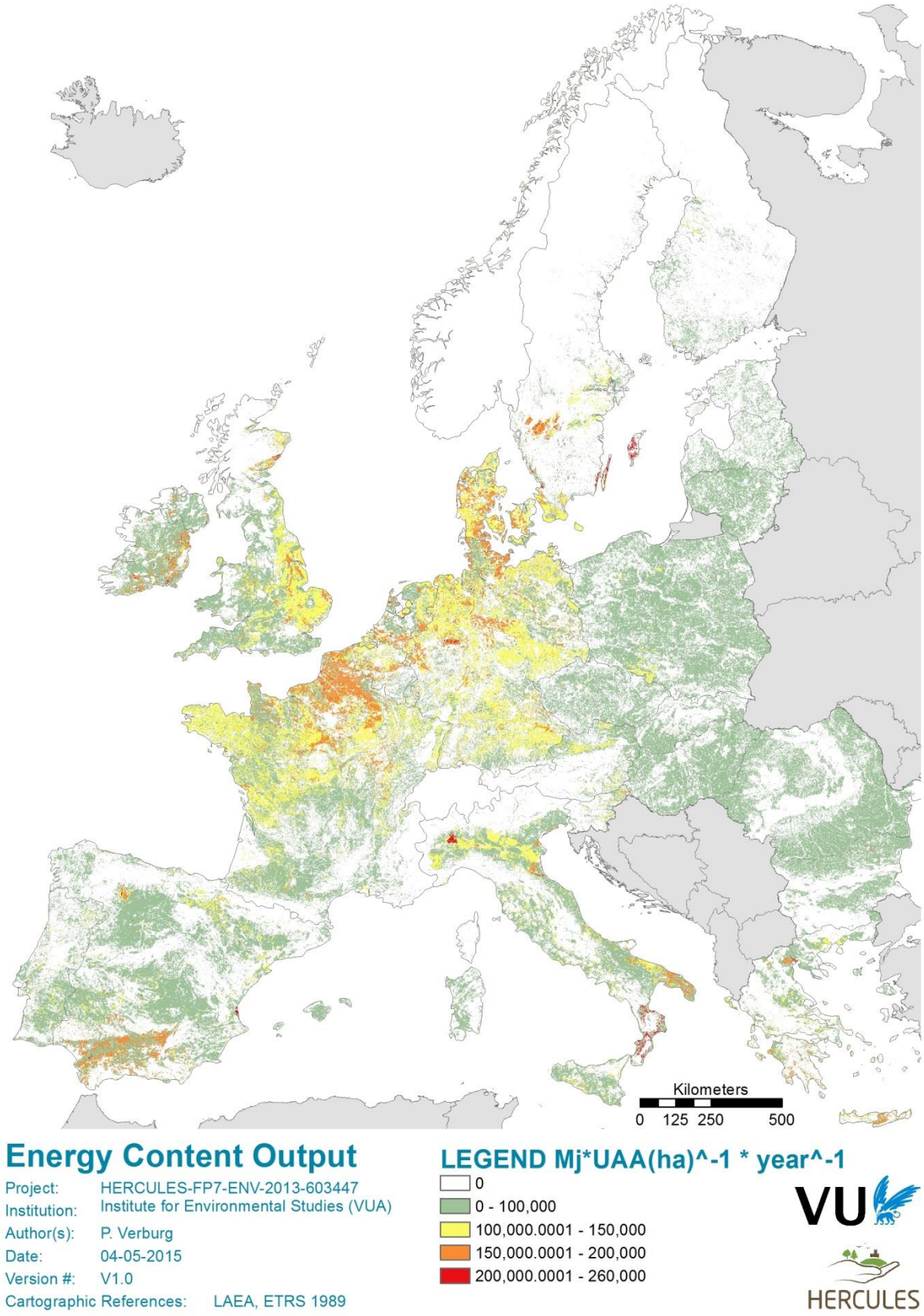
Time period	**Spatial extent**	**Resolution**	**Version**
1990, 2000, 2006	EU-27	1km²	V1.0

Map: Data is shown only for yields on arable croplands and permanent crops in the year 2004



Grazing intensity

Description

We provide maps that describe the spatial distribution of livestock, which we derived from consistent regional livestock statistics – specifically, we distinguish between five different types of livestock: dairy cattle, beef cattle, sheep, pigs, and poultry. To derive these maps, we integrated an expert- based and an empirical approach. Within the expert-based approach we specified land-related suitability rules for herbivores and monogastrics based on case study evidence. In the empirical approach we related European livestock distribution to a set of socio-economic and biophysical location factors in a regression-based approach. Livestock statistics for the regression analysis came from a number of EU countries. Using the outcomes from the expert- and the empirical approach, we calculated grid cell specific probabilities for livestock distribution. In order to do so, we developed an allocation mechanism, in which livestock types were individually allocated to land use types starting with the grid cell with the highest probabilities that came from either the empirical or the expert-based approach. The allocation had a hierarchical structure for livestock type allocation. Allocation of herbivores starts with dairy cattle, followed by beef cattle and finally sheep. For monogastrics, pigs had a higher priority than poultry and were allocated first without consideration of the presence of herbivores in a cell. In general, we assumed no competition between herbivores and monogastrics for the same location. In addition, herbivores were always allocated to pasture first and if there is no land left they were shifted to arable land, while monogastrics were firstly allocated to arable land.

Input data

- CLC 2000 land cover data (EEA, 2005)
- EU-wide regional statistics on livestock types, their numbers and their distribution across land use types. Data were collected at the finest available administrative level, and came from the EUROSTAT EUROFARM database from Eurostat
- Selected socio-economic (e.g., travel-time to cities/.ports, population density), land-use (e.g., crop types from CAPRI DynaSpat and CORINE land-cover maps) and biophysical factors (e.g., soil types, soil depth, environmental zone). For more information: Neumann et al. 2009

Validation

A validation of all simulated livestock maps was performed using national livestock census data for 12 European countries. This gave an independent validation for the expert-based approach. The empirical approach also used the national livestock census data for validation, to identify the location factors for livestock distribution. The livestock densities per administrative unit from national livestock census were compared with the livestock densities resulting from the downscaling procedure aggregated the same administrative unit (NUTS3) and compared using correlation analysis. The results were also compared with a random distribution mode, where livestock was allocated to randomly selected grid cells with an assumed similar probably for all locations. The validation of the empirical approach yielded correspondences (R^2) between livestock types and census data from 0.14 to 0.87. In the expert-based approach, the correspondence of downscaled livestock densities varied regionally and for livestock types between 0.03 and 0.96.

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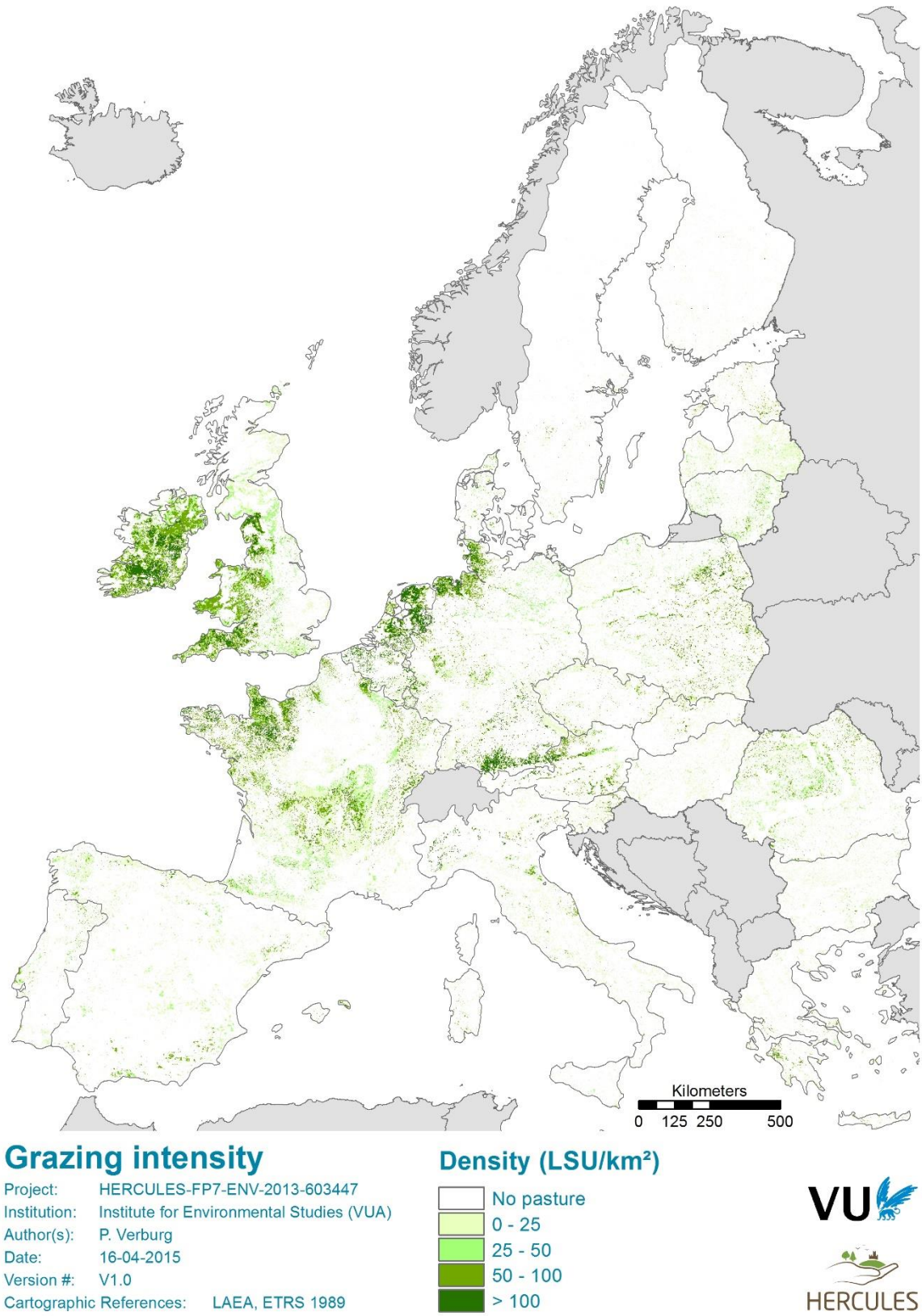
References

- Neumann, K., Elbersen, B.S., Verburg, P.H., Staritsky, I., Pérez-Soba, M., de Vries, W. & Rienks, W.A. (2009). Modelling the spatial resolution of livestock in Europe. Landscape Ecology 24:1207-1222.

Time period	Spatial extent	Resolution	Version
1990, 2000, 2006	EU-27	1km²	V1.0

Map: Data is shown for the year 2000. Data for the entire study period is available in the data repository.



Wood extraction

Description

This indicator builds upon a European-wide database of forest harvesting data on administrative unit level to map wood production patterns on a pixel scale based on asymmetric mapping.

Forest harvesting statistics were collected from the respective National Forest Institutes, collated and harmonized. A literature review was conducted to identify possible influential factors of wood production patterns (see below). For these factors, predictor variables were gathered or, if necessary, produced and stored a geodata-base (see below). All data were spatially harmonized and checked for outliers and data gaps. Regression models were used to predict wood production [m³/ha forest] across Europe. Models were fit on the NUTS0-3 level, defined by the level of detail of the target variable (i.e., mean predictor values were calculated for the respective level of detail). We weighted those predictors that were not related to forest area itself by forest area per aggregated unit before calculating mean values.

Data models (linear models) and algorithmic models (Boosted Regression Trees) were fitted and compared. Final models were used to predict wood production across Europe. Predictions maps were converted to suitability maps by min-max transformation. We multiplied a forest cover map with the respective suitability maps and disaggregated wood production volumes based on these layers by allocating wood production statistics on the administrative unit level (wood production volume that was allocated to an individual pixel was highest for pixels with high harvest suitability and high forest cover). We finally used data derived from the best performing linear model.

This indicator has been developed in close cooperation with the EU FP7 project GHG Europe (www.ghg-europe.eu), specifically with the Wageningen UR / Alterra, The Netherlands.

Input data

- Regional harvest levels (forest inventories) from National Forest Services / Institutes (EFI 2012)
- Pan-European forest cover map (Gunia et al 2012, www.efi.int/portal/virtual_library/information_services/mapping_services/forest_map_of_europe)
- Forest biomass map: See Gallaun et al. 2010 (For. Ecol. & Manag. 260: 252-261) for details
- Net annual increment: See Verkerk et al. (submitted). Mapping wood production in European forests. Forest Ecology and Management
- Forest ownership database: See Pulla et al. 2013 (EFI technical report)
- Tree species composition: See Brus et al. 2011 (Eur. J. For. Res., 131: 145–157)
- Protected areas: See IUCN & UNEP-WCMC 2012 (www.protectedplanet.net) and EEA 2011 (www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-5)
- Soil quality: See Verkerk et al. 2011 (For. Ecol. & Manag. 261: 2007-2015), and EC 2006 (http://eusoils.jrc.ec.europa.eu/data.html) for details
- Accessibility: Travel times to major cities (Nelson 2008. Estimated travel time to the nearest city of 50,000 or more people in year 2000 [Online]. Ispra, Italy: Global Environment Monitoring Unit - Joint Research Centre of the European Commission. Available: http://bioval.jrc.ec.europa.eu/products/gam/index.htm)
- Terrain (Elevation, slope and terrain ruggedness): CGIAR SRTM (http://srtm.csi.cgiar.org) and GTOPO30 (http://www1.gsi.go.jp/geowww/globalmapgsi/gtopo30/gtopo30.html). Terrain ruggedness was calculated following Riley et al. 1999 (Intermountain J. Sciences 5: 23-27)
- Climate (Temperature, precipitation and water shortage): WorldClim (http://www.worldclim.org/current) and the ATEAM project (http://www.pik-potsdam.de/ateam)
- Population density: LandScan 2004 (http://www.ornl.gov/sci/landscan/ landscan_sample.shtml)

Validation

Algorithmic models were internally validated using a ten-fold cross-validation. The linear model was not directly validated but Bayesian Model Averaging was applied to account for all possible model setups and to derive the probability if a certain variable is included in the "true" model describing the observed process. Suitability maps were validated using plot data from the 3rd Spanish National Forest Inventory. We verified out disaggregation results by rasterizing national-level harvesting statistics and subsequent re-aggregation to NUTS units with a finer resolution than the one used for regression modelling (possible for Norway and Baden-Württemberg, Germany). We used Spearman correlations to assess the goodness of fit between observed and disaggregated harvesting statistics.

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References

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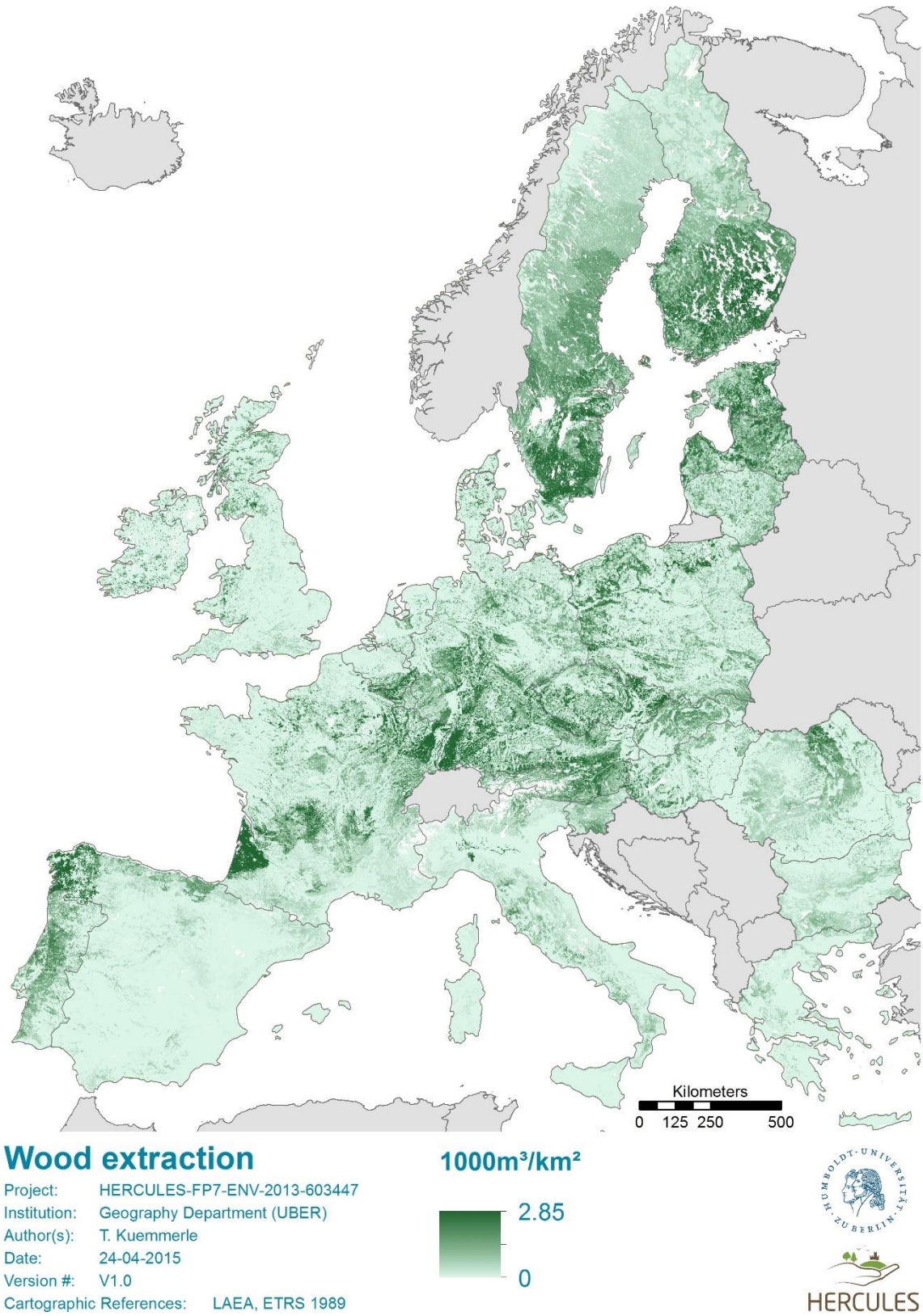
Time period	**Spatial extent**	**Resolution**	**Version**
1990, 2000, 2006, 2010	EU-27	1km²	V1.0

Map: Data is shown for the year 2000. Data for the entire study period is available in the data repository.



Land-use history

Description

Historic land-cover/use change is an important feature to consider for characterizing cultural landscapes. This indicator shows the 'age' of every grid cell within our study area in the year of 2010 and serves as a proxy for the persistence of land use throughout the twentieth century. As an example, if a grid cell was defined as arable land from 1900 until 1950 and forest from 1960 to 2010 the landscape has an age of 50 years.

This indicator is derived using a database prepared by Fuchs et al. (2014) comprising a land-cover map of Europe for every decade between 1900 and 2010. Multiple European and national datasets, old military maps, and the Historic Land Dynamics Assessment (HILDA) modelling framework were used to generate these maps. For detailed information please see the referenced articles.

Input data

Land –cover statistics were derived for every decade between 1900 and 2010 using the following databases:

- Forest resource assessment FRA (FAO) from 1948 to 2010
- National land-cover statistics (1900 – 2010)
- 1900 land cover statistic Meyer Conversation Encyclopaedia (1908)
- CORINE land cover for 1990 to 2006
- EUROSTAT land-cover statistics (1974 – 2010)
- FAO statistics (1961 – 2010)

Validation

The land cover maps were validated by comparing them with other existing historic modelling approaches on both a continental scale as well as in nine different regional validation sites. See referenced articles for details.

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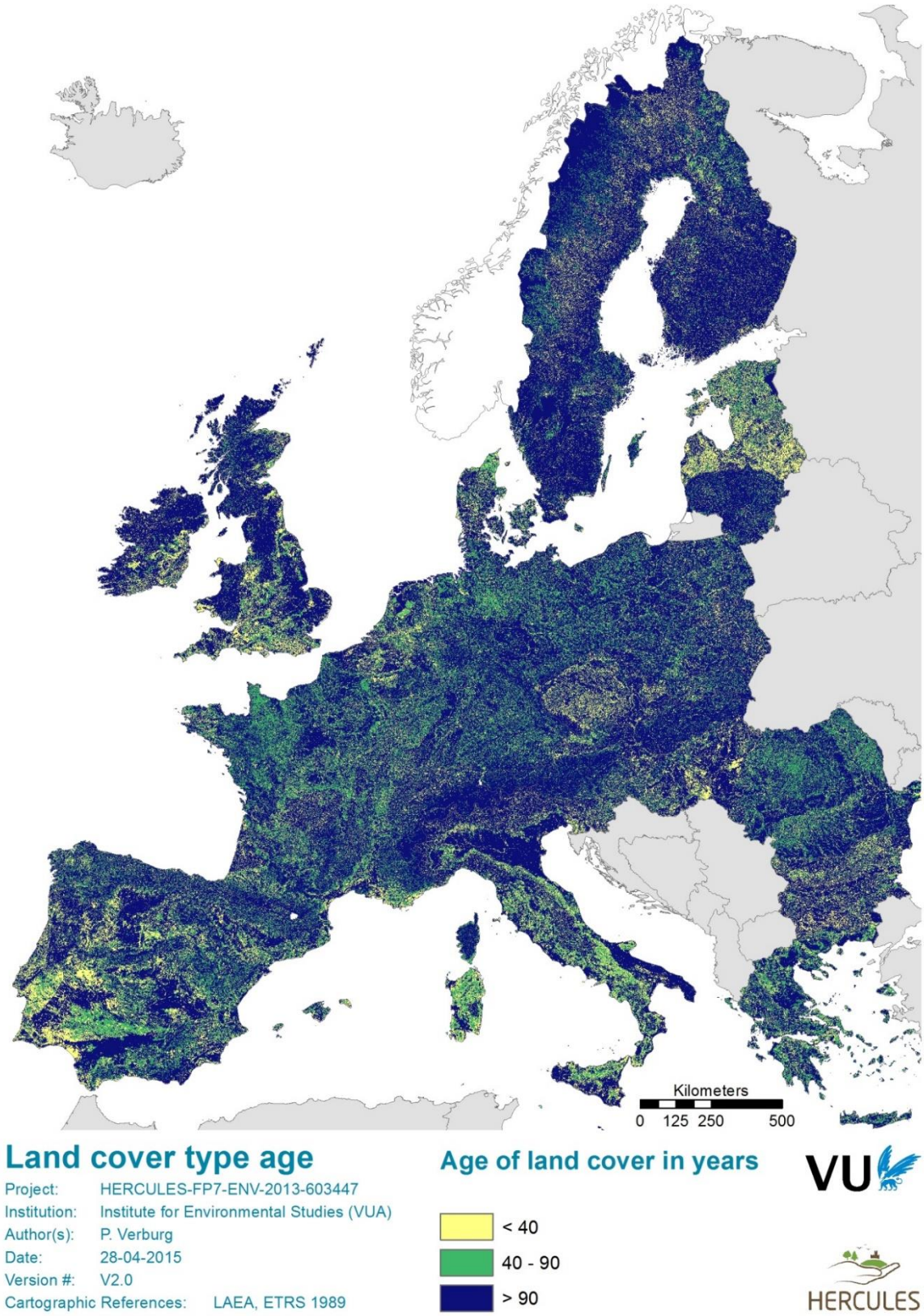
References

- Fuchs, R., Herold, M., Verburg, P. H., Clevers, J. G., & Eberle, J. (2014). Gross changes in reconstructions of historic land cover/use for Europe between 1900 and 2010. Global change biology, 21(1), 299-313.
- Fuchs, R., Herold, M., Verburg, P. H., & Clevers, J. G. P. W. (2012). A high-resolution and harmonized model approach for reconstructing and analysing historic land changes in Europe. Biogeosciences Discussions, 9, 14823-14866.
- Fuchs, R., Verburg, P. H., Clevers, J. G., & Herold, M. (2015). The potential of old maps and encyclopaedias for reconstructing historic European land cover/use change. Applied Geography, 59, 43-55.

Time period	Spatial extent	Resolution	Version
1900 - 2010	EU-27 + CH	1km²	1.0

Map: Age of each land cover type in 2010



Traditional Foodstuffs

Description

This indicator assesses at the production of traditional food products. As a proxy for traditional food production, we used local foodstuffs that are geographically protected by EU regulations. A Protected Designation of Origin (PDO) is an official EU certificate that requires traditional foodstuffs such as "Parmigiano Reggiano" to be produced according to certain traditional guidelines within a bounded geographical area. Following the example of van Berkel and Verburg (2011) we mapped all PDOs with explicit geographical denomination to identify landscapes of traditional foodstuffs. Legal documents protecting the PDO either specify an administrative region or (a number of) village(s) where the relevant product can be produced. When the geographical denomination was a list of villages instead of an explicit region, we used a five-kilometre radius buffer around the village to define the production area. The number of PDOs per region varies between 0 and 12.

Input data

- Legal PDO documents from DOOR database http://ec.europa.eu/agriculture/quality/door/list.html?recordStart=0&recordPerPage=10&recordEnd=10&filter.status=REGISTERED&sort.milestone=desc

Validation

none

Contact

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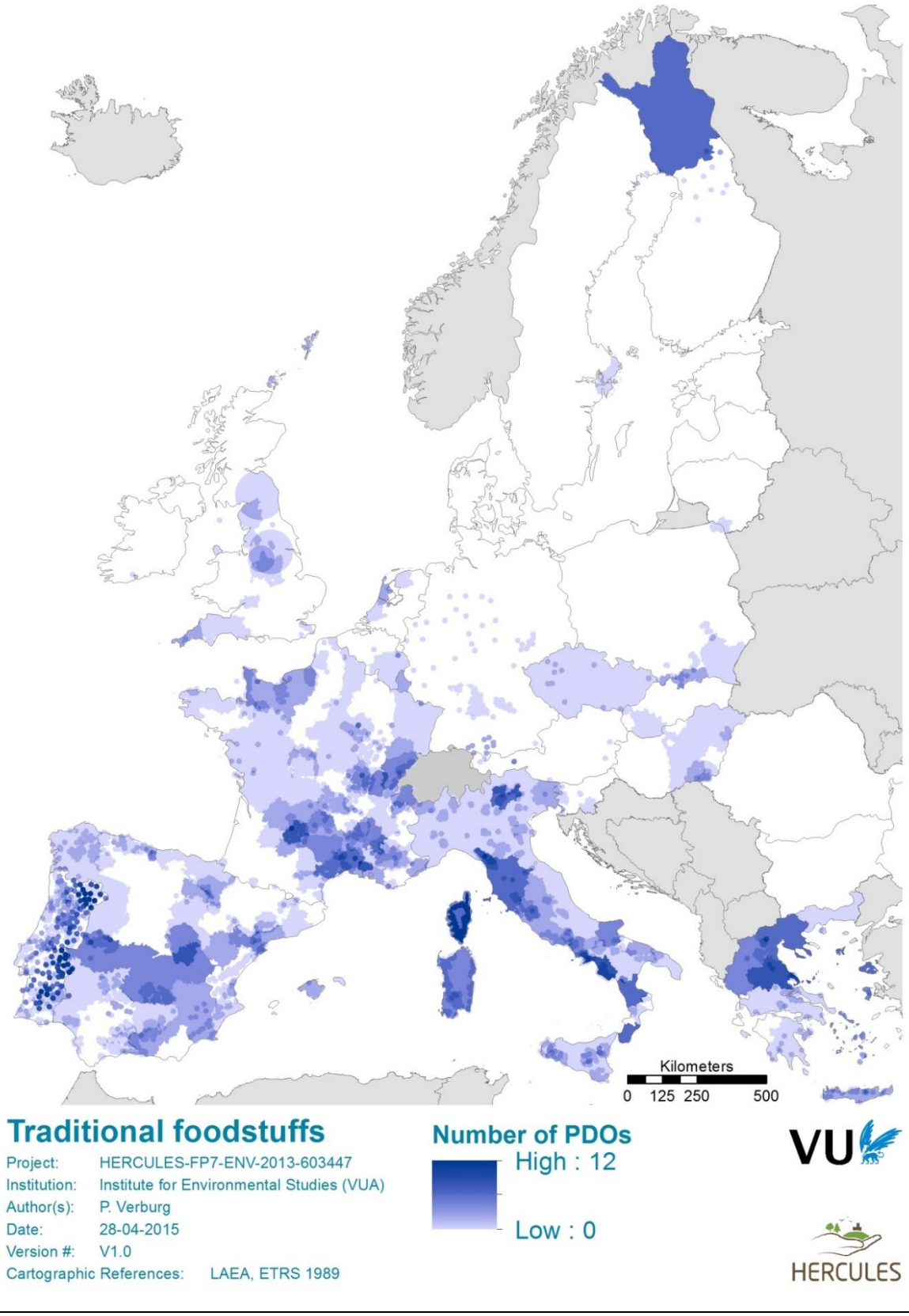
References

- Paper in preparation.

Time period	Spatial extent	Resolution	Version
2014	EU27	1km^2	1.0

Map: Data show number of PDOs per NUTS region in November 2014



Panoramio images

Description

Panoramio is an online service for sharing of geotagged photos. The service is featured in Google Earth and contains only in Europe over 30 million geotagged photos. For HERCULES, we collected a database with the density of unique user uploads per square kilometre of geotagged photos in non-urban areas. This type of passively crowdsourced data can give a very good insight into the preference of people for different landscapes and elements of the landscape. This indicator will not be used as such in the typology, but will be used to compare with the results of the typology and possibly of other analyses.

Input data

- REST API from Panoramio
- Photos geotagged in built-up area (see CORINE data layer), including metadata (photo title, user name, photo date, exact coordinates, and photo url) see http://www.panoramio.com/api/data/api.html for detailed information on Panoramio API

Validation

none

Contact

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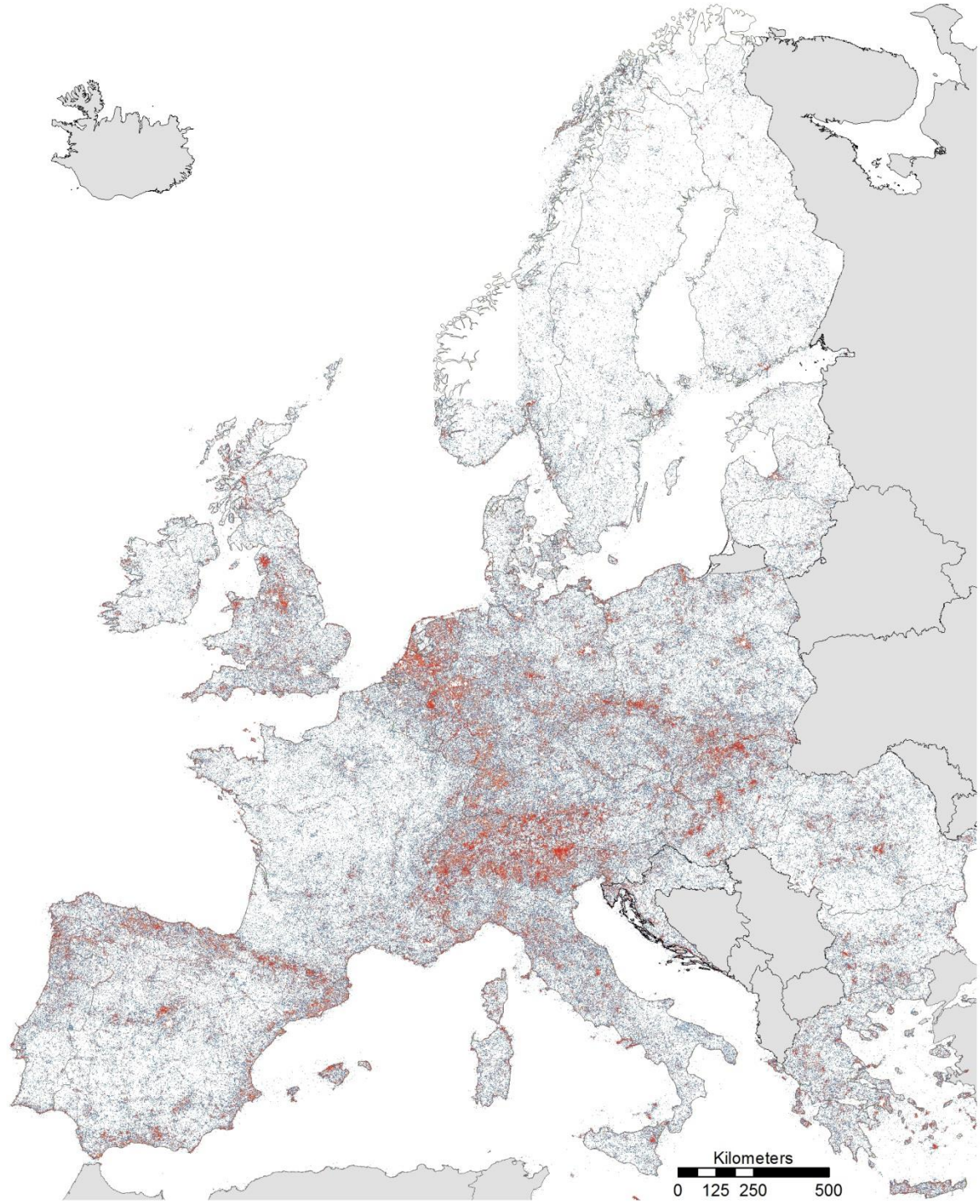
References

- Paper in preparation.

Time period	Spatial extent	Resolution	Version
2014	EU28 + CH	1km^2	1.0

Map: Data show number of unique user uploads per km^2



Panoramio density

Project: HERCULES-FP7-ENV-2013-603447
Institution: Institute for Environmental Studies (VUA)
Author(s): P. Verburg
Date: 04-05-2015
Version #: V1.0
Cartographic References: LAEA, ETRS 1989

of geotagged photos

High : 200

Low : 1

VU

HERCULES

References

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