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Measuring landscape diversity and fragmentation in EU agricultural areas from LUCAS Data

A. Palmieri | Eurostat | Luxembourg | Luxembourg
M. Masselli | Consultant - Senior statistician | Rome | Italy
M. Scarnò | CINECA | Rome | Italy

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ABSTRACT

Landscape is characterised by interaction of natural processes and cultural feature. Human activities affect landscape and landscape linear elements such as hedges, dry stone walls, ditches, roads and railways influence biodiversity; landscape analysis requires an appropriate set of information able to describe land cover diversity and fragmentation. Since 2006, Eurostat carries out an area frame statistical survey on the state and the dynamics of land use and cover in the European Union called the LUCAS survey (Land Use/ Cover Area Frame Survey). The LUCAS surveys are completed in-situ every three years. LUCAS provides information for monitoring a range of socio-environmental challenges, such as land take, soil degradation, and the environmental impact of agriculture or the degree of landscape fragmentation. The latest LUCAS survey, carried out in spring - summer 2015, covers all the 28 EU countries and observations on more than 270 000 points. To this extent, we consider the latest available data collected by the LUCAS surveys in the years 2009 and 2012. The analysis can be generalised to LUCAS data 2015 when available.

The aim of the paper is to attempt of using the data collected by LUCAS survey for landscape analysis in an evolving system such as the EU countries, providing an appropriate set of information able to describe the landscape diversity and its fragmentation in agricultural land, jointly with the changes in land cover and in land use. In particular the paper shows an example of use of the informative capacity of LUCAS survey in describing and monitoring the variation of the territorial structural elements.

Keywords: landscape fragmentation, transect, data analysis

PAPER

1. Introduction

The impact of human activities on the land cover has grown enormously, being able to alter entire landscapes with important ecological consequences. A landscape refers to an area of land whose character and functions are defined by the complex interaction between natural processes (relief, soil type, water availability, climate, biological diversity) and cultural features (human intervention through agriculture, forestry, rural policies, construction and economic structures). European countryside is also characterized by structural linear elements that portray the joint role of nature and humankind on environment. The presence of grass verges, hedges, dry stone walls, ditches and other semi-natural linear elements is considered as an important factor to biodiversity, in some cases helping to promote ecosystem services (such as pollination or pest control), in others constituting negative barriers that could limit the movement of species. In this sense can be intended, for example, all those linear elements which have a dissecting nature (such as roads, railways and aerial cables), that are closely linked to population and infrastructure developments, and impact on biodiversity.

The analysis of these topics, in an evolving system such as the EU countries, requires exploiting an appropriate set of information able to describe the landscape diversity and its fragmentation in agricultural land, jointly with the changes in land cover and in land use. To this extent, we consider the data collected by the LUCAS (Land Use and Cover Area frame Survey) surveys in the years 2009 and 2012. The analysis will include LUCAS data 2015 when available.

LUCAS survey is carried out at EU level every three years; it is based on a sample of about 270 thousands geo-referenced points, selected from a frame of more than 1 million of points that belong to the intersections of a 2 square km grid built all over the EU territory. LUCAS is carried out by direct observations of surveyors in a small area centred on the selected point (with a width of 20 square meters). For each of them information on land cover (i.e. the bio-physical coverage of land, like natural areas, forests, buildings and roads or lakes) and of land use (i.e. the socioeconomic use that is made of land, like agriculture, commerce, residential use or recreation) is collected; it is allowed to get a main and a secondary land cover and land use codes. Moreover, the surveyors take a series of photographs of the point itself, and of what in all four cardinal directions (north,

[1] Contribution to the ICAS VII: Rough draft on gender and rural women's empowerment in relation to DW/rural employment.

south, east and west); some specific information are also collected as "ad hoc modules" added in each survey (top soil sample in 2009 and the transects in surveys 2009 and 2012).

The aim of the paper is to attempt of using the data collected by LUCAS survey for landscape analysis and to check the performances of the survey in describing and monitoring the territorial structural elements. The analysis is carried out considering the level ~~Country,~~ because of the simplicity in presentation, even if the same methodology can be easily extended to regional level. The richness of the LUCAS classifications allows defining agricultural areas in different ways; in this context we referred to an extensive definition that considers the points belonging to Cropland and Grassland or characterized by a land use of agriculture (including fallow land, kitchen gardens) or forestry. The selections were made over the main or secondary land covers and land uses values. Moreover, in order to facilitate the comparison, only the countries that participated to the survey in both 2009 and 2012 are considered. These conditions led us to consider 23 countries and about 75% of their total area. In the following analysis, a set of indicators derived from the transects and concerning the richness and fragmentation of landscape are defined, calculated and synthetized with multivariate techniques on weighted data.

2. The Transect in LUCAS survey

Transect in LUCAS survey consists of a straight line walk of 250 meters in an eastwards direction from the point, where surveyors record the transition of the different land covers and of the linear elements, according to a specific classification in the sequence of their appearance (figure 1). Land covers are collected by means of the first digit of the standard LUCAS definitions (table 1).

Figure 1 -Transect information collected by LUCAS

Table 1 - Land cover classification, LUCAS 2009 - 2012

A	*Artificial land*	*E*	*Grassland*
B	*Cropland*	*F*	*Bare land*
C	*Woodland*	*G*	*Water*
D	*Shrub land*	*H*	*Wetland*

The linear features include 19 elements such as walls, hedges, roads, railway lines, irrigation channels or electric power lines; these features are taken into account if their width is larger than 1 meter (with the exception of walls ditches electric lines and fences) and at least 20 meters long. These elements could be grouped into five main subclasses, with a further distinction by considering a positive or negative impact on the biodiversity (as identified by experts in the topic) or classified according to their capacity to structure the countryside or to cause dissection of landscape (table 2). It has to be noted that the evaluation of the impact depends on the environmental context. Single bushes or single tree

Table 2 - Linear element classification, LUCAS 2009 – 2012

Linear element	Macro classification	type	Impact
Grass margins <3m	Green linear feature	structure	++
Heath/Shrub, tall herb fringes <3m	Green linear feature	structure	++
Single tree, single bushes	Green linear feature	structure	+
Avenue trees	Green linear feature	structure	+
Conifer hedges <3m	Green linear feature	structure	+
Bush/tree hedges/coppices, visibly managed	Green linear feature	structure	+++
Bush/tree hedges, not managed, with single trees	Green linear feature	structure	+++
Grove/Woodland margins (if no hedgerow) <3m	Green linear feature	structure	+++
Dry stone walls	Rock/stone linear elements	structure	++
Artificial constructions (other than dry stone walls)	Infrastructure linear elements	dissection	--
Fences	Infrastructure linear elements	dissection	--
Electric lines	Infrastructure linear elements	dissection	---
Ditches, channels <3m	Water linear feature	structure	++
Rivers, stream <3m	Water linear feature	structure	+++
Ponds, wetland <3m	Water linear feature	structure	+++
Rocks, outcrops with some natural vegetation	Green linear feature	structure	++
Tracks	Transport linear feature	dissection	--
Roads	Transport linear feature	dissection	--
Railways	Transport linear feature	dissection	--
Other linear elements	Other	dissection	0

could be positive (e.g. solitary trees in grassland) or part of a degradation process if remnants of tree lines. Avenue trees are positive for biodiversity, but completeness has to be taken into account. Conifer hedges are positive for biodiversity in boreal or alpine regions, where they are part of natural forest, and negative in Atlantic regions where they are part of gardens in residential areas. Visibly managed bush and tree hedges (pollarded) indicate a cultural landscape, that's well managed, probably rich on birds. Not managed vegetation deriving from abandonment can show plant species decline, but they can be good for larger mammals. Groves are mostly important for birds, butterflies and plant species.

Dry stone walls are relevant for plants, reptiles, insects and mosses, while other artificial constructions are barrier for natural species. Fences potentially constitute a bar and together with electric lines disturb landscape aesthetics. Water linear elements are in general positive for biodiversity, depending on the quality of the water or the vegetation along, or whether permanent or temporary water; ditches can be negative for the landscape (drainage of wetlands) and temporary ponds can be important habitat. Transport linear features (tracks, roads and railways) can be absolute barriers for invertebrates.

Land covers that characterize the transect are used to represent the richness of the landscape in terms of diversity, while the linear elements were considered as indicators of fragmentation. They can be calculated at elementary level or grouped according to the definitions reported in table 2 or by aggregations based on statistical analysis (see the next paragraph).

3. Dissection elements analysis

Generally synthetic indicators are previously identified and then applied to data to be analysed; they can be based, for example, on one or more classifications reported in table 2 as already done (Palmieri A, Dominici P, Kasanko M., Martino L., 2011). In this paper we propose a different approach: in the first place to analyse the data in order to identify relationships between variables and, on this base, to build up the indicators.

An analysis of the fragmentation (the variables in the first column of table 2) was made to verify the existence of a relation within the linear elements and between them and the countries, or, in other words, whether and how the fragmentation elements are able to shape groups useful to calculate synthetic indicators and to discriminate the countries; the analysis was carried out both on 2009 and 2012 survey data. To this purpose, the correspondence analysis (CA) (Benzécrì, 1973) was used. Starting from the table of cross frequencies of the linear elements by countries, CA allows to graphical identify the correspondence between the row categories (in our case the countries) with the column ones (the different kinds of linear elements). Such correspondence is obtained by projecting all the categories in a ~~c~~ompromise space~~ ~~(usually of dimension 2, i.e. a place). The coordinates of such projections are obtained by taking into account the row and the column profiles; this permits to take into account a metric that is not influenced by the different marginal totals.

To verify the effects of the years (2009 and 2012), we conducted a CA by considering the projections of the variables as estimated for the 2012 and, in the resulting space, we projected the countries according to the distribution of transects as observed in 2009.

The first result obtained by the CA analysis allows identifying groups of linear elements that can summarise the fragmentation of the landscapes. In particular it is possible to create six groups, each of these defined by considering the projections as in figure 2. In particular:

- Ditches, channels ←3m, Ponds, wetland ←3m;

- Single tree, single bushes, Avenue trees, Conifer hedges ←3m, Bush/tree hedges/coppices, visibly managed, Bush/tree hedges, not managed, with single trees;

- Grass margins ←3m, Heath/Shrub, tall herb fringes ←3m, Rivers, stream ←3m, Dry stone walls, Rocks, outcrops with some natural vegetation, Grove/Woodland margins (if no hedgerow) ←3m;

- Tracks, Roads, Railways;

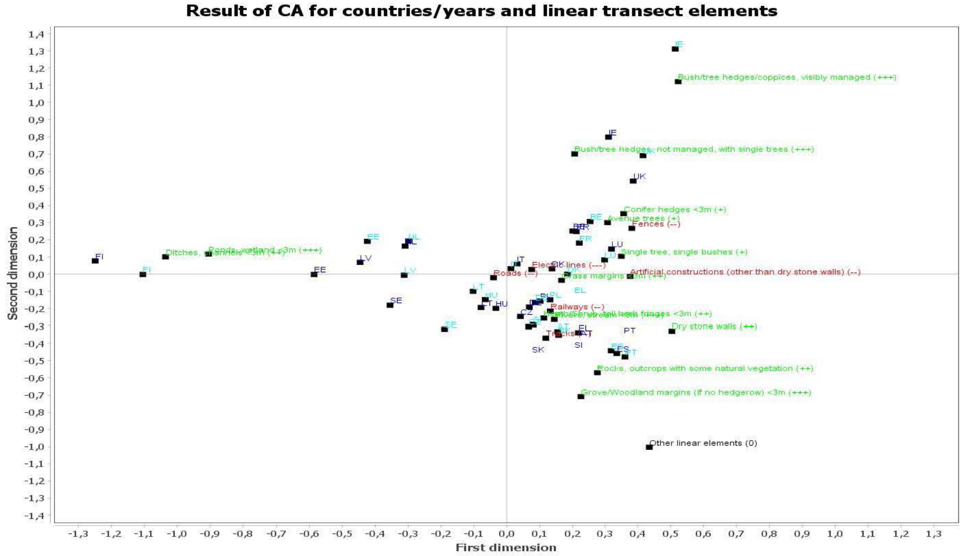
- Artificial constructions (other than dry stone walls), Fences;

- Electric lines.

For each group it was calculated an indicator that represents the relative frequencies of its linear elements on their totals; the indicators have been calculated on each point surveyed in the LUCAS framework.

Moreover, as second result, the CA allows us to describe the relations between the linear elements and the countries. In particular Finland, Estonia, Netherland and Latvia are grouped and characterised by ditches and ponds (it has to be noted that the rivers, initially classified in the same water linear feature are, instead, positioned in the opposite quadrant). Bush/tree, conifer hedges and avenues trees are features that seem typical of Ireland, UK, France Belgium and Luxembourg. Heath/Shrub, rivers,

Figure 2 – Projections of countries by year (2012 in blue and 2009 in cyan) and of the linear transect elements (in red those with a negative impact and in green those with positive impact) as resulting from the Correspondence Analysis



grove/woodland margins, rocks and fry stone walls characterize Spain, Portugal, Greece, Austria, Slovakia and Slovenia. The remaining countries/linear features are, instead, not well interpretable because projected near the barycenter of the axes, that represents the area in which the relations are not discriminant. Another interesting result of the CA relies on the fact that the countries maintain their relative position between the two years, showing a stability in their characterization.

4. The landscape diversity indicators

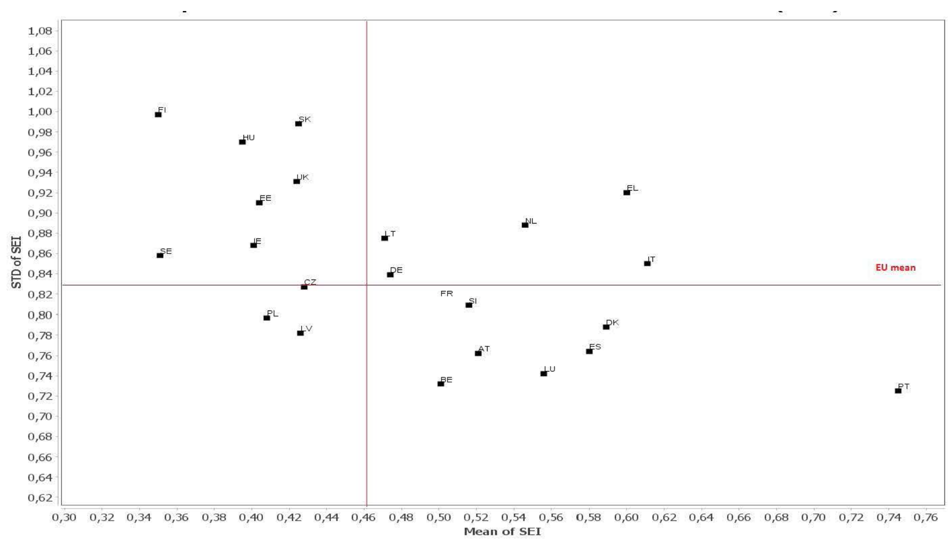
A direct measure of the degree of homogeneity or heterogeneity in terms of the physical coverage of the land can be drawn by the number of different land cover types (see table 1) observed in each of the transects surveyed.

The information on different types of land cover and their relative abundance (i.e. whether the same type of land cover recurs in a transect) can be summarised by means of two Shannon indices (Palmieri et al., 2011): the Shannon Diversity Index (SDI) and the Shannon Evenness Index (SEI).

The latter, obtained by dividing the SDI by its maximum value, is easier to read, as it varies between 0 (no diversity, i.e. a single land cover type) and 1 (maximum observed diversity combined with complete evenness).

To verify the discriminating capacity of SEI, further indexes are computed: 1) mean values at country level of SEIs, calculated for each point; their distribution is reported, for the year 2012, in the scatterplot in figure 3; 2) SEI standard deviations, taken as indicators of the heterogeneity of the index within the countries are also shown in vertical axis.

Figure 3 – Scatterplot of means and standard deviations of the SEI indexes for each country, as observed in LUCAS 2012 (the red lines identify the values for EU)



Analysing the SEI distributions for 2009 and 2012 it is possible to characterize the countries in four main typologies, considering those with a higher, or lower, value of the diversity index and, respectively, its variability. In particular Czech Republic, Poland and Latvia seems to have a higher homogeneity in the land cover with a less variability in respect to Finland, Hungary, Slovakia, UK, Estonia and Belgium, also characterized with a less diversity in land cover. Latvia, Netherland and Greece, instead, have a higher diversity index, but also more changing in their territories than the remaining countries. Because of its potentiality in discriminating the countries, SEI index is taken into consideration in analysing landscape together with dissection indexes.

5. The landscape analysis

As shown above, dissection as well as diversity indexes can be used separately to analyse the countries landscape but a different approach can be adopted. A further analysis has been carried out by considering together two sets of indicators; on one hand the six synthetic indexes, built up according to the grouping of linear elements identified in paragraph 3, and the SDI diversity index of land cover. On these seven indicators, a principal component analysis was carried out in order to obtain the latent variables (factors) representing the optimal combination of the indicators not affected by multicollinearity. The groups where identified by means of a disjoint cluster analysis (based on the K-means algorithm) applied on the resulting factors and the optimal clustering of the countries landscapes per year was obtained.

The analysis identified four clusters; they are characterized in terms of the original seven indicators by considering their mean value per cluster that more discriminate the groups; figure 4 reports the means for EU and for each cluster in the years 2009 and 2012.

Figure 4 – Mean values of the indicators for the dissection linear elements and for the SEI index as observed in EU and as obtained by the cluster analysis on the countries/years

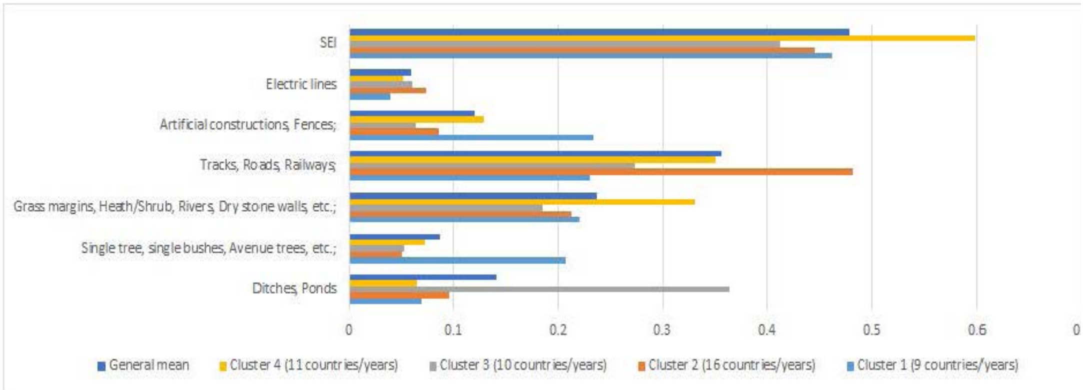
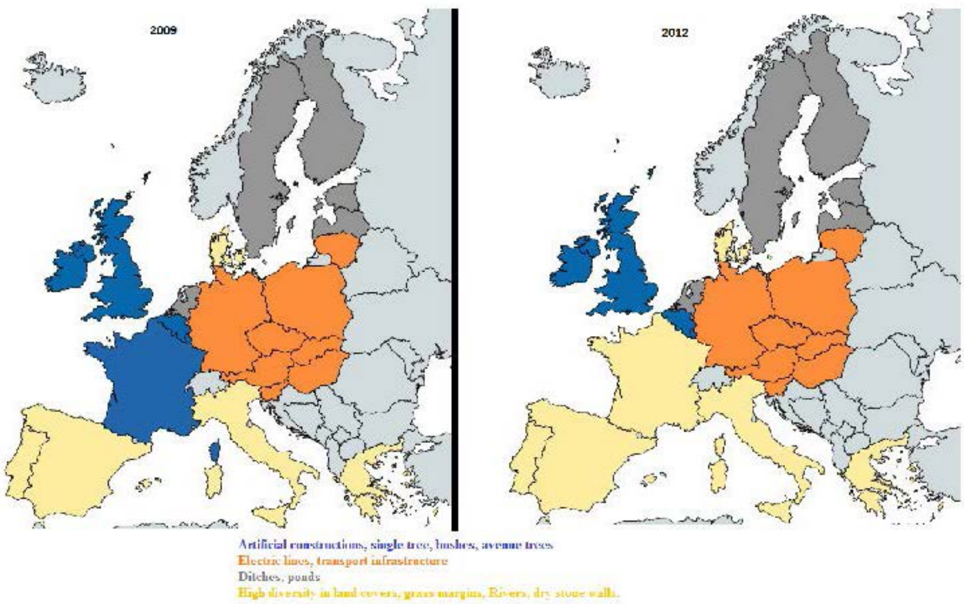


Figure 5 – EU countries according to the cluster to which they were attributed



The analysis allows us to label the clusters in the following way:

- Cluster 1: Artificial constructions, single tree, bushes, avenue trees, medium diversity in land covers
- Cluster 2: Electric lines, transport infrastructure, medium diversity in land covers;
- Cluster 3: Ditches, ponds, lower diversity in land covers;
- Cluster 4: Higher diversity in land covers, grass margins, Rivers, dry stone walls.

Maps in figure 5 report, for the years 2009 and 2012, the different countries coloured according to the cluster in which they are classified. The maps show a stable classification among the two survey years except for France that passes from an “Atlantic” cluster to a “Mediterranean” one. The country indicators in 2009 were close to the new group and so the change it is probably due to sample variations that in 2012 privileged the south points with regards to the north ones. Denmark, in both years, is classified in the “Mediterranean” cluster mainly because of its value of the Shannon index, which shows the diversity of land covers in comparison with the other countries/groups.

5. Conclusion

The paper shows how data collected by LUCAS survey, allow landscape analysis in an evolving system such as the European Union countries, and provide an appropriate set of information able to describe the landscape diversity and its fragmentation in agricultural land, jointly with the changes in land cover and in land use. In particular the paper describes how the application of multivariate statistical techniques is able not only to describe and discriminate different landscapes typologies in different countries but also to identify a set of indicators to support and complete the ones derived from the dissection elements classifications. The stable results obtained in correspondence and in cluster analysis could indicate that variations in point's selection and in data collection do not affect substantially the capacity of LUCAS in monitoring the EU landscape, even though a pure panel approach is to be preferred for a periodical monitoring.

The above analysis is a first attempt to exploit the potentiality of LUCAS using multivariate analysis on specific indicators derived from LUCAS primary data. The methodology can be fine-tuned using other indicators derived from auxiliary information collected by the survey; moreover the heterogeneity within countries, at level of regions and/or elevation classes, can be further studied in order to obtain a more analytical description of the EU agricultural area and probably a new picture of the variations over the time. We are including in the analysis the data from 2015 survey and results will be compared for different land cover classes; this will allow us to improve the system of indicators and to verify their dynamic. As far as regional context is concerned the efficiency of sample with panel structure has to be studied too.

LUCAS transects allow to study the richness of the land cover and of its dynamic though the years. The information could be used in estimating proper models to analyse agricultural systems when enriched with other information.

Other approaches for landscape observation, based on remote sensing or administrative sources are not included in this paper but the integration of such information could offer new opportunities in ameliorating the analysis. Both predefined and derived indicators, combined with suitable auxiliary information can be used for monitoring territory at macro level.

LUCAS micro-data are freely available to the user by direct download from Eurostat web site

References

Benzécri, J.-P. (1973). L'Analyse des Données. Volume II. L'Analyse des Correspondances. Paris, France: Dunod.

Palmieri A, Dominici P, Kasanko M., Martino L., (2011), Diversified landscape structure in the EU Member States, in Eurostat, Statistics in focus, November 2011

Regmi A, Lara T.R, Kleinwechter U., Conwell A., Gotor E. (2016) Integrating Biodiversity and Ecosystem Services into the Economic Analysis of Agricultural Systems, in Bioversity International , Working Paper, January 2016

Swift, M. J., A. -M. N. Izac, and M. van Noordwijk. (2004), Biodiversity and Ecosystem Services in Agricultural Landscapes—are We Asking the Right Questions? in Agriculture, Ecosystems & Environment, Published by Elsevier B.V, 104 :113–134.