Explaining land-use change in Portugal 1990-2000

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ABSTRACT

This paper studies the processes of land-use change in Portugal between 1990 and 2000 and analyses which driving forces were responsible for these changes. Urbanization and agricultural land abandonment were the most prevailing processes. While urbanization occurred mainly next to urban centers in coastal areas, agriculture abandonment took place in marginal areas with scarce water resources. Intensification of agriculture was also a significant process in areas where water is available, as a response to EU policies and market incentives. Natural driving forces such as soil characteristics did not seem to be important, indicating that physical environmental conditions are not influencing the observed processes.

KEY WORDS

Land-use change, Portugal, driving forces, transition matrix, multinomial regression model

1. INTRODUCTION

Changes in land-cover and -use constitute important features in shaping the physical and human environment. Although land-use change occurs in discrete sites, it is so pervasive that its aggregated outcome constitutes a key element of environmental global change (Vitousek, 1992). Land-use change patterns are the result of complex interactions between numerous factors operating at different spatial scales (Lambin et al, 2001). Five major types of driving forces that influence landscape development can be identified (Hesperger & Burgi, 2007; Verburg et al, 2004), namely:

- natural driving forces, e.g. soil characteristics and drainage conditions, determining the biophysical potentials and constraints for natural and agricultural vegetation, as well as the basic suitability for residential areas;
- socio-cultural driving forces, including demography, lifestyle and historical events;
- economic driving forces, e.g. comprising market structure, existing accessibilities and consumer demands;
- political driving forces, particularly policies with a spatial dimension related to e.g. nature conservation and infrastructure development;
- technological driving forces, such as the mechanization of agriculture, including also social and organizational expertise.

The Mediterranean region is an example of a landscape that has been modeled by human activities for centuries (Stevenson and Harrison, 1992). Since the middle of the 20th century important changes in land use have strongly impacted local ecosystems through processes such as farming intensification, increased migration to urban centers and expansion of tourism-related activities on coastland (Alados et al, 2007). An increase in forest and scrubland vegetation has been also observed, due to the marginalization of traditional agricultural and grazing practices and consequent abandonment of agricultural land (Millington et al, 2007).

Similar ongoing processes have been perceived in Portugal in recent years (e.g. Pinto-Correia, 1993; Moreira et al, 2001; Van Doorn & Bakker; 2007; Ramos & Santos, 2009, Petrova et al, 2009). However, despite the research carried out at local and regional level, a thorough analysis of land-use change patterns at national level in Portugal has not been performed so far. Even though a few surveys at European level have included Portugal into their accounts (EEA,2006; Feranec et al, 2010) they have solely quantified the changes in land-cover stocks and the various flows between them, without presenting a systematic inference on the core driving forces underlying these processes. In order to fill this gap, the present research has as its main goals:

- identify the main land-use changes in Portugal between 1990 and 2000;
- determine the key processes during that period;
- evaluate how different driving forces influenced these processes.

The study area corresponds to mainland Portugal. Since entering the European Union in 1986, agricultural practices have been increasingly determined by subsidies and regulations associated to the Common Agricultural Policy (CAP), e.g. leading to intensification by irrigation. A substantial decrease of rural population occurred since the 1950's, leading to abandonment of agricultural lands.

Several European Union structural programs were implemented in Portugal to develop new infrastructure and improve accessibility among regions and to external markets. Although this public investment promoted long-term growth and brought the country up to EU living standards, it also contributed to the concentration of economic activity mainly in Lisbon and reinforcing asymmetries between regions (Pereira & Andraz, 2006). Indeed, Portugal is still solving some structural problems typically observed in developing countries, whilst it has simultaneously to cope with issues that are well-know in more developed countries. While the population in the interior is only now becoming urbanized, urban sprawl is currently taking place in the coastal areas (Gaspar et al, 1998).

2. DATA

2.1 Land use

For the analysis of land-use changes, the CORINE land cover (CLC) dataset for 1990 and 2000 with 100 meters grid resolution was used (http://www.eea.europa.eu/data-and-maps). It is derived from satellite imagery for the majority of the European Countries, using a system of 44 land-cover classes organized at three levels of detail. These classes have been aggregated into 10 more general classes (Table 1), to allow an analysis of the main land-use change processes.

Table 1: Aggregation of CLC classes and resulting classification

CLC classes	***Aggregated class***
1.1 – Continuous urban fabric 1.4 – Artificial non-agricultural vegetated areas	Urban areas
1.2.1 – Industrial or commercial units 1.3 – Mine dump and construction sites	Industry and related uses
1.2.2 – Road and rail networks 1.2.3 – Port areas 1.2.4 – Airports	Infrastructures
2.1 - Arable land 2.4.2 p(50%)[1] – Complex cultivation patterns 2.4.3 p(25%)[1] - Land principally occupied by agriculture, with significant areas of natural vegetation	Arable land
2.2 – Permanent crops 2.4.1 – Annual crops associated with permanent crops 2.4.4 – Agro-forestry areas	Permanent crops
2.3 – Pastures 2.4.2 p(50%)[1] – Complex cultivation patterns 2.4.3 p(45%)[1] - Land principally occupied by agriculture, with significant areas of natural vegetation	Pastures
3.1 - Forests	Forests
3.2.1 - Natural grasslands 3.2.3 - Sclerophyllous vegetation 3.2.4 - Transitional woodland-scrub 2.4.3 p(30%)[1] - Land principally occupied by agriculture, with significant areas of natural vegetation	Semi-natural vegetation
3.2.2 – Heather and moorlands 3.3 – Open spaces with little or no vegetation 4 – Wetlands	Other nature
5 – Water	Water

2.2 Driving forces

To explain the land-use changes statistically, a set of spatially-explicit explanatory variables was collected to reflect political, economical and natural driving forces (see Table2). Prior to this selection, an assessment on the existence of correlation between the variables was carried out, leading

[1] The ‘p’ indication after certain land-use classes denotes that only part of this type is to the mentioned class. This partial assignment has been done randomly within the mentioned quantitative constraints.

to the exclusion of other considered factors, such as yearly accumulated rainfall, water deficit during the growing season and accessibilities to airports and ports.

Table 2: Driving forces used as explanatory variables

Variable	*Description*	*Type*	*Source*
Time to city	Timecost to nearest city with population > 100.000 (minutes)	economic	EU-ClueScanner model
Clay content	Soil clay content (%)	natural	JRC European Soil database
Soil depth	Depth to root-restricting layer, such as bed-rock, pan, or ground water (cm)	natural	JRC European Soil database
Slope	Slope in 6 classes: - Flat to gently sloping (0-3^{o}) - Gently sloping (3-8 ^{o}) - Sloping (8-15^{o}) - Moderately steep (15-30 ^{o}) - Steep (30-60^{o}) - Very steep (60 ^{o})	natural	Derived from the Shuttle Radar Topographic Mission (SRTM) 90m elevation data
Distance to water	Distance to nearest rivers and water bodies (m)	natural	Derived from CLC – EEA database
Mean temperature	mean yearly temperature (^{o}C)	natural	WorldClim database
South slope	South facing slopes (0 = absent, 1 = present)	natural	Derived from SRTM 90m elevation data
Elevation breakdown	Homogeneous areas as a function of height, slope and distance to the sea, defined in five classes: - Low coasts ($d<10km$, $h<50m$) - High coasts ($d<10km$, $h>50m$) - Inlands ($d>10km$, $0<h<200m$) - Uplands ($d>10km$, $200m<h<500m$ and flat areas $500m<h<1000m$) - Mountains ($d>10km$, $h>1000m$ and steep areas $500m<h<1000m$)	natural	EEA database
Natura2000 area	Protected ecological network, derived from the Habitats and Birds Directives (0 or 1)	political	Derived from the EEA database

3. METHODOLOGY

3.1 Analysis of land use change

The land-use change dynamics were analyzed by identifying the substitution patterns among classes during the 1990-2000 period. A transition matrix was created, using cross-tabulation tools provided in the ArcGIS 9.x software package and regular spreadsheet software. By that means, we established the "quantity of anticipated land-use changes from each existing category to that of each of other categories over the time period" (Pena et al, 2007), which allows identifying the transitions between land-use classes.

3.2 Analysis of the main processes

According to previous approaches (EEA, 2006; Feranec et al, 2010), the main processes of land-use change can be defined as aggregated flows representing groups of transitions sharing common features. In our case, five main processes were considered (see also Figure 1):

1) Urbanization – conversion from agricultural and natural land to artificial land;

2) Conversion from nature to agriculture – transitions from natural areas to agricultural land;

3) Agriculture intensification – internal conversion of agricultural land, representing a shift from lower to higher intensity of use;

4) Agriculture extensification – the reverse of agriculture intensification;

5) Agricultural land abandonment – conversion of agricultural land to natural land.

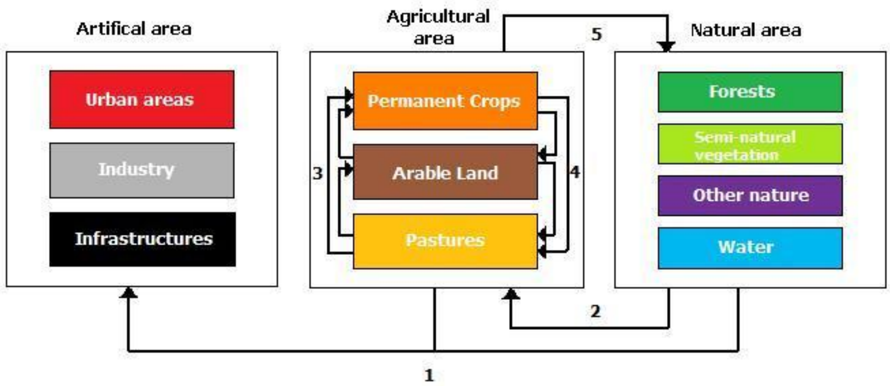

Figure 1: Main processes of land-use change. Legend: 1 – Urbanization; 2 – Conversion from nature to agriculture; 3 – Agriculture intensification; 4 – Agriculture extensification; 5 – Agricultural land abandonment

Other changes such as internal conversions in natural land between forests and semi-natural vegetation were intentionally not taken into account as they may be the result of different interfering processes such as deliberate human activities, ecological succession or wildfires.

3.3 Evaluation of the driving forces

Since land-use changes are discrete phenomena, logistic regression is an adequate statistical method to analyze them (Millington et al, 2007). Multinomial regression models are used when the dependent variable is categorical and has more than two classes. Each category of the dependent variable is then compared to a reference category and a coefficient is estimated that indicates the direction and intensity of each explanatory variable. A more detailed account on the multinomial regression model is provided elsewhere (e.g. Lesschen et al, 2005).

In this study, the categories of the dependent variable are constituted by the processes described in the previous section. An additional category was also included, comprising all the other changes that were not integrated in those processes, and was used as reference category in the model. By using the driving forces described above as explanatory variables, the statistical model assesses how these influence each process.

4. RESULTS

4.1 Land-use change

The transition matrix of land-use change (Table 3) shows that new urban fabric is mainly the result of conversions from agricultural areas, whereas industrial and commercial areas tend to appear mostly where natural areas existed before. In terms of internal agricultural conversions, considerable intensification can be observed, particularly from arable land to permanent crops. The reverse change - agriculture extensification - also occurs, but to a lesser extent. A remarkable part of agricultural land abandonment can be accounted for by transitions from arable land to forests and semi-natural vegetation. Conversely, shifts from agriculture to nature also occur, but not so sharply.

Table 3: Land-use transitions between between 1990 and 2000 (ha)

			2000										
	Land-use class		*Urban fabric*	*Industry and related uses*	*Infrastructures*	*Arable land*	*Permanent Crops*	*Pastures*	*Forests*	*Semi natural vegetation*	*Other Nature*	*Water*	*Total 1990*	
													Area	*%*
1990	Urban fabric		137792	560	96	0	0	0	11	0	0	0	138459	1,55
1990	Industry and related uses		1091	22186	504	1	3	8	106	331	161	51	24442	0,27
1990	Infrastructures		51	0	5670	0	0	0	0	0	0	0	5721	0,06
1990	Arable land		10984	3527	302	1760974	17967	7030	12194	23013	1221	2325	1832508	20,57
1990	Permanent Crops		12196	2584	229	16924	1540921	7936	6097	6699	98	928	1594612	17,90
1990	Pastures		8822	2160	269	23925	8750	632031	4619	11376	1470	797	694219	7,79
1990	Forests		5607	8500	595	8173	5930	3550	2152638	278307	7614	477	2471391	27,74
1990	Semi natural vegetation		5655	5915	342	8411	7641	3964	238767	1183738	14560	1500	1470493	16,51
1990	Other Nature		1049	1294	57	2161	1502	1004	21159	44186	500191	817	573420	6,44
1990	Water		11	33	101	164	29	0	12	753	430	101298	102831	1,15
	Total 2000	Area	183258	46759	8165	1820733	1582743	648494	2435603	1548403	525745	108193		
	Total 2000	%	2,06	0,52	0,09	20,44	17,77	7,28	27,34	17,38	5,90	1,21		

4.2 Processes of land-use change

Table 4 provides an overview of the main land-use change processes and shows that urbanization and agricultural land abandonment prevail. Figure 2 shows that urbanization appears mainly in coastal areas, particularly in the Lisbon and Oporto metropolitan areas, while agriculture abandonment occurs mostly in interior regions and especially in the south of Alentejo region. On the other hand, agriculture intensification is much more prevalent than extensification. Ramos and Santos (2009) documented that increasing demand for products such as olive oil and wine resulted in a significant conversion of open arable and pastures into intensive permanent crops such as vineyards and irrigated olive orchards.

Table 4: Main land-use change processes in 1990-2000

Processes	*Area (ha)*	*%*
Urbanization	70232	0.79
Conversion from nature to agriculture	42529	0.48
Agriculture intensification	50642	0.57
Agriculture extensification	31890	0.36
Agricultural land abandonment	70837	0.79
Other changes	611556	6.86
No change	8037439	90.16

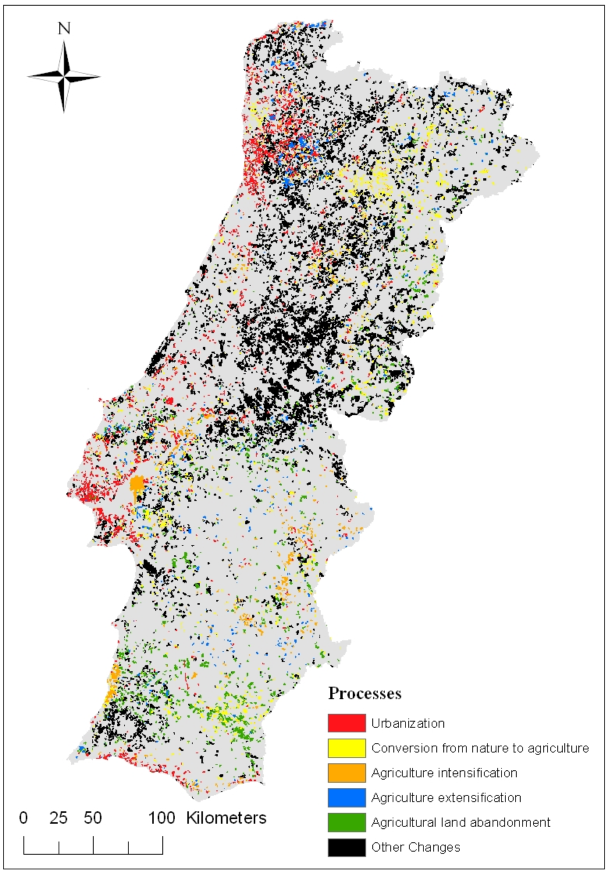

Figure 2: Main land-use change processes occurring in Portugal 1990-2000[2]

[2] For visualization purposes, the size of the grid cells has been increased fivefold.

4.3 Explaining land-use change

The multinomial regression (Table 5) shows that agricultural land abandonment tends to occur in areas distant of urban centers and water bodies. In contrast, urbanization is related to the existence of accessibilities. Similarly, all agriculture activities seem to be located close to urban centers.

Slope has a negative influence in all processes, since steeper areas are less suitable for housing construction and agricultural practices. South facing slopes, which are more exposed to sunlight, do not appear to favor any of the studied processes.

The mean temperature reflects the temperature gradients along the country. Coefficients with higher values were obtained for agriculture intensification and agricultural land abandonment, both occurring mostly in the south of the country, where the mean temperature is higher. The observed negative correlation between temperature and conversion from nature to agriculture may indicate that new agricultural areas are more prone to appear in the north.

The elevation breakdown shows that urbanization tends to occur in coastal areas, but it is highly unrelated with mountain ranges. Conversion from nature to agriculture, agriculture extensification and agricultural land abandonment are neither prone to occur in coastal areas nor at higher altitude. On the other hand, agriculture intensification appears to occur in all typologies, but mostly in coastal areas, possibly due to the proximity of the markets in the major urban centers.

Urbanization is highly unlikely to occur in Natura 2000 areas. However, agriculture intensification seems to be highly related to these regions, whereas agriculture extensification would be more desirable. Nonetheless, agricultural abandonment also tended to happen there.

Additionally, it can be deduced that soil depth may not drive the land-use change processes, but rather be a consequence of the current land-use. Actually, it appears to be higher in locations where more intensive land-use had not taken place yet, namely where agricultural land was converted from nature. At the same time, the clay content of the soil does not seem to play an important role in defining the land-use.

Table 5: Estimated coefficients for the driving forces explaining various land-use change processes in a multinomial regression model[3]

Explanatory Variable	*Urbanization*	*Conversion from nature to agriculture*	*Agriculture intensification*	*Agriculture extensification*	*Agricultural land abandonment*
Intercept	3.544	-0.530	-3.109	0.473	-9.759
Time to city	-0.019	-0.002	-0.002	-0.009	0.003
Clay content	0.053	0.031	0.083	0.062	0.040
Soil depth	-0.006	0.008	-0.006	-0.006	-0.011
Distance water	0.027	-0.026	-0.025	-0.013	0.023
Mean temperature	-0.166	-0.076	0.169	-0.047	0.596
Slope	-0.916	-0.568	-1.478	-0.841	-0.866
South slope (=1)	-0.288	-0.168	-0.303	-0.073	-0.148
Natura2000 (=1)	-0.965	0.006[4]	0.751	-0.184	0.385
Elevation breakdown[5]:					
- Low coasts	1.316	-0.497	0.368	-0.270	-1.932
- High coasts	0.739	-0.421	0.180	-1.288	-0.736
- Uplands	-0.464	-0.150	0.100	-0.323	-0.397
- Mountains	-1.578	-0.264	0.105	-1.310	-0.772

5. CONCLUSIONS

Urbanization and agricultural land abandonment were the most prevalent land-use change processes observed in Portugal in 1990-2000. Both processes appeared to be related with the distance to the main urban centers: while new urban areas tend to appear close to the cities in coastal areas, namely Lisbon and Oporto, agricultural abandonment is prone to occur in marginal areas in the interior of the country where the water resources are scarce, such as South Alentejo.

Intensification of agriculture also demonstrated to be a relevant process, being likely to happen in areas near to water bodies in the south of the country, probably as response to the growing demand for products such as olive oil and wine.

Natural areas have a tendency to arise in areas with higher slope, where urban and agricultural areas are not feasible to take place. Natura2000 policy avoided urbanization in protected areas and to some extent lead to agricultural abandonment, but agriculture intensification appeared to take place in these areas. Interestingly, soil attributes did not appear to be relevant driving forces for the studied processes.

The results of this analysis will be used to help specify models of land-use change. Based on the observed processed of change, projections of future land-use change will be established that help policy makers get prepared for potential, upcoming changes. Such simulations of land-use change are currently being performed with a new pan-European land-use model: the EU-ClueScanner model that has been developed for the European Commission (Perez-Soba et al., 2010).

[3] Other changes are used as reference category; Nagelkerke Pseudo-R^2= 0.404
[4] Not significant at the 0.05 level
[5] Using inlands as the reference class

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