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Original Research Article

Analysis of agricultural land uses through land suitability classes in Terceira Island, Azores, Portugal

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The aim of this paper is to identify the long-term determinants of land uses. To achieve this, we analyse land-use changes in Terceira island in response to a short run period of major changes in market conditions and policy interventions under different environmental conditions defined by land suitability classes. For this purpose land uses are crossed with thirteen land suitability classes that result from grouping all the combinations of four biophysical attributes that are suitable for alternative land uses and land covers. Land uses showed a good adherence to the corresponding areas of land suitability classes, despite the occurrence of land uses on marginal areas of suitability. A cartographic interpretation of Land Parcel Identification System inventory is carried out and analysed. Landscape metrics and transition matrix are designed to detect the differences between agricultural landscape structures and land-use changes from 2001 to 2011. Although changes in land-use classifications impede a more indepth analysis, results show that land-use changes under the dynamic economic and policy context (2001-2011) are strongly constrained by the biophysical features of the territory indicating also the unsuitability of policies that do not take into account that diversity.

Key words: Land suitability, agricultural land-use, land-use change, Azores.

INTRODUCTION

Agriculture and rural landscapes are closely interconnected. The institutional framework for agricultural sustainability (Evrendilek and Ertekin, 2002) encompasses agricultural production, the provision of ecosystem services and the amenity and recreational values provided by the multifunctional rural landscape systems (Holmes, 2006). The actions of agriculture generate cultural landscapes, and landscapes are the theatre of agricultural activities. However, from the agricultural perspective, the basic units are economic and social entities usually associated with farms, while from the landscape perspective the basic units result from the complex land systems area analysed at different spatial levels (Vejre et al., 2007).

Man's value system leads to changes in land-use and landscape, adapting the land to better accommodate alternative and complementary activities. Particularly, farmers and foresters are specific developers of adapted-spaces continually interacting with nature using evolving technologies and seeking to use the territory to their own advantage (Chadwick, 1971), strongly influenced by institutions that define the allocation of property rights. In that regard, the structure of agricultural landscape strongly depends on farmers' land-use decisions, which are limited by the biophysical constraints and driven by socioeconomic and technological developments, demographics, environmental and cultural factors, as well as government policies (OECD, 2001; Primdahl et al., 2004; Levin, 2006; Klijn, 2004; Nassauer and Wascher, 2007; Primdahl and Swaffield, 2010).

An integrated approach of agricultural landscape analysis and dynamics should considerer all the above factors and interrelations. Land-use observed at farm parcel level can be seen as the interface between agriculture and landscape.

Table 1. Characteristic of the two main Terceira Island agricultural landscapes

Characteristic	Intensively managed dairy landscape	Semi-natural pastoral landscape
Landscape elements	Almost no hedges, farm buildings (milking parlours, barns), stonewalls	Scrubland and hedgerows, no farm buildings, forest and/or natural vegetation patches, few stonewalls
Main ongoing processes	Intensification, specialization, concentration	Expansion, extensification
Main production	Milk production	Milk and beef productions
Major animals	Dairy cows	Suckler cows, bulls "*raça brava*", dairy heifers
Major crops	Cultivated temporary grassland, maize silage	Permanent pasture (semi-natural or improved grassland)

On the other hand, changes in agricultural land-use from arable crops to pasture, from more to less intensive cropping systems and between different cropping patterns, can have considerable environmental, social and economic effects on broader scales.

The aim of this paper is to identify the long-term conditioning factors of land uses focusing on the case of land-use changes in Terceira Island from 2001 to 2011. The paper specially intends to assess the role of biophysical constraints in agricultural land-use change and therefore in landscape dynamics - expressed through a specific land suitability classification system that integrates flexibility regarding different uses: urban/touristic, horticulture, arable farming, pasture and forest. The problem is how the historical and actual agricultural uses depend on the diversity of the potential uses of the land for several economic activities.

To achieve this aim, we try to answer two main questions:

(1) Concerning the adaptation of different sources of data, are land-use data obtained from Land Parcel Identification System (LPIS) consistent to analyse land-use changes?

(2) Is the flexibility implicit in each land (multi)suitability class an important factor to justify the resilience of agricultural land uses?

MATERIALS AND METHODS

The study area

Terceira Island located in the North Atlantic Ocean, between Longitudes 38⁰38' – 38⁰47' N and Latitudes 27⁰02' – 27⁰23' W is one of the nine volcanic islands of the Azores archipelago. The island has an area of 402.2 km^2 with a total population of 56,437 inhabitants (INE, 2011a). The climate is temperate oceanic, strongly influenced by the island's topography which produces high levels of relative atmospheric humidity and little temperature fluctuation throughout the year.

Most of the Land in Terceira is devoted to agriculture, dominated almost entirely by grass and forage crops. Regarding forage two main crops stand out: maize (*Zea mays*) and Italian ryegrass (*Lolium multiflorum*) both grown for silage and generally interspersed in short crop rotation. These crops support cattle livestock farming as the animals stay outdoor all year round. The island economy relies heavily on milk production and the industry associated with the processing of dairy products even though beef production has experienced significantly positive developments in recent years (INE, 2011b).

In the first decade of the 21st century two main agricultural landscape systems are evident (Table 1): an intensively managed dairy landscape with higher livestock density and productivity (Figure 1), and a semi-natural pastoral landscape with patches of natural vegetation and/or exotic forest (Figure 2). The recent variations in the main characteristics of Terceira Island agricultural sector reported by the 10 year agricultural census conducted by Statistics Portugal (INE) show an increase in cow milk production (16%), cow yield (23%) and average farm size (45%).

Land-use data collection

A standardized database and accurate and dynamic quantifications of biophysical resources are the basis for land-use decisions (Kilic et al., 2005). The creation of classes for land suitability is based on the work done by Silveira and Dentinho (2010) that use GIS-based analysis to group all the combinations of four biophysical attributes (average temperature, annual accumulated precipitation, slope and soil capability) (Table 2) that are suitable for alternative land uses and land covers (i.e., urban/touristic, horticulture, arable farming, pasture and forest). The methodology classifies the territory on 13 different classes (Table 3).

The area of 40,138.13 ha of the Island (Figure 3) is divided into 10 out of the 13 classes because the suitable

Figure 1: Intensively managed dairy landscape
Source: Luis Godinho (March 2011).

Figure 2: Semi-natural pastural landscape
Source: Luis Godinho (February, 2011).

Table 2. Environmental restrictions[1] considered by Silveira and Dentinho (2010).

Environmental factor	TMP (°C)	PRC (mm)	SLO (%)	CAP (I-VII)
Urban/touristic	≥ 16	≥ 0	0-25	I-VII
Horticulture	≥ 16	≥ 1000	0-25	I-VI
Arable farming	≥ 10	≥ 750	0-15	I-IV
Pasture	≥ 12.5	≥ 1300	0-25	I-V
Forest	≥ 0	≥ 750	0-50	I-VI

[1] Average annual temperature (TMP), annual accumulated precipitation (PRC), slope (SLO) and soil agricultural use capability (CAP)

classes 7,8 and 11 are absent.

Although class area 13 is not suitable for any of the activities considered, it can be related to environmental uses as water supply or nature conservation (Silveira, 2009).

The Land Parcel Identification System makes part of the Integrated Administration and Control System (IACS) for direct support schemes under the Common Agricultural Policy (CAP). LPIS is a geographical information system that facilitates the geographical identification of agricultural parcels and land uses monitoring. The system is periodically updated with data provided by farmers, mainly

Table 3. Areas by land suitability classes in Terceira Island

Class	Suitable activities[1]	Area (ha)	Area (%)
Class 1	U, H, A, P, F	4 069.25	10.14
Class 2	A, P, F	6 393.44	15.93
Class 3	U, H, P, F	2 295.38	5.72
Class 4	P, F	8 294.31	20.66
Class 5	U, H, A, F	4 824.75	12.02
Class 6	H, A, F	2.00	0.00
Class 7	U, A, F	0.00	0.00
Class 8	A, F	0.00	0.00
Class 9	U, H, F	1 687.50	4.20
Class 10	F	3 218.88	8.02
Class 11	U, F	0.00	0.00
Class 12	U	245.38	0.61
Class 13	-	9 107.25	22.69

[1] Adapted from Silveira and Dentinho (2010): Urban and touristic (U), Horticulture (H), Arable farming (A), Pasture (P) and Forest (F).

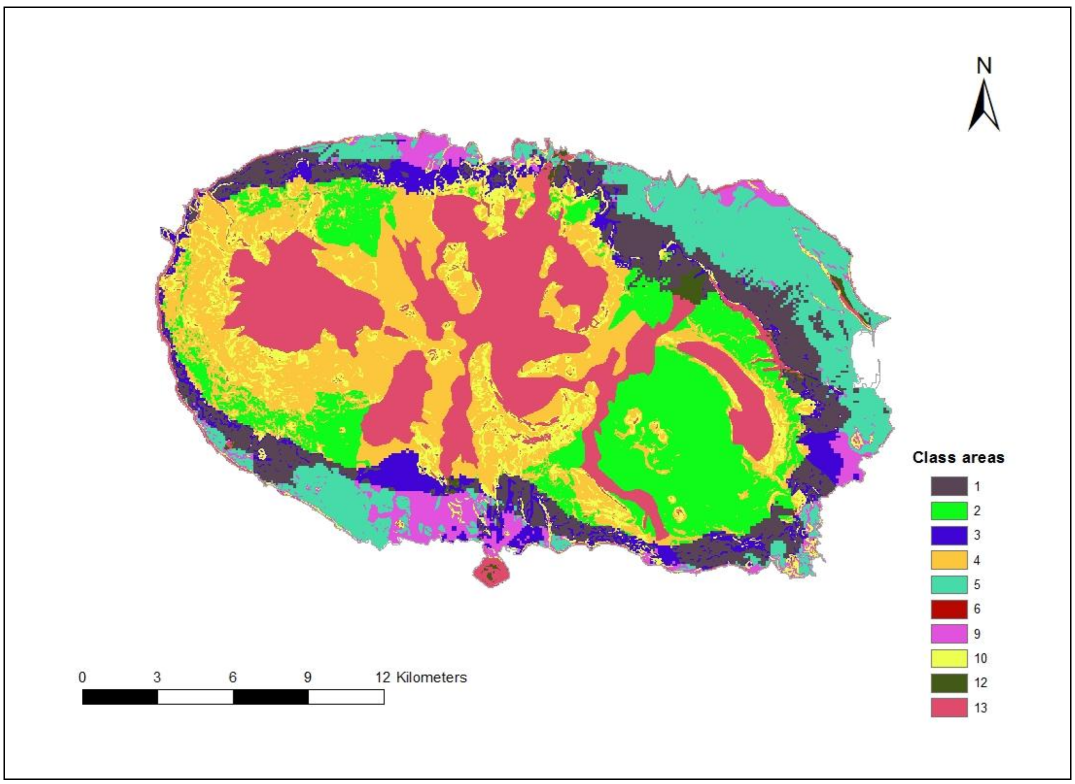

Figure 3. Terceira Island land suitability map (25 x 25 m² grid)

at the time of preparation of their annual applications (MARS Unit, 2011). It is a detailed source of information about subsidized agricultural land-use (Willems et al., 2001).

Grandgirard et al. (2008) considered LPIS as the central geographic database actually able to provide the most accurate and up-to-date information about land-use and land-use changes in the European Union.

Willems et al. (2001) and Feranec et al. (2007) compared LPIS with CORINE land cover data, both have concluded that most of the administrative data fit CORINE inventory.

The original 2001 LPIS land-use classes were previously aggregated and reduced to eight categories (Table 4): I) Arable land; II) Forage crop; III) Permanent pastures; IV) Vineyards; V) Fruit orchards; VI) Other agricultural land; VII) Forests and; VIII) Other land; an extra class "No data" relates to missing values on LPIS database. Caused by a modification on LPIS nomenclature "forage crops" and "arable land" classes have been discontinued in 2007 and replaced by the new class "temporary crops". However the

Table 4. LPIS Land-use classes

Land-use class	LPIS nomenclature (2001)	LPIS nomenclature (2011)
I	Arable land	Temporary crops
II	Forage crops	
III	Permanent pastures	Permanent pastures
IV	Vineyards	Vineyards
V	Fruit orchards Citrus orchards Banana	Fruit orchards
VI	Olive groves Mixed permanent crops Other agricultural land	Olive groves Mixed permanent crops Greenhouses and nurseries Other agricultural land
VII	Agro-forestry land	Wooded agro-forestry land Non-wooded agro-forestry land with forage use
	Forests	Wooded forest land Copse Non-wooded forest land, with no forage use
VIII	Residential land, industrial and agricultural buildings	Residential land, industrial and farm buildings Roads
	Unproductive land	Unproductive land
	Other non-agricultural land	Inland waters Other non-agricultural land

"forage crops" parcels were reclassified on either "permanent pastures" or "temporary crops", depending if they were kept for direct animal feed permanently for more than five years consecutively or not.

Figures 4 and 5 show Terceira Island maps for the eight categories mentioned above in 2001 and 2011. Each map contains 642,210 25 m grid cells, corresponding to a total area of 40,138.13 ha. The percentage of Terceira Island covered by LPIS has been increasing over time, from 51.0% (2001) to 66.5 % (2011). In 2001, the two main classes represented were "arable land" (32.8%) and "forage crops" (12.5%), which were replaced by "temporary crops" (43.1%) and "permanent pastures" (16.4%) in 2011.

Statistical analysis

Cross tabulation analysis between geographical datasets was supported by ESRI ArcGIS®9.3.1 software. The transition models are based on a matrix (A) that describes the probability of a cell changing from state i to j (for all classes) in some discrete time step, and a vector (x_t) containing the abundance area value for each class at time t (Pontius Jr. et al., 2004).

An approach for quantifying the spatial patterns of land-use for each class of suitability can be sustained in the landscape metrics. A great variety of metrics for landscape composition and configuration were developed for categorical data (Uuemaa et al., 2009). However there are very few pattern indices that are useful on their own. Their most instructive use is in comparing alternative landscape configurations, either the same landscape at different times (or under alternative scenarios), or comparing different landscapes mapped in the same manner (Gustafson, 1998).

The use of landscape metrics and indices have been applied in several fields of landscape research (e.g. biodiversity and habitat analysis; water quality; evaluation of landscape pattern and its change; urban landscape pattern and road network; aesthetics of landscape and; management, planning and monitoring). From 1994 to 2008, the majority of scientific publications using landscape metrics was dedicated to biodiversity and habitat analyses, but also to the evaluation of landscape pattern and its change (Uuemaa et al., 2009).

Landscape metrics measure and describe the spatial structure of patches, classes of patches, or the entire landscape (Botequilha Leitão et al., 2006). In the current study, it is assumed that landscape-level corresponds to the areas under the same class of land suitability, despite its

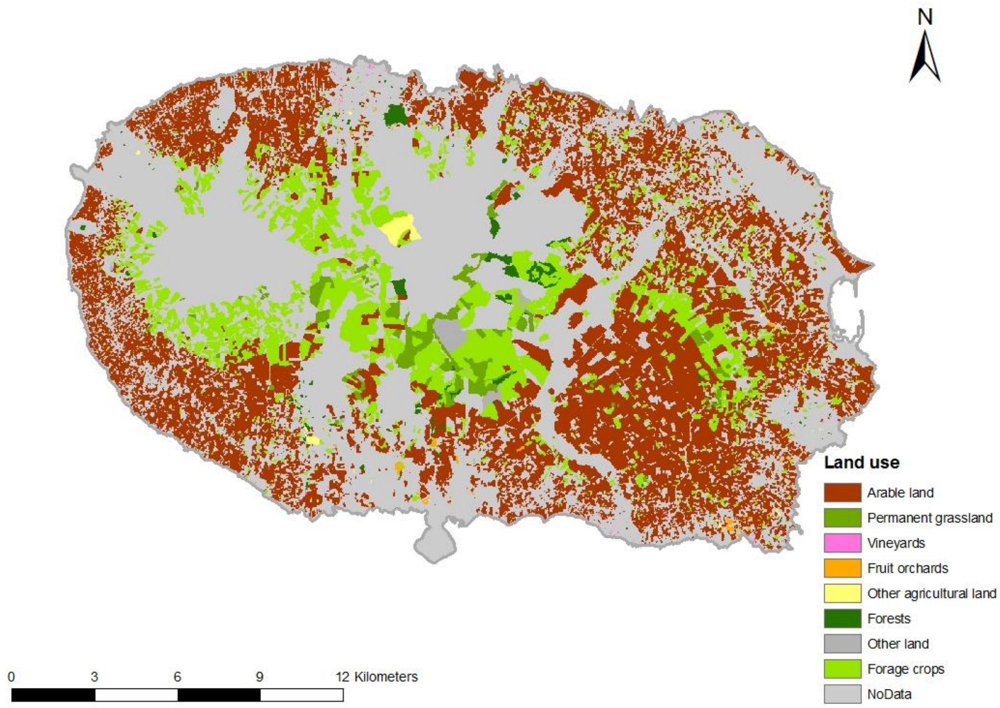

Figure 4. Land-use of the study area in 2001 (25 x 25 m² grid)

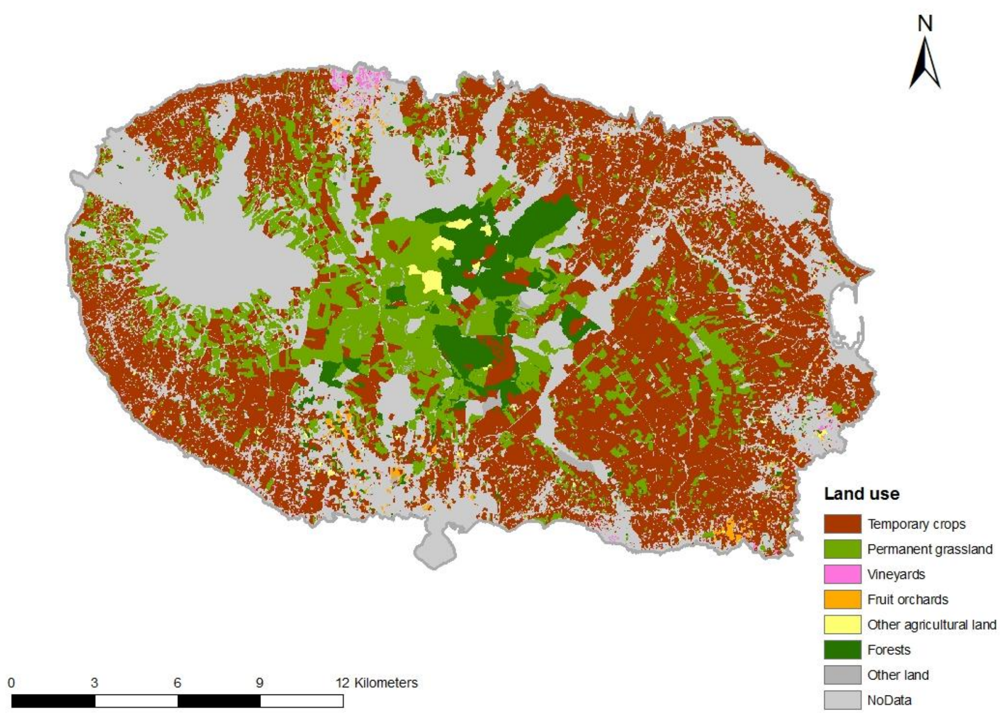

Figure 5. Land-use of the study area in 2011 (25 x 25 m² grid)

territorial discontinuity. For each land suitability class the following landscape-level metrics were calculated on Fragstats 3.3 software (McGarigal et al., 2002): class richness (number of different classes types), percentage of landscape (proportion of the territorial unit area comprised of a particular class), Shannon's diversity index, number of

Table 5. LPIS land-use occurrences per land suitability class, 2001 (in hectare, ha)

	Class combination no.	1	2	3	4	5	6	9	10	12	13
Land suitability	Urban & touristic	x		x		x		x		x	
	Horticulture	x		x		x	x	x			
	Arable farming	x	x			x	x				
	Pasture	x	x	x	X						
	Forest	x	x	x	X	x	x	x	x		
LPIS land-use	Arable land	2 274.50	4 460.88	734.44	2 224.56	2 105.56	0.56	281.06	661.19	57.25	363.69
	Permanent past.	0.94	7.06	4.00	253.31	2.31	0.00	0.56	116.31	0.00	319.06
	Vineyards	4.94	0.00	5.63	0.06	6.00	0.00	8.50	2.00	0.00	0.31
	Fruit orchards	19.81	3.69	15.06	8.38	14.63	0.00	10.56	6.31	1.50	2.50
	Other agr. land	4.94	0.38	15.88	58.44	4.00	0.00	1.88	23.19	0.00	8.50
	Forests	2.75	2.69	32.00	104.31	1.56	0.00	10.06	65.88	0.13	109.19
	Other land	9.19	6.31	8.13	18.69	6.44	0.00	2.81	20.94	0.19	143.50
	Forage crops	158.44	473.88	59.63	2 328.88	174.44	0.00	26.00	675.25	13.25	1 121.38
	No data	1 593.75	1 438.56	1 420.63	3 297.69	2 509.81	1.44	1 346.06	1 647.81	173.06	7 039.13

Table 6. Landscape metrics for land suitability classes (2001)[1].

Class	CR	AL	FC	PP	VN	FO	OA	FT	OL	ND	SHDI	NP	PD	MN	AM	SD
1	8	55.9	3.9	0.0	0.1	0.5	0.1	0.1	0.2	39.2	0.35	1112	27	2.23	78.34	13.02
2	7	69.8	7.4	0.1	0.0	0.1	0.0	0.0	0.1	22.5	0.35	1087	17	4.56	1208.73	74.09
3	8	32.0	2.6	0.2	0.2	0.7	0.7	1.4	0.4	61.9	0.69	1328	58	0.66	4.61	1.61
4	8	26.8	28.1	3.1	0.0	0.1	0.7	1.3	0.2	39.8	1.03	2334	28	2.14	56.71	10.81
5	8	43.6	3.6	0.0	0.1	0.3	0.1	0.0	0.1	52.0	0.37	928	19	2.49	60.23	12.00
6	1	28.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.9	0.00	2	100	0.28	0.45	0.22
9	8	16.7	1.5	0.0	0.5	0.6	0.1	0.6	0.2	79.8	0.74	740	44	0.46	1.86	0.80
10	8	20.5	21.0	3.6	0.1	0.2	0.7	2.0	0.7	51.2	1.20	2224	69	0.71	6.49	2.02
12	5	23.3	5.4	0.0	0.0	0.6	0.0	0.1	0.1	70.5	0.60	103	42	0.70	2.78	1.21
13	8	4.0	12.3	3.5	0.0	0.0	0.1	1.2	1.6	77.3	1.30	889	10	2.33	66.46	12.21

[1] CR – Class richness, AL – Arable land percentage of landscape, FC - Forage area percentage of landscape, PP – Permanent pasture percentage of landscape, VN – Vineyards percentage of landscape, FO – Fruit orchards percentage of landscape, OA – Other agricultural land percentage of landscape, FT – Forests percentage of landscape, OL – Other land percentage of landscape, ND – No data percentage of landscape, SHDI – Shannon's Diversity Index, NP – Number of patches, PD – Patch Density, MN – Mean patch area, AM – Area-weighted mean, SD – Patch area standard deviation.

patches (number of discrete patches in the territorial unit), patch density (number of patches per 100 ha of total unit area, does not include "no data" patches despite its addition on the total unit area), mean patch area (sum of areas across all patches in territorial unit divided by the total number of patches), area-weighted mean patch area (sum of areas across all patches in territorial unit multiplied by the proportional abundance of the patch) and patch area standard deviation (equals the square root of the sum of the squared deviations of each patch area from the mean patch area computed for all patches in the territorial unit, divided by the total number of patches; that is, the root mean squared error (deviation from the mean).

RESULTS

The occurrences of LPIS land uses are computed for 2001 and 2011 for each land suitability class (Tables 5 and 7). Despite the increase in the areas covered, the observed trends are valid for both years (Tables 6 and 8). Land suitability class combination 6 is not considered due to lack of representativeness (only 2 ha). The predomination of "arable land" (in 2001) or "temporary crops" (in 2011) land uses and lower landscape diversity is observable in all the arable farming suitable classes (classes 1, 2 and 5). Therefore, regardless of the remaining land suitability classes, in all the combinations with arable farming

Table 7. LPIS land-use occurrences per suitability class combination, 2011 (in ha)

	Class combination No.	1	2	3	4	5	6	9	10	12	13
Land suitability	Urban & touristic	x		x		x		x		x	
	Horticulture	x		x		x	x	x			
	Arable farming	x	x			x	x				
	Pasture	x	x	x	x						
	Forest	x	x	x	x	x	x	x	x		
LPIS land-use	Temporary crops	2 977.06	4 994.13	962.13	3 345.94	2 897.06	0.81	442.38	757.19	89.56	843.44
	Permanent past.	168.69	767.19	115.69	2 584.81	157.69	0.00	36.63	1 035.19	5.31	1 699.00
	Vineyards	7.13	0.00	16.94	0.06	17.75	0.00	64.94	6.63	0.00	0.50
	Fruit orchards	43.44	1.13	71.31	27.44	34.06	0.00	42.81	21.63	2.63	8.44
	Other agr. land	18.50	6.31	13.00	9.81	14.25	0.00	8.94	5.06	0.75	137.13
	Forests	7.00	8.75	43.88	288.13	7.63	0.00	28.50	172.25	0.75	1 368.13
	Other land	25.25	22.69	10.81	47.75	15.63	0.00	14.06	36.13	0.63	129.06
	No data	822.19	593.25	1 061.63	1 990.38	1 680.69	1.19	1 049.25	1 184.81	145.75	4 921.56

Table 8. Landscape metrics for land suitability class classes (2011)[1].

Class	CR	TC	PP	VN	FO	OA	FT	OL	ND	SHDI	NP	PD	MN	AM	SD
1	7	73.2	4.1	0.2	1.1	0.5	0.2	0.6	20.2	0.38	1674	41	1.94	139.08	16.31
2	6	78.1	12.0	0.0	0.0	0.1	0.1	0.4	9.3	0.44	1582	25	3.67	1070.08	62.53
3	7	41.9	5.0	0.7	3.1	0.6	1.9	0.5	46.3	0.85	2576	112	0.48	4.34	1.36
4	7	40.3	31.2	0.0	0.3	0.1	3.5	0.6	24.0	0.91	4373	53	1.44	39.27	7.38
5	7	60.0	3.3	0.4	0.7	0.3	0.2	0.3	34.8	0.37	1352	28	2.33	284.61	25.62
6	1	40.6	15.0	0.0	0.0	0.1	0.2	0.4	43.6	0.00	5	250	0.16	0.29	0.15
9	7	26.2	2.2	3.8	2.5	0.5	1.7	0.8	62.2	1.11	1633	97	0.39	3.53	1.11
10	7	23.5	32.2	0.2	0.7	0.2	5.4	1.1	36.8	1.07	4225	131	0.48	5.04	1.48
12	6	36.5	2.2	0.0	1.1	0.3	0.3	0.3	59.4	0.45	143	58	0.70	6.41	1.99
13	7	9.3	18.7	0.0	0.1	1.5	15.0	1.4	54.0	1.29	1708	19	2.45	190.17	21.45

[1] CR – Class richness, AL – Temporary crops percentage of landscape, PP – Permanent pasture percentage of landscape, VN – Vineyards percentage of landscape, FO – Fruit orchards percentage of landscape, OA – Other agricultural land percentage of landscape, FT – Forests percentage of landscape, OL – Other land percentage of landscape, ND – No data percentage of landscape, SHDI – Shannon's Diversity Index, NP – Number of patches, PD – Patch Density, MN – Mean patch area, AM – Area-weighted mean, SD – Patch area standard deviation

suitability option those types of land uses clearly dominates. This is indicative not only of a certain level of specialization as well as an intensification of the agricultural activity. These areas roughly correspond to the intensively managed dairy landscape, with higher livestock density and productivity.

Highest permanent pasture percentages and forage crops occur on "Forest" and "Forest/Pasture" exclusive of suitable land classes (classes 4 and 10). This continues to support the issue of specialization but also reveals the expansion of farming to marginal areas such as areas of exclusive forest suitability. We may consider that these areas correspond to the semi-natural pastoral landscape, with patches of natural vegetation and/or exotic forest.

Classes 3, 9 and 12 are all suitable for urban and touristic activities and not suitable for arable farming. They share a lower LPIS cover percentage and a slight presence of vineyards and fruit orchards, generally placed in close proximity to dwellings. Apart from the high percentage of LPIS "No data", the class 13 (not suitable for any of the activities considered) has very low arable land representativeness and the highest SHDI. This area includes the main natural vegetation patches, which are obviously not represented on LPIS.

As shown in Table 9, the changes in the LPIS categories distribution between 2001 and 2011 can be observed. The most obvious result is the disappearance of LPIS 2001 nomenclature classes "arable land" and "forage crops" replaced by the LPIS 2011 class "temporary crops". It is important to emphasize that this alteration in

Table 9. General land-use transition matrix of the island surface (LPIS 2001-LPIS 2011)

Land parcel identification system (2001)	Land parcel identification system (2011): Arable land	Temporary crops	Permanent grassland	Vineyards	Fruit orchards	Other agricultural land	Forests	Other land	Forage crops	No data	Total 2001	Loss
Arable land	-	27.5	4.4	0.0	0.0	0.0	0.0	0.1	-	0.6	32.8	32.8
Temporary crops	-	-	-	-	-	-	-	-	-	-	-	-
Permanent grassland	-	0.3	1.2	0.0	0.0	0.0	0.2	0.1	-	0.0	1.8	0.6
Vineyards	-	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-	0.0	0.1	0.0
Fruit orchards	-	0.0	0.0	0.0	0.2	0.0	0.0	0.0	-	0.0	0.2	0.0
Other agric. land	-	0.1	0.2	0.0	0.0	0.0	0.0	0.0	-	0.0	0.3	0.3
Forests	-	0.1	0.0	0.0	0.0	0.0	0.6	0.0	-	0.1	0.8	0.2
Other land	-	0.0	0.0	0.0	0.0	0.0	0.3	0.2	-	0.0	0.5	0.4
Forage crops	-	5.7	5.9	0.0	0.0	0.0	0.5	0.1	-	0.2	12.5	12.5
No data	-	9.4	4.6	0.2	0.4	0.5	3.1	0.3	-	32.6	51.0	18.4
Total 2011	-	43.1	16.4	0.3	0.6	0.5	4.8	0.8	-	33.5	100.0	
Gain	-	43.1	15.2	0.2	0.5	0.5	4.2	0.6	-	0.9		

nomenclatures involved about 45% of the area on LPIS 2001 and 43% on LPIS 2011. In this regard two different tendencies were observed: on the one hand LPIS 2001 "arable land" areas switched mainly to LPIS 2011 "temporary crops" and just in a lesser extent to LPIS 2011 "permanent grassland"; on the other LPIS 2001 "forage crops" area was equally divided by both.

Consequently the representativeness of "permanent grassland" has largely augmented from 1.8% in LPIS 2001 up to 16.4% on LPIS 2011 not just because of the reported gains but also benefiting from the increase of LPIS area traced. Actually we found for that period a positive net change of 17.5% points on the surface covered by LPIS corresponding to the losses of 18.4 pp and gains of 0.9 pp on "no data" class. When comparing the land-use change through LPIS for the period 2001 to 2011 "permanent grassland" class appears as the main winner. However this fact may be biased due to changes in LPIS nomenclature and the increment of traced area.

In order to avert the issues with the modifications and misinterpretations of LPIS nomenclature and to limit the area of study to the data effectively available in both periods, the original data were rearranged. For this purpose the former classes "arable land", "temporary crops", "permanent pastures" and "forage crops" were regrouped into a single class named "pastures and forages". On the other hand polygons with "no data" records in 2001 or 2011 were discarded. After workup was obtained, the remaining area of 19,298.19 ha (48% of Terceira Island surface) was distributed as follows: land suitability classes 1 (2,417.75 ha), 2 (4,886.56 ha), 3 (835.44 ha), 4 (4,923.25 ha), 5 (2,259.13 ha), 6 (0.56 ha), 9 (332.75 ha), 10 (1,528.63 ha), 12 (70.94 ha) and 13 (2,043.19 ha).

The analysis of the transition period of 2001 to 2011 for each land suitability class took into account land-use classes' persistence, swap, net change and total change (Pontius Jr. et al., 2004). The aggregation of individual land-use changes results in the changes for the entire land suitability class. Due to the fact that the individual categories double-count the changes in the land suitability classes (because the change in one grid cell counts as gain in one category and a loss in another category), the aggregated change is one-half the sum of individual categories' total changes. Similarly, the aggregated swap and net change for each land suitability class are one-half the sum of their individual category values. Aggregated change values were computed for all Terceira Island's land suitability classes (Table 10).

Our results highlight the global prevalence and persistence of "pastures and forages" LPIS Land-use class during the period, although there was a total negative net change of 1.59% points (96.2% in 2001 versus 94.6% in 2011). On the other hand LPIS Land-use class "forests"was the main winner benefiting from a total net gain of 2.04 pp.

The most dynamic land suitability classes, with higher values total aggregated changes were the classes 3 (4.44), 4 (3.19), 9 (4.09) and particularly 10 (7.38) and 13 (19.24). It should also be noted that class 13 has a lower relative swap component than the other four classes. Since none of these classes is suitable for "arable farming" it can be assumed that land-use changes occurred primarily in classes non-

Table 10. Analysis of Terceira Island LPIS land-use changes (2001-2011) per land suitability class[1]

Class	Pastures and forages	Vineyards	Fruit orchards	Other agricultural land	Forests	Other land	Aggregated values
1	98.31	0.20	0.80	0.20	0.11	0.37	100.00
	97.82	*0.17*	*0.88*	*0.27*	*0.17*	*0.69*	*100.00*
	0.50	**0.03**	**0.08**	**0.07**	**0.06**	**0.31**	**0.52**
	(1.10)	(0.07)	(0.29)	(0.24)	(0.09)	(0.46)	(1.13)
	[1.60]	[0.10]	[0.37]	[0.31]	[0.16]	[0.77]	[1.65]
2	99.74	0.00	0.08	0.01	0.05	0.13	100.00
	99.49	*0.00*	*0.00*	*0.03*	*0.09*	*0.39*	*100.00*
	0.25	**0.00**	**0.08**	**0.02**	**0.04**	**0.26**	**0.32**
	(0.41)	(0.00)	(0.00)	(0.00)	(0.02)	(0.25)	(0.34)
	[0.66]	[0.00]	[0.08]	[0.02]	[0.05]	[0.51]	[0.66]
3	92.92	0.66	1.72	1.89	1.85	0.97	100.00
	93.78	*0.73*	*2.10*	*0.52*	*2.39*	*0.46*	*100.00*
	0.86	**0.07**	**0.38**	**1.36**	**0.55**	**0.50**	**1.86**
	(2.29)	(0.28)	(0.69)	(0.55)	(0.84)	(0.49)	(2.57)
	[3.15]	[0.36]	[1.07]	[1.92]	[1.38]	[0.99]	[4.44]
4	96.18	0.00	0.17	1.19	2.09	0.38	100.00
	96.56	*0.00*	*0.16*	*0.07*	*2.41*	*0.79*	*100.00*
	0.38	**0.00**	**0.01**	**1.11**	**0.32**	**0.42**	**1.12**
	(2.69)	(0.00)	(0.04)	(0.11)	(1.03)	(0.26)	(2.07)
	[3.08]	[0.00]	[0.05]	[1.23]	[1.35]	[0.68]	[3.19]
5	98.62	0.25	0.61	0.17	0.07	0.28	100.00
	97.89	*0.36*	*0.84*	*0.28*	*0.14*	*0.50*	*100.00*
	0.73	**0.11**	**0.24**	**0.10**	**0.07**	**0.22**	**0.73**
	(0.87)	(0.08)	(0.14)	(0.29)	(0.08)	(0.47)	(0.97)
	[1.61]	[0.19]	[0.38]	[0.40]	[0.15]	[0.69]	[1.70]
6	100.00	0.00	0.00	0.00	0.00	0.00	100.00
	100.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
9	90.03	2.48	3.10	0.56	2.99	0.85	100.00
	88.07	*2.82*	*3.47*	*0.92*	*3.46*	*1.26*	*100.00*
	1.95	**0.34**	**0.38**	**0.36**	**0.47**	**0.41**	**1.95**
	(1.54)	(0.53)	(0.34)	(0.68)	(0.64)	(0.56)	(2.14)
	[3.49]	[0.86]	[0.71]	[1.03]	[1.11]	[0.98]	[4.09]
10	93.50	0.13	0.41	1.51	3.07	1.37	100.00
	90.73	*0.17*	*0.64*	*0.08*	*6.46*	*1.92*	*100.00*
	2.77	**0.04**	**0.23**	**1.44**	**3.39**	**0.55**	**4.21**
	(4.30)	(0.02)	(0.08)	(0.15)	(1.46)	(0.35)	(3.18)
	[7.07]	[0.05]	[0.31]	[1.58]	[4.85]	[0.90]	[7.38]
12	97.44	0.00	2.11	0.00	0.18	0.26	100.00
	97.09	*0.00*	*1.76*	*0.09*	*0.44*	*0.62*	*100.00*
	0.35	**0.00**	**0.35**	**0.09**	**0.26**	**0.35**	**0.70**
	(3.35)	(0.00)	(2.64)	(0.00)	(0.00)	(0.35)	(3.17)
	[3.70]	[0.00]	[3.00]	[0.09]	[0.26]	[0.70]	[3.88]
13	87.20	0.02	0.12	0.42	5.22	7.02	100.00
	75.34	*0.02*	*0.07*	*0.27*	*20.67*	*3.64*	*100.00*
	11.86	**0.00**	**0.05**	**0.15**	**15.44**	**3.38**	**15.44**
	(2.10)	(0.00)	(0.02)	(0.46)	(0.58)	(4.43)	(3.80)

Table 10. cont.

	[13.96]	[0.00]	[0.08]	[0.61]	[16.02]	[7.81]	[19.24]
Total	96.23	0.14	0.42	0.60	1.50	1.12	100.00
	94.64	*0.16*	*0.47*	*0.17*	*3.54*	*1.03*	*100.00*
	1.59	**0.02**	**0.05**	**0.44**	**2.04**	**0.09**	**2.11**
	(2.00)	(0.05)	(0.17)	(0.26)	(0.51)	(1.35)	(2.17)
	[3.59]	[0.07]	[0.22]	[0.70]	[2.55]	[1.44]	[4.29]

[1] The normal number is the percent of Land-use per land suitability class in 2001. The number in italics is the percent of Land-use per land suitability class in 2011. The number in bold is the absolute value of net change percentages. The number in round parentheses is the Land-use swap percentage. The number in square brackets is the total Land-use change percentage.

suitable for arable-farming. Secondly, considering the variation in the number of multiple suitability of these classes 13 (0), 10 (1), 4 (2), 9 (3) and 3 (4), it is not possible to establish a causal relationship between the implicit flexibility in each land suitability class and the resilience of land uses. Class 13 is a paradigmatic case due to the extent of changes and their theoretical inability to either of the uses considered.

DISCUSSION

In the introduction two questions were presented. The first one referred to the quality of "Land Parcel Identification System" as data source for land-use change analysis; the conclusion is that although land-use classes for 2001 and 2011 were not comparable for all the set classes but they could be grouped to support a consistent analysis of land-use changes in Terceira Island. For this purpose the classes "arable land", "temporary crops", "permanent pastures" and "forage crops" were regrouped in a single class "pastures and forages". However, this process corresponds to a significant loss of information especially for a system where this new class represents about 95% of the characterized landscape. On the other hand, the Land Parcel Identification System just covers the parcels for farmers under Common Agricultural Policy direct support schemes. Therefore it does not cover the entire rural landscape and furthermore the areas concerned in a given year may change in the subsequent year. Therefore applying LPIS on land-use change analyses requires special focus on the polygons with "no data" records.

Such constraints have not prevented us from finding a generic consistency between land uses and land suitability classes (i.e. usually the most representative land-use of each combination class occur in the presence of compatible suitability). Nevertheless, systematic discrepancies between land-use and land suitability classes are reported (i.e. land-use occurrences on non-suitable land classes), especially relevant in this aspect are pasture and forage overuses on classes 9, 10, 12 and 13.

The comparative analysis of agricultural land-use characteristics on land suitability classes showed significant differences between them which allowed for their grouping as follows:

- Specialization and intensification of agricultural processes on suitability classes for arable land (classes 1, 2 and 5);

Specialization associated with agricultural expansion on "Forest" and "Forest/Pasture" exclusive land suitable classes (classes 4 and 10);

- Marginal and diversified agriculture on suitable classes for urban and touristic activities and not suitable for arable farming (classes 3, 9 and 12);
- Marginal agriculture on the class not suitable for any of the activities (class 13).

The second question was related to how the flexibility implicit in each land suitability class is an important factor to justify the resilience of land uses. It has been proved that temporal changes in land-use were not correlated to the flexibility implicit in each land suitability class (i.e., to the greater or lesser amplitude of generic biophysical factors) but with some very specific biophysical constraints. In the case studied, the major key factor was the "arable farming" suitability (average annual temperature of ≥ 10°C, annual accumulated precipitation of ≥ 750 mm, slope 0-15% and soil agricultural use capability I-IV). Thus it was found that temporal land-use changes occurred primarily in non-suitable "arable farming" classes. This reveals a Von Thünen (1826) phenomena through which conflicting uses in areas closer to the market are associated with more inertia in land-use than less conflictual uses in marginal areas (Thünen, 1826). The land combinational classes including "arable farming" suitability not only expressed the higher levels of pastures and forages land-use that support the agricultural activities prevailing in the island (dairy and beef production), but also showed to be the most persistent during the decade. On the remaining land suitability combinations, we also registered the occurrence of pastures and forages but on these marginal areas the competition with alternative uses increases and therefore the changes and swaps happen more often.

Conclusions

This study confirms the contribution of biophysical constraints to the differentiation of agricultural landscape and their changes over time. However, our results put in perspective this aspect indicating the existence of other drivers involved. Thus, only the strong predominance of pastures and forages can be justified, even in areas theoretically unsuitable for this purpose. The socio-cultural factors, functioning of markets and agricultural policies are certainly to be taken into consideration when agricultural landscape and its changes are analysed. Since European farmers largely depend on community aids for a stable income, CAP measures will certainly contribute as a major driving force to landscape change on the EU level.

Having assessed the structural diversity, the present study needs to be expanded so as to further focus on the role of the CAP incentive schemes as landscape drivers within the local socio-cultural framework under a global open market and technological development progress. Taking into account the structural diversity captured in this study, we will incorporate in the analysis land suitability as a variable. Then a probabilistic approach on agricultural landscape dynamics based on farmer management will be developed to support policy-making on agricultural and agri-environmental regimes.

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