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Extensification trends in Mediterranean land use systems: does the landscape homogenisation dogma apply?

A landscape change study (1958-2000) in the Portuguese Alentejo

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Abstract

This paper explores the landscape dynamics of two areas in the south east of the Portuguese Alentejo region by systematic comparisons of land cover maps of 1958, 1985 and 2000, which were for this purpose derived from aerial photographs. The study consists of 2 separate analysis: 1) detection of processes of extensification through analysis of land cover class transitions with the use of transition matrices; 2) monitoring landscape composition and configuration through the application of a set of landscape metrics. The results show clear changes during the past forty years in landscape composition and configuration. The landscape metrics display a trend towards a more fragmented, complex, fine-grained landscape. Most widespread land cover changes were transformations from arable / grassland to other land cover categories, such as *montado*, forest plantations and *matorral*. The shift from arable/grassland to land cover classes dominated by woody species suggests an extensification of agricultural practices. The results are partly consistent with the generally assumed trends in Mediterranean landscapes: extensification of land use being a main process. However, contrary to what is often observed and assumed, this process is associated with a trend towards a more fine grained and fragmented landscape.

Introduction

As is inherent to their dynamic nature, landscapes continuously change, though the pace and magnitude of these processes have been increasing in many rural landscapes in Europe, especially during the 20th century (Vos and Stortelder 1992; Wood and Handley 2001; Antrop 2005). Intensification of agricultural production caused rapid changes in traditional landscape structures, mainly in the areas with most favourable conditions for cultivation. In less favourable areas (LFA's) extensification of agricultural activities is an important process driving landscape change. Both processes often result in a loss of biodiversity and of cultural heritage, and consequently most of the landscape changes are seen as a threat (Jongman 1996; Antrop 2005).

Mediterranean European landscapes comprise a wide variety of ecosystems and habitats that accommodate a diverse flora and fauna (Blondel and Aronson 1995). Many of them have been shaped through the centuries by traditional low-input farming, with extensive grazing and agro-silvo-pastoral practices, a type of management which is in balance with the natural resources, which had high levels of biodiversity as unplanned by-products. Many Mediterranean landscapes are subject to profound landscape changes (Naveh 1982), which occur very fast at a large scale, and destroy most traditional structures (Baudry and Tatoni 1993; Pinto-Correia and Mascarenhas 1999). These changes are caused by both intensification and extensification of agriculture. In the less favoured areas (LFA) marginalisation and extensification are common processes, with afforestation with fast-growing trees and land abandonment being the main ones. These trends cause increased risk of wild fires (Moreira et al. 2001), degradation of cultural values (Vos 1993) and loss of biodiversity (Burel and Baudry 1995).

For the prevention of negative landscape impact of these changes, new forms of management are of outermost importance. These should be based on conclusive knowledge of patterns and processes of landscape change. Empirical research by monitoring is a growing concern of today's landscape research. Within landscape ecology concepts, tools and methods are applied and developed to quantify patterns of change and link them to processes (Naveh and Lieberman 1994). Procedures for the analysis of changes in landscape pattern through remotely sensed images have been reported, e.g. by Kienast (1993), Dunn et al. (1991) and Bender et al. (2003). As will be discussed, Geographical Information Systems, landscape metrics and transition matrices are of increasing importance in today's landscape change research (e.g Romero-Calcerrada and Perry 2004; Pan et al.1999; Poudevigne and Alard 1997).

The present study deals with landscape change in the Alentejo region in Southeast Portugal. Up to now the number of (international) research papers dealing with landscape change in South Portugal is limited (Roxo, Mourão, et al. 1998 , Casimiro 2002) and none of these addressed landscape changes at the local level. This lack of knowledge at the local level contrasts sharply with the urgency of landscape research since, in the Alentejo and the Algarve landscapes, dramatic changes are taking place (Pinto-Correia 1995). For example, an analysis of Corine land cover data (Breman and Pinto-Correia 2003) shows that 16% of the territory of the municipality of Mertola has undergone land cover change in the period 1990 - 2000. These changes are especially dominated by afforestation of agricultural land and extensification.

The processes of extensification are often associated with a simplification and homogenisation of Mediterranean landscapes (Fernandez Ales et al. 1992; Pinto-Correia 1993b; Lehouerou 1993). In other words, extensification leads to a loss of fine grained landscape structures. Also recent publications (Rounsevell et al. 2005) predict this trend for the near future. However, it remains to be seen if extensification of agricultural activities associated with homogenisation applies to every landscape in Mediterranean agro-silvo-pastoral land use systems.

The study consists of 2 separate parts: 1) to identify processes of extensification, by analizing land cover transitions with transition matrixes; 2) to monitor the changes in landscape structure over the period 1958 - 2000, using a set of landscape metrics.

Both analyses contribute eventually to question whether extensification processes are in any case associated with homogenisation of the rural landscape, as is generally assumed in the literature.

The present study starts with a short literature review and a discussion of conceptual and methodological aspects of landscape change studies.

Studying landscape change: conceptual and methodological considerations

In this paper the definition of Forman (1986) of the concept landscape is adopted and is as follows: 'A landscape is a mosaic where the mix of local ecosystems or land uses is repeated in similar form over a kilometres wide area'.

The holistic aspect of the concept of landscape, is by some considered to be a fundamental topic in landscape research (Naveh and Lieberman 1994). However, studying the overall change of a landscape as a holistic entity, including aesthetical, historical and cultural considerations, it is a rather complex process, if possible at all (Antrop and Van Eetvelde 2000). The majority of papers published dealing with landscape change base their analysis on the change of landscape elements, like land cover patches. But the study of landscape change is related to, but not co-extensive with, land cover change (Wood and Handley 2001), being a change in individual elements, within a landscape, not necessarily linked with an overall landscape change(Antrop 1998; Golley2000). Describing a landscape in terms of land cover is a simple and aggregated way, representing the interface between natural conditions and human influence. As such, it is regularly used to quantify landscape change, as in the patch-corridor-matrix model of Forman and Godron (1986). The spatial configuration and composition of land cover patches is often applied to describe landscape structures and patterns. Landscape structure is an important factor in the study of ecological processes. O'Neill et al. (1988) introduced indices of landscape patterns, also known as 'landscape metrics', as a useful tool for an objective description and quantification of the landscape structure, as has been used successfully in studies of landscape structure at different scales by McGarigal and Marks (1995) and Lausch and Herzog (2002).

Depending on the objective of the study, one has to choose carefully the size of the study area, time frame of the study, tools and data sources, in order to constitute a reliable spatial-temporal data model (Burgi and Russell 2001).

As in many other Mediterranean landscapes, land cover changes in the Alentejo region originate mostly at a local scale, this implies that monitoring of the changes should be done rather on a local scale than on a regional scale (Antrop 1993). The choice of scale and the size of the pilot area is a trade-off between the reliability of the representation of the rural landscape under study and, on the other hand, the logistical effort with respect to the detailed photo interpretation.

The timeframe of this type of study depends strongly on the available data sources. Detailed spatially explicit land cover data are at present widely available through satellite images. However, for historic information, historical maps and cadastral archives should supply the data, but in Portugal these rarely date back earlier than 1800, and cause many problems in geo-referencing and interpretation. When these data are also lacking, as in the present case, one is restricted to the oldest available information, which are here aerial photographs from the 1950's. Although aerial photographs may have potential drawbacks, like doubtful quality and problems with registration and distortion (Dunn et al. 1991), they remain a valuable data source in landscape research (Longley et al. 2005).

Material and methods

Study area

The municipality of Mertola is located in the southeast of the Portuguese region of the Alentejo. Within the municipality two sample areas of both 44 square km have been selected: Amendoeira da Serra (37º 40' N, 7º 47' E, datum WGS-1984) and João Serra (37º 40' N, 7º 50' E, datum WGS-1984). Previous studies (e.g. Oliveira 1998) indicated that these areas are representative for landscape changes in this region.

Mertola is located on the Guadiana river and ranges from 50 to 300 m a.s.l. The prevailing rock is schist, on which shallow and poor soils occur. The area has a typical Mediterranean climate, with averagely 700 mm rainfall a year, concentrated during the winter months. Periods of drought from two to eight months occur during the hot summers (Perez 1990).

Mediterranean-type vegetation dominates the area, with, as dominating species, *Quercus rotundifolia* and *Cistus spp.* High, dense *matorral*, a typical Mediterranean scrub type (Tomaselli 1981) occurs along the watercourses, with species like *Arbutus unedo, Nerium oleander, Tamarix hispanica* and *Securinega buxifolia*. A lower, dispersed type of matorral hosts a richness of aromatic plant species, like *Rosmarinus officinalis*, *Lavendula spp., Thymus cephalotus* etc.

Due to its peripheral location, specific history and socio-cultural conditions, the municipality is considered as a marginal agricultural area (Oliveira 1998; Roxo et al. 1998). The agro-silvo-pastoral system of the *montado* (Pinto-Correia 1993a) is one of the typical management systems, especially in the study area of Amendoeira da Serra. Main agricultural activity is sheep breeding, but there are also some cattle, goats and pigs. Besides extensive livestock breeding, there is cereal growing, especially in the area of Joao Serra, and forest plantations are recently spreading.

The landscapes of the two sample areas are slightly different. The landscape of the area of Amendoeira da Serra is described by Cancela d'Abreu et al. (2004) as follows: '*In spite of its homogenous character the landscape presents variations in the landscape pattern, based on the spots of holm oak Montado, together with open fields or with a scarce presence of trees. Besides the variation in land cover, like agriculture, forestry and pastoralism or dense shrub formations, the rolling slopes are the other determinative element of the landscape, some times interrupted by the hidden valleys of the watercourses'.* High natural values especially occur along the watercourses, with formations of *Juniperus* and wealth of aromatic herbs and medicinal plants'.

The landscape of the second study area, João Serra, is much more plain and open, with the absence of the agro silvo pastoral system. Cancela d'Abreu et al. (2004) writes about this landscape: '*the character of this landscape results essentially from its slightly undulating cereal fields, pastures and fallow land, where trees are absent, and the open space dominates'.*

The agro-silvo pastoral area, and the *matorral* vegetation in the area of Amendoeira, constitute habitats for different wildlife species like *Felix silvestris, Genetta Genetta, Aegypus manclus* and *Falco naumanni*. The recognition of this important role has been formalized in 1995 with the constitution of the natural park of the Guadiana valley.

The open, steppe-like landscape of the area of Joao Serra has an important role in steppe-bird conservation, with species like *Otis tarda, Tetrax tetrax,* and *Falco naumanni.* As such, the area is subject to special habitat regulations since 1993, aiming at preserving bird populations.

The general historic land use changes in the municipality of Mértola are described by Roxo et al. (1998). In the beginning of the 18th century most of the area was covered with *montado* and *matorral* that were used as commons ('baldios') for hunting and collecting of honey and firewood. The baldios were mainly the most remote areas, hilly and with difficult access. Apart from the mentioned activities, also livestock breeding was important (sheep, pigs and goats that were kept pastorally). At the end of the 18th century the population of the municipality almost doubled, and there was a necessity to enlarge the area under cultivation of cereals and the pastures for livestock. This enlargement happened at the expense of the natural vegetation. The end of the 19th century was a decisive period in the development of the agriculture in the Alentejo. Policies were focused on the enlargement of the agricultural production. Agriculture was the most important economical sector, and all action was focused on it, which had severe effects on the natural resources. Large areas of uncultivated land were seen as potentially to be cultivated. In order to improve the national production of wheat, under the fascist regime of Salazar a wheat campaign started in 1926, and lasted until the late 60's. The policies were urging the farmers to produce more cereals in order to attain national self-sufficiency of food production. The national production of wheat doubled in these decades from 306 427 tons in 1918 up to 649 320 tons in 1950.

After the revolution of the early 1970's the protectionist cereal campaigns stopped and in the most peripheral areas the cultivation of wheat and other arable crops was abandoned. In some areas, where soil degradation was most severe, extensive Eucalyptus-stands were planted.

After Portugal's entrance of the EU in 1985, financial support from the Common Agricultural Policy (CAP) became available for the Portuguese agriculture, also for revival of livestock breeding (especially sheep), and cereal cultivation. Later on, afforestation programs for less favoured areas as part of the second pillar measures of the CAP gained importance for some areas in the Alentejo.

Still, at present aging and depopulation are significant processes, and given the limited employment opportunities, the human population decline is expected to continue in the near future. Distant landowners tend to switch their management to less intensive practices, this process is clearly visible in our study areas, e.g. with in the significant increase of forest plantations during the last decade.

Land cover data

Data on land cover were derived from grey-scale (8-bit) aerial photographs of 1958 (scale 1: 26.000), 1985 (scale 1: 15.000) and digital ortho photo-maps of 2000 (1: 22.000). The hard-copies of the aerial photographs were scanned (600 dpi) and georeferenced, using the ortho photo-maps of 2000 as the reference.

A land cover classification with 21 classes was used (see legend of figure 1). The classification distinguishes different types of the Montado and matorral based on differences in tree and shrub densities, since these might imply different types of land use or regimes of management. Also various types of forest plantations with different dominant tree species were considered, since they require different kinds of maintenance and serve different goals.

The visual interpretation of the aerial photographs was done on screen and the land cover patches were manually digitised using a minimal mapping unit of 0,5 ha. For the most recent time period also field work was done. All work was done by the same person to avoid different judgement in the interpretation, and carried out with the software package for geographical information systems ArcView 3.2.

Our two analyses are based on an aggregated version of the land cover classification: the 6 classes of *montado* are aggregated to 3, defined by their tree cover. The 4 forest plantations are aggregated into one, without a distinction between the tree species. These aggregations facilitated the identification of the main trends in land cover transition and landscape change.

Transition matrices

The land cover database of the two sample areas was used for the diachronic analysis of land cover change with Markov-type transition matrices. In these matrices rows and columns represent land cover classes, and the entries rates of change from one land cover category to the other category. Transition matrices are frequently used to explore the dynamics of land cover categories (Romero-Calcerrada and Perry 2004; Poudevigne and Alard 1997). An extensive analysis of transition matrixes in terms of gains, losses, persistence, net change, swap and systematic transitions among the categories has been proposed by Pontius et al. (2004). A net change in the quantity of a specific land cover category indicates the definite change of that land cover class. A swap change indicates a change in the location of a category, while the quantity remains the same. The concept of swap change allows avoiding underestimations of the total change on the landscape.

In order to properly identify the most systematic transitions of the land cover categories, the transitions should be interpreted relative to the size of the categories. By deducting the observed proportions with the expected proportions of change, systematic transitions were identified. Large positive deviations from zero indicate that systematic transitions between two land cover categories occurred, rather than random transitions. For details on the methodology see Pontius et al. (2004). All calculations were carried out in Excel 2000. Figure 4 visualises the persistence, gains and losses of land cover in the study area of Amendoeira da Serra.

Landscape metrics

Useful indicators for landscape change in terms of composition and configuration are quantitative landscape indices or landscape metrics. This is a tool for the quantification of specific spatial attributes of patches, classes of patches and larger mosaics (McGarigal and Marks 1995), and are widely applied and discussed (e.g. Botequilha Leitao and Ahern 2002; Gustafson 1998; Romero-Calcerrada and Perry 2004). The combination of an analysis of statistical land cover change and the use of landscape metrics is considered to be indispensable for the analysis of landscapes and their changes (Herzog and Lausch 2001; Lausch and Herzog 2002). Albeit, the use of landscape metrics, and especially the choice of which ones to use, is a matter of controversy.

Therefore we choose to use four metrics which are widely used and understood, being simple and suitable indicators to measure landscape heterogeneity (Herzog and Lausch 2001; Gustafson 1998): the mean patch size (MPS), the Landscape Shape Index (LSI), the Simpson diversity index (SIDI) and contagion. The MPS is an indicator of the grain of the landscape and the LSI is an indicator of landscape complexity: when the LSI decreases, the patches in the landscape simplify. The Simpson Diversity Index (SIDI) is a diversity index, which is recommended when richness, in this case corresponding to the number of land cover classes, is smaller than 100 (Herzog and Lausch 2001). A representative and most commonly used indicator of spatial configuration is contagion. This measures the degree of spatial aggregation or clumping of different spatial units (Gustafson 1998).

Based on the vector maps, the metrics were calculated, using Fragstats 1.0 for ArcView.

Results

Land cover maps

The land cover maps of the sample areas are shown in figure 1, while figure 2 and 3 depict the percentages of area per land cover class for the three study periods. In 1958 arable/ grassland is dominating the study area of Amendoeira, accounting for 66% of the area, which is a result of the cereal growing promotion in the beginning of the 20th century. Around the settlements there is some *montado* (16%), mostly with a tree cover of more than 30% and without shrub in the understorey. On the steep banks of the rivers high dense *matorral* occurs, which obviously reflects the difficult physical conditions, which do not allow any cultivation.

The land cover map of 1985 shows a gradual increase of *matorral* and *montado*. A shift from open arable/grass land without trees, to a more closed landscape with open oak forest and shrubs is taking place. The *montado* is getting more varied in terms of tree and shrub densities. The *matorral* does not only appear on the steep slopes along the watercourses, but also at the suitable areas for agriculture, in these areas it is low and scattered. Also the first forest plantation appears in the northeast corner of the area.

At the land cover map of 2000 a significant occupation of forest plantations has developed, accounting for 30% of the whole area. Different tree species are planted; being *Quercus suber* and *Quercus rotundifolia* the most frequent ones.

At present, arable/grassland (15%), *montado* (21%), *matorral* (17%) and the new forestations (30%) are the main land cover categories in the area of Amendoeira.

In the area of Joao Serra, arable/grassland is much more dominant, at present accounting for 69% of the area. Forest plantations are also here an increasingly dominant land cover class, at present occupying 22% of the area. The area of matorral is relatively small, mainly concentrated on the rocky areas and steep slopes. In the past the open agricultural area dominated even more, in 1958 accounting for 95%.

Transition matrices

We did not include the full transition matrices. Instead, tables 1 to 5 show the most important information derived from the full matrices. Table 1 (sample area of Amendoeira da Serra, period 1958 - 1985), 3 (sample area of Amendoeira da Serra, period 1985 - 2000) and 5 (sample area of João Serra, period 1985 - 2000) show the persistence, losses, gains, the total change, swap and the net change for the most dynamic land cover classes. Tables 2 and 4 include the most systematic land cover transitions for the Amendoeira area for both time periods.

Study area 1 Amendoeira da Serra

Period 1958 - 1985

The total persistence for the period accounts for the 41%, which means that only this percentage of the land cover did not change over this period. Arable/grassland accounted for the great part of this percentage, only 27% of that area did not change. Still, almost 60% of the total sample area

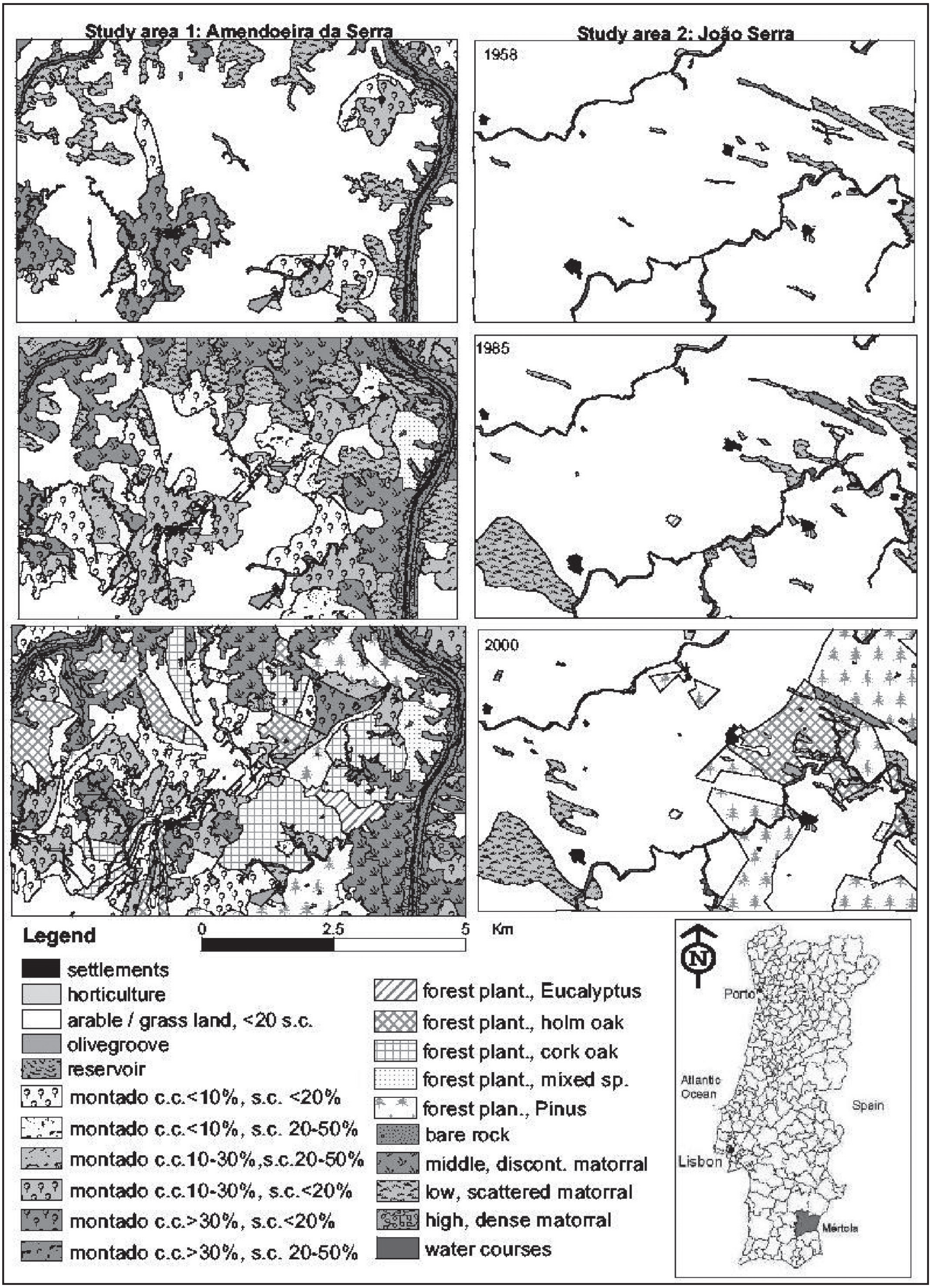
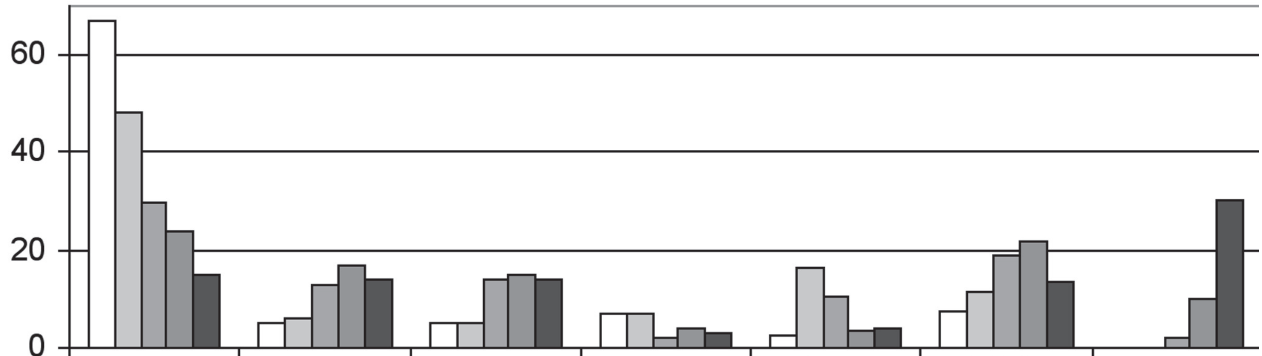
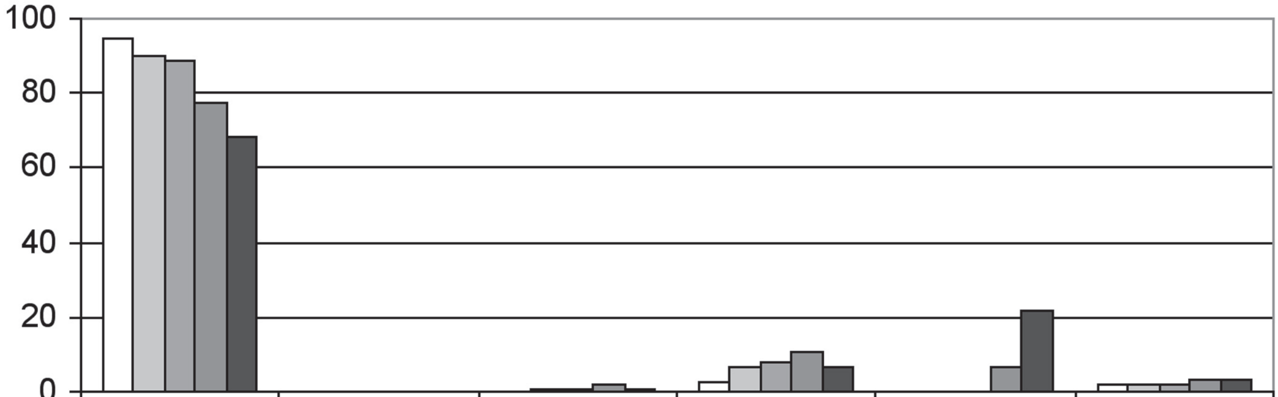


Figure 1: Land cover maps of 1958, 1985 and 2000, derived from aerial photographs for sample areas of 44 square km at Amendoeira da Serra and João Serra (municipality of Mértola)



	Arable / grassland	Montado «10% c.c.	Montado 10-30% c.c.	Montado »30% c.c.	Low scattered matorral	Middle discont. matorral	Plantations
□ 1958	67	5	5	7	3	7	0
□ 1969	48	6	5	7	16	12	0
□ 1985	30	13	14	2	10	19	2
□ 1990	24	17	15	4	4	22	10
■ 2000	15	14	14	3	4	13	30

Figure 2: Changes in land cover of the Amendoeira da Serra sample area (in % of the whole sample area); only most dynamic classes area shown.



	Arable / grassland	Montado 10-30% c.c.	Low scattered matorral	Middle discont. matorral	Plantations	Others
□ 1958	95	0	0	2	0	2
□ 1969	90	0	1	6	0	2
□ 1985	89	0	1	8	0	2
□ 1990	78	0	2	11	7	3
■ 2000	68	0	1	6	22	3

Figure 3: Changes in land cover of the João Serra sample area (in % of the whole sample area); only most dynamic classes area shown.

changed. For example 11% switched from arable/grassland to *montado* with less than 10% tree cover, and whereas in 1958 69% of the area was arable/grassland, this was only 30% in 1985.

For the Amendoeira area the calculations of losses and gains for the period 1958 - 1985 are shown in table 1, which includes also the total change, swap and absolute value of net change area. The values are relative to the whole area.

According to table 1, the largest loss is that of arable/grassland, which declines with 39 %. Most of this change is a net change, only 2.67% is swap.

Middle discontinuous *matorral* increases most in this period, as do *montado* <10% c.c., *montado* 10-30 % c.c. and low scattered matorral. The gain of low scattered matorral is merely a swap change, *montado* with <10% c.c. is partly a swap change partly a net change, while the gains of the

Table 1: Gains, losses, swap and net change of land cover in percentages of the whole Amendoeira da Serra sample area (1958 – 1985).
A= arable land / pasture; Ss= low, scattered matorral; F= forest plantations; M<10= montado, c.c.<10%; M10-30= montado, c.c.10-30%; M>30= montado, c.c.>30%; Sd= middle discontinuous matorral; M=high, dense matorral.

	loss	gain	tot. change	swap	net. change
A	**39,0**	**1,3**	**40,4**	**2,7**	**37,7**
Ss	**8,7**	**10,2**	**18,9**	**17,4**	**1,4**
F	0,0	1,8	1,8	0	1,8
M<10	**3,5**	**11,8**	**15,3**	**7,1**	**8,2**
M10-30	**0,8**	**13,8**	**14,6**	**1,7**	**12,9**
M>30	**5,3**	**0,5**	**5,8**	**0,9**	**4,9**
Sd	**0,2**	**18,2**	**18,4**	**0,3**	**18,1**
M	1,1	0,4	1,4	0,7	0,7

montado 10-30% tree cover and middle, discontinuous *matorral* are net changes.

Table 2 shows the most systematic land cover transitions in the period. Large positive values in the 'O-E column' (the observed proportion minus the expected proportion) indicate systematic transitions between two land cover classes. Large negative values indicate that the transition between categories occurred less than expected with a random process.

The overall trend in land cover change from 1958 to 1985, is the transition from arable/grassland to *montado* <10% c.c. and low, scattered *matorral*, which respectively develop gradually to *montado* 10-30% c.c. and intermediately high, discontinuous *matorral*. This explains the swap change in low, scattered matorral: on the one hand it gains from arable/grassland, and on the other it looses to intermediately high discontinuous matorral, a sequence like a normal secondary succession. The increase of land cover classes dominated by woody species reflects an extensification in cultivation, with declining activities like ploughing and other types of soil tillage.

Period 1985 - 2000

In the next time period (1985 -2000) the total percentage of area that persists its land cover class is 42,5 %, which is slightly higher than in the first study period (table 3). Only 10% of arable/grassland stayed like that, and 19% was lost to other classes. It is the land cover class, which has the largest decline, and again most of this is a net change (table

Table 2: Main land cover transitions in the Amendoeira da Serra sample area (1958 – 1985)

transition from 1958 - 1985	O-E	interpretation
arable/grassland -> montado <10%	2.93	montado <10% replaces arable/grassland
arable/grassland -> low matorral	2.3	low matorral replaces arable/grassland
low matorral -> middle matorral	6.64	middle matorral replaces low matorral
montado<10% -> montado 10-30%	1.96	montado 10-30% replaces montado <10%
montado >30% -> montado 10-30%	3.18	montado 10-30% replaces montado >30%
arable grassland -> montado 10-30%	-3.76	montado 10-30% does not replace arable/grassland
montado >30% -> middle matorral	-1.25	middle matorral does not replace montado >30%

Table 3: Transition matrix of land cover changes in the Amendoeira da Serra sample area (1985 – 2000)

entries are % of total case study area	Land cover 2000															
	U	**L**	**H**	**O**	**A**	**SS**	**F**	**M<10**	**M10-30**	**M>30**	**SD**	**M**	**W**	**R**	**total 1985**	***loss***
U	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0	**0,2**	*0*
L	0	0,1	0	0	0	0	0	0	0	0	0	0	0	0	**0,1**	*0*
H	0	0	0,1	0	0	0	0	0	0	0	0	0	0	0	**0,1**	*0*
O	0	0	0	1,1	0	0	0	0	0	0	0,1	0	0	0	**1,2**	*0,1*
A	0	0,2	0	0	9,9	0,8	11,2	4,8	1,3	0,1	0,3	0	0	0	**28,7**	*18,8*
Ss	0	0	0	0	1,5	1,2	5,0	0,6	0,2	0	1,8	0	0	0	**10,4**	*9,2*
F	0	0	0	0	0	0	1,8	0	0	0	0,1	0	0	0	**1,8**	*0,1*
M<10	0	0	0	0	1,3	0	6,5	3,6	1,8	0	0,2	0	0	0	**13,3**	*9,7*
M10-30	0	0	0	0	0,2	0	2,8	3,3	7,4	1,7	0,5	0,1	0	0	**16,2**	*8,8*
M>30	0	0	0	0	0,2	0	0	0	1,3	0,8	0	0	0	0	**2,4**	*1,6*
Sd	0	0	0	0	0,5	2,1	3,1	1,1	1,1	0,0	10,4	0,8	0	0	**19,3**	*8,8*
M	0	0	0	0,1	0	0,1	0	0	0	0	0,2	2,7	0	0	**3,0**	*0,3*
W	0	0	0	0	0	0	0	0	0	0	0	0	1,4	0	**1,4**	*0*
R	0	0	0	0	0	0	0	0	0	0	0	0	0	1,9	**1,9**	*0*
total 2000	**0,2**	**0,3**	**0,1**	**1,2**	**13,5**	**4,2**	**30,4**	**13,6**	**13,1**	**2,7**	**13,6**	**3,6**	**1,6**	**1,9**	persistence = **42,5**	
gain	*0*	*0,3*	*0*	*0,1*	*3,6*	*3,0*	*28,7*	*10,6*	*8,5*	*1,9*	*4,2*	*0,9*	*0,2*	*0*		

Land cover classes: **U=** settlements; **L=** reservoirs; **H=** horitculture; **O=** olivegroove; **A=** arable/grassland; **Ss=** low, scattered matorral; **F=** forest plantations; **M<10=** montado with less than 10% tree cover; **M10-30=** montado with 10-30% tree cover; **M>30=** montado with more than 30% tree cover; **Sd=** middle, discontinuous matorral; **M=** high, dense matorral; **W=** waterlines; **R=** bare rock

4). Also low, scattered matorral, *montado* <10% c.c. and *montado* 10-30% c.c. lost area. For the last two this loss is mainly a swap change, whereas for low scattered matorral it is half swap and half net change, which also accounts for intermediately high, discontinuous matorral.

The new forest plantations are a definite change, at least until they are cut. They gained most area in this period, together with *montado* <10% c.c. and *montado* 10-30% c.c.

Table 4: Gains, losses, swap and net change of land cover in percentages of the whole Amendoeira da Serra sample area (1985 – 2000).
A= arable land / pasture; Ss= low, scattered matorral; F= forest plantations; M<10= montado, c.c.<10%; M10-30= montado, c.c.10-30%; M>30= montado, c.c.>30%; Sd= middle discontinuous matorral; M=high, dense matorral.

	loss	gain	tot. change	swap	net. change
A	18,8	3,6	22,4	7,2	15,2
Ss	9,2	3,0	12,2	6,0	6,2
F	0,1	28,7	28,8	0	28,8
M<10	9,7	10,6	20,4	19,5	0,9
M10-30	8,8	8,5	17,3	17,0	0,3
M>30	1,6	1,9	3,5	3,2	0,3
Sd	8,8	4,2	13,0	8,5	4,6
M	0,3	0,9	1,2	0,6	0,6

The most systematic transitions are shown in table 4. New forest stands are predominantly planted on arable/grassland, low, scattered matorral and areas with montado <10%c.c. Intermediately high, discontinuous matorral is not substituted by new forest plantations. This is caused by 1) the steep slopes, 2) the EU regulation 2080, which only gives subsidies for plantings on agricultural land, and not on land that is abandoned for more than six years. Like the period 1958 - 1985, the systematic transitions in this period also suggest processes of extensification in agricultural activities.

Study area 2 Joao Serra

Period 1958 - 1985

The level of persistence in the João Serra area for 1958-1985 is 93%, which is mainly caused by the continuation of arable land/grassland, which accounts for 89% of the area. Most important changes are those from arable/grassland to low, scattered *matorral* (7%), from low, scattered matorral to a somewhat higher, discontinuous matorral (0.55%), and from arable/grassland to Eucalyptus plantation. There were hardly any changes in the land cover categories urban area, lakes, olive grooves and watercourses.

The largest loss is that of arable/grassland; most of its loss is a net change, only 1.83% is a swap. Also the land cover classes with the greatest gain, the low scattered matorral, have a loss which is mostly a net change (5,97% net change; 2,29 % swap change).

In short, the only systematic change is the transition from arable/grassland to low scattered matorral, suggesting extensification of land use. The difference between the observed proportion and the expected proportion is 1.75, indicating a systematic transition between these land cover categories, rather than a random process.

Period 1985 - 2000

In contrast with the previous period, from 1985 to 2000 the level of persistence fell to 74%. In this period only 70% of the arable/grassland remained. A part of this area changed to low scattered matorral (2,1%), a larger part changed to pine plantation (13.5%) and plantation of holm oak (5.4%). Also some areas of low, scattered matorral were turned to pine (1,7%) or holm oak (0.5%) plantation. For the other land cover classes like montado, olive grooves and watercourses there are hardly any land cover changes observed.

Gains, losses, swap and net change are shown in table 5. The loss of arable/grassland is mostly a net change, whereas changes of low, scattered matorral are mostly a swap change. The gains of forest plantations are net changes.

Thus, most systematic transition in the Joao Serra area in this period is the change from arable/grassland to forest plantation, either pine or holm oak (with respectively values for obs - exp 3 and 1.3). In contrast with the earlier study period, arable/grassland is less probable to be replaced by low scattered matorral (obs - exp= -2.2). Another systematic change is the transition from low scattered matorral to forest plantation of pine (obs-exp= 1.13).

Summarizing, for both study areas in both study periods, the identified systematic land cover transitions concern changes from arable/grassland to land cover classes dominated by woody species like *matorral,* forest plantation and *montado.* This suggests an ongoing process of extensification in land use.

Table 5: Main land cover transitions in the Amendoeira da Serra sample area (1985-2000)

transition from 1985 - 2000	O-E	interpretation
arable/grassland -> montado <10%	1.31	montado <10% replaces arable/grassland
arable/grassland -> forest plantations	2.78	forest plantations replace arable/grassland
low matorral -> middle matorral	1.26	middle matorral replaces low matorral
montado<10% -> forest plantations	2.24	forest plantations replace montado <10%
montado >30% -> montado 10-30%	1.07	montado 10-30% replaces montado >30%
low matorral -> forest plantations	2.18	forest plantations replace low matorral
middle matorral -> forest plantation	-2.23	forest plantations do not replace middle matorral

Table 6: Gains, losses, swap and net change of land cover in percentages of the whole João Serra sample unit (1985 – 2000).
A= arable land / pasture; Ss= low, scattered matorral; F= forest plantations; M10-30= montado, c.c.10-30%; Sd= middle discontinuous matorral.

	loss	gain	tot. change	swap	net change
A	21,8	1,4	23,1	2,7	20,4
SS	3,7	2,1	5,8	4,3	1,6
F	0	22	22	0	22
M10-30C	0	0	0	0	0
SD	0,1	0,2	0,3	0,1	0,1

Changes in landscape metrics

Figure 4 and 5 display the graphics of four landscape metrics, representing the dynamics of the spatial configuration of the landscapes of the sample areas.

The area of Amendoeira shows clearly a decreasing mean patch size (MPS), this indicates that the landscape has become more fine-grained. This reflects that the large area of arable land in 1958 turned into a more varied area with different shrub and tree densities. In the Amendoeira area, the LSI increases, which means that the shapes of the patches become more complex and irregular.

Over the study period the Simpson Diversity Index (SIDI) increases in the Amendoeira area, because the dominant area of arable land in 1958 becomes more balanced by the increasing area of *montado*, *matorral* and forest plantations. But in contrast, contagion decreases, which means that the landscape mosaic of the study area has become less aggregated and more fragmented.

The area of Joao Serra displays more or less similar trends (figure 5): the LSI and SIDI increase, while the MPS and contagion decrease, indicating a shift towards a more complex, fragmented and fine grained landscape.

Discussion

The present study shows that in both sample areas: 1) an ongoing process of extensification of land use is taking place; 2) the landscape structure became more fine grained and fragmented: there is a trend towards increasing heterogeneity.

The general trend of invading shrubs and trees, either through natural succession or artificially planted, corresponds with a main land use change trend in the Mediterranean: the relaxation of land use. Several authors, like Vos (1993), Pinto Correia (1995) and more recently Romero-Calcerrada and Perry (2004), observed comparable trends in Mediterranean landscapes.

The second observation, a trend towards a more fragmented and complex landscape by the invasion of shrubs and trees, does not correspond with other observed trends in *dehesa* / *montado* landscape of the Iberian Peninsula. These studies, on the contrary, show that through extensification, this type of landscape becomes more homogenous. For example, the studies carried out by Fernandez Ales et al. (1992) and Romero-Calcerrada and Perry (2004), both analysing structural changes in Spanish *dehesa*-landscapes, stress the risk of homogenisation of the landscapes under study through extensification of the land use. Closely related with this process are some problems as increasing fire risk, decreasing biodiversity and loss of cultural values.

Within the timeframe and at the spatial scale of our study, the landscapes of the sample areas show a trend towards increasing heterogeneity. A fundamental element in this discussion is the issue of scale. Whereas trends towards heterogenisation can be found at local level, this might be towards homogenisation on the regional level. Evidence from literature of research carried out at the regional level could elucidate this issue. However, as has been stated in the introduction, studies on landscape change in this region are up to now rare, which complicates comparison of the results. Nevertheless, the only landscape change study carried in the

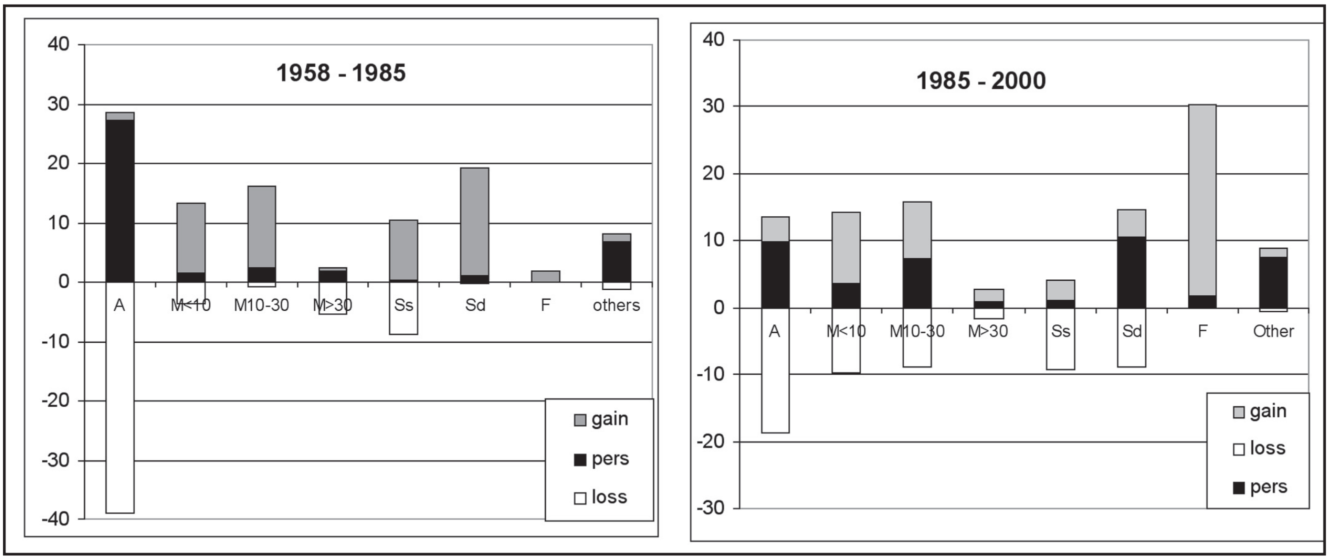


Figure 4: Persistence, gain and losses of land cover in the Amendoeira da Serra sample area (1958 –1985 and 1985 – 2000) in percentages of the whole area. A= arable land / pasture; M<10= Montado, c.c.<10%; M10-30= Montado, c.c.10-30%; M>30= Montado, c.c.>30%; Ss= low, scattered matorral; Sd= middle discontinuous matorral; F= forest plantations.

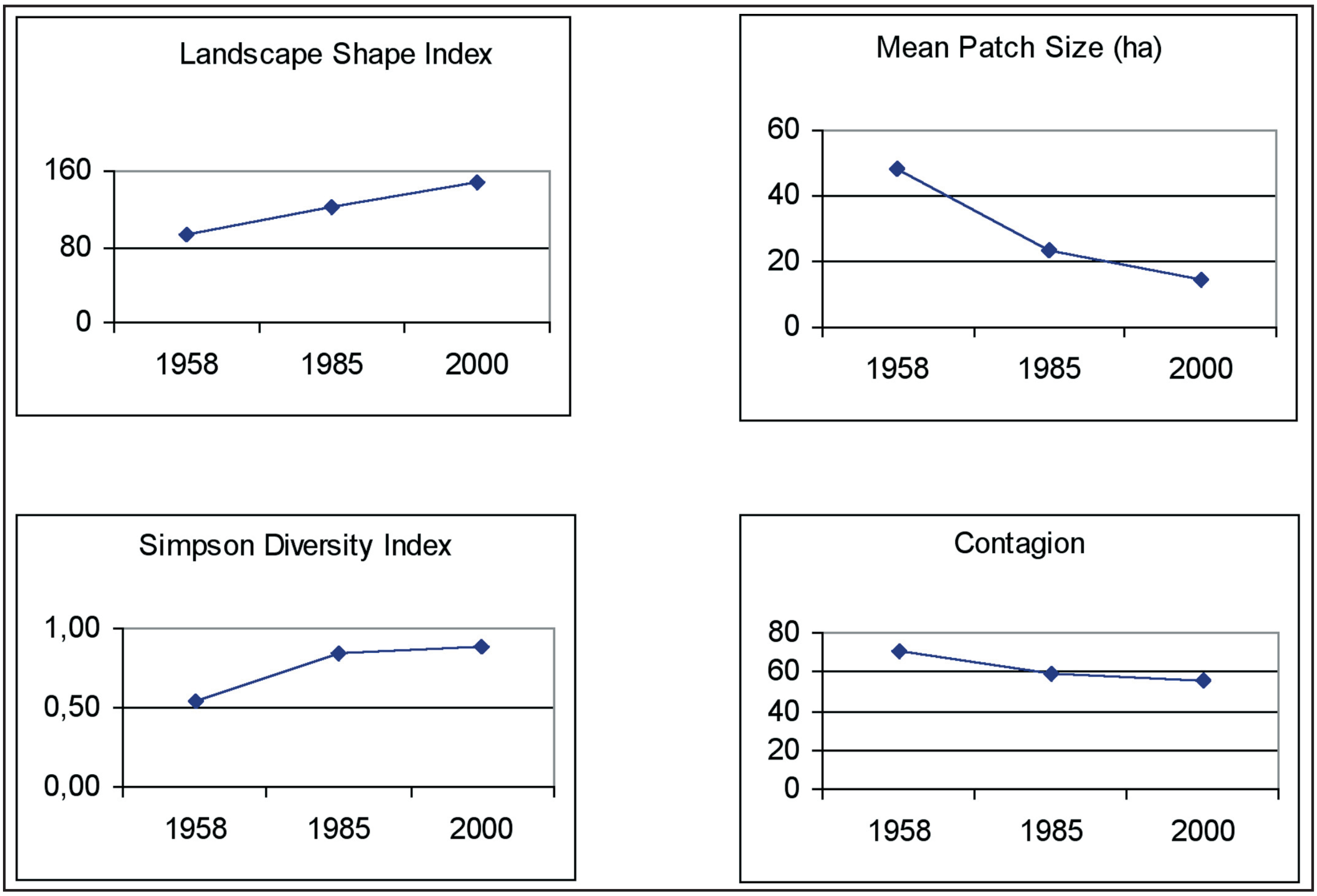


Figure 5: Changes in landscape metrics, representing changes in landscape configuration in the Amendoeira da Serra sample area (1958 – 2000)

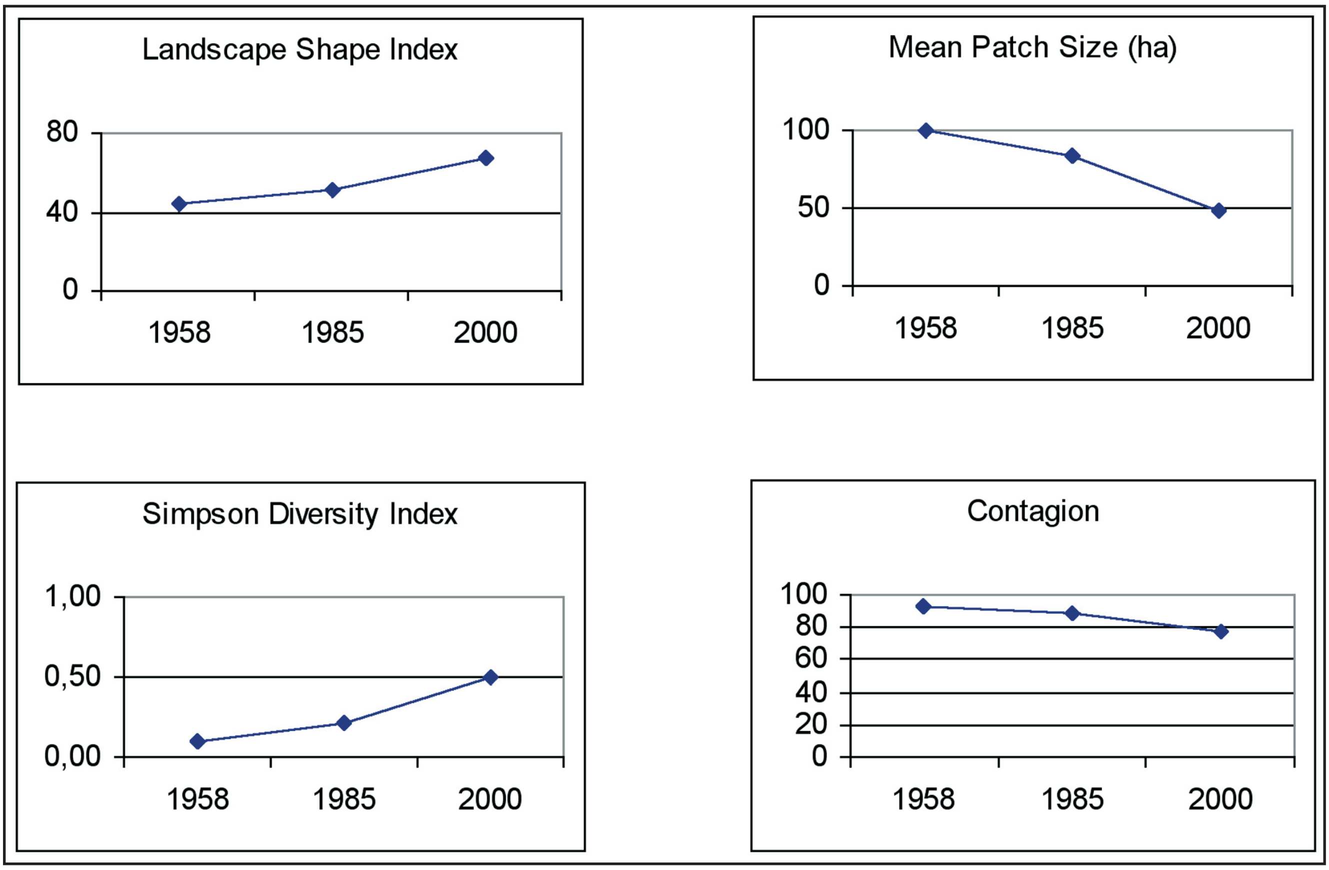


Figure 6: Changes in landscape metrics, representing changes in landscape configuration in the João Serra sample area (1958 – 2000)

region reveals similar trends (Casimiro 2003). In this study, the landscape structure analysis is based on satellite images of 1985, 1995 and 2001. A number of landscape indices are used, also the MPS, LSI, SIDI and contagion. Each index shows in the study of Casimiro the same trend found in the present paper: towards more heterogeneity. However, more evidence should be gained through landscape change study on regional and (sub) national level.

In the specific case of our study areas, an explanation of the trend observed can be found in the starting period of the study: after the cereal campaigns in the beginning of the 20th century the landscape was very homogenous, dominated by arable / grassland without tree cover. Next, the extensification processes, that started at the beginning of the 1970's, differed at each property. The differences between properties are closely related with the different types of land owners. Each landowner copes in a different way with the biophysical constraints of the area, and profits in a different way of the available CAP-subsidies. One can choose e.g. for production subsidies on livestock or cereals, but one can also choose in the region of the case study area for special LFA-regulations, as are the subsidies for forest plantations. Hence, the farmers' choice depends on a complex set of socio-economic factors, has an important impact on the landscape structure.

As the results show, especially the forest plantation gained recently importance and are an important factor in the increasing landscape heterogeneity. The forest plantation itself is, in general, rather homogenous, with a mono-species stand planted in rows. But because of the dispersed parcel structure, with only some parcels being planted, the landscape pattern becomes more heterogenous.

Besides the starting period of the study and the spatial processes going on, the short period of observation may play a role as well in explaining the trend towards heterogeneity. As the study area is still in a dynamic transition, with from the 1970's on different approaches in different stages of development on different properties. When the forest plantations are more developed and extensification trends progress, it may look different, perhaps eventually evolving towards homogenisation.

Nevertheless, the trend towards a more heterogeneous landscape is unmistakable, and is often related to a greater change for biologic diversity and at the same time floristic, faunistic and structural vegetation diversity enhances ecological heterogeneity (Naveh 2001). Whether the landscapes of the sample areas will indeed continue to follow this direction depends very much on management decision, especially those of the new forest plantations, and this aspect deserves further monitoring and research.

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