

# Differences in land cover interpretation in landscapes rich in cover gradients: reflections based on the *montado* of South Portugal

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**Abstract** This paper contributes to the discussion on current issues in methodologies of mapping land cover in the agro-silvo-pastoral landscapes of the Mediterranean. These landscapes, characterized by intermixed land use and indefinite boundaries, require particular attention in applying the patch-corridor-matrix model when classifying patches and their delineation. In a case study area in southeast Portugal, mainly characterized by agro-silvo pastoral systems, the land cover for 1990 has been mapped. The paper discusses the consequences of the complexity of some Mediterranean land use systems for land cover mapping dealing with detailed landscape dynamics. Within this scope a land cover mapping project in a small case study area is compared with the mapping undertaken within a national land cover database. Both studies were carried out on the same scale and through visual interpretation of aerial photographs. Differences in land cover classification and allocation are explored using

matrix with levels of agreement. Recommendations for future land cover mapping projects are: the application of fuzzy approaches to land cover mapping in agro-silvo-pastoral landscapes should be explored and land cover classifications should be standardized in order to enhance consistency between databases. On the other hand, the fuzziness of the boundaries in this kind of landscapes is inherent to the system and should be accepted as such. The accompanying uncertainties should be taken into account when undertaking landscape analysis on the basis of land cover data.

**Keywords** Land cover classification · *montado*/dehesa · Thematic cartography · Visual aerial photo interpretation

## Introduction

In landscape ecology the patch-corridor-matrix model of (Forman 1995) is widely adopted. In this model, landscapes are represented as matrices, which are constructed of (1) mosaics, consisting of collections of discrete patches and (2) networks, consisting of collections of corridors. Many fundamental ideas as well as tools and methodologies within landscape ecology are constructed upon this paradigm (McGarigal and Cushman 2005). These concepts are mainly based on studies of

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North America (Forman 1995) and northwest Europe (Zonneveld 1995), and not of the Mediterranean or other complex landscapes. Land cover maps, derived from aerial photographs or satellite image, are usually categorical maps, in which the land cover is classified into discrete, non-overlapping land cover classes. Subsequently, patches are delineated qualitatively according to the land cover classification, assuming homogeneity throughout the whole patch. Although the discrete land cover categories have been set up artificially as well as the boundaries of the patches, this approach applies well to landscapes, monitored on a regional or local scale, which display a clear matrix. This is the case in landscapes where the boundary between two areas, for example pasture and forest, is fixed, because it coincides with a clearly defined line on the ground: e.g. a vegetation border, a fence, a hedgerow or a watercourse. Examples can be found in the landscapes of e.g. the Netherlands, Denmark, New Zealand, etc.

However, other landscapes contain continuous gradients in terms of land cover, e.g. the agro-silvo-pastoral landscapes on the Iberian Peninsula, also known as *montados* (Pt.) and *dehesas* (Es.). Delineating patches in these landscapes is currently more a matter of judgement (interpretation) than based on strict rules as defined in the patch-corridor-matrix model. Moreover, categories of forest cover are often created in different ways, using different rules. Consequently, the classification and the delineation of the land cover patches poorly represents true heterogeneity of the landscape (McGarigal and Cushman 2005). Efficient classification and mapping methods are important for systematic collection of information of *montados* and *dehesas*. At present, reliable data on trends in agro-silvo-pastoral systems are still lacking (Eichhorn, Paris et al. 2006).

The main goal of the paper is to discuss the issues regarding classification and mapping of land cover in Mediterranean agro-silvo-pastoral landscapes using aerial photographs. The paper stresses the risk of important imprecision and different representations of reality when land cover maps, originating from different sources and created by using different rules for classification and mapping, are compared. The paper has two objectives:

- To discuss the issues involved in the classification of land cover in European Mediterranean landscapes
- To discuss the delineation of land cover units in landscapes rich in land cover gradient.

The land cover mapping done within the VISTA-project (EVK2-2001-000356) was compared with a already existing land cover map, which is the national land cover database COS'90 (Instituto Geográfico Português 1990), to illustrate the differences in approaches of classification and delineation of patches and the accompanying problems. The paper aims at understanding the differences between these two representations of one real world situation. Weaknesses and uncertainties are inherent to representations, and create differences between the geographic models and the real world. These differences are inevitable, but understanding them helps us to cope with this uncertainty (Longley et al. 2005).

### Land cover mapping of Mediterranean landscapes at different scales

In parts of the Mediterranean a highly diversified landscape pattern emerged, still in existence today, through mixed land use and agro-forestry practices. This resulted in some of the most diverse ecosystems in Europe (Council of Europe 1992). The landscape is often characterized by continuous gradients of shrub and tree densities, a result of variable, extensive land use practices. For the purpose of this paper extensive land use practices are defined as land use practices that are characterized by low levels of inputs per unit area of land (EEA 2006). The presence of many continuous gradients of shrub and tree densities deserves extra attention when one starts to classify and map land cover and is in particular relevant for landscapes characterized by agro-silvo-pastoral systems e.g. the *dehesas*, in Spain and *montados*, in Portugal.

According to the description of the European Environment Agency (2005), the agro-silvo pastoral landscapes constitute 'a characteristic

landscape in which crops, pasture land or Mediterranean scrub, in juxtaposition or rotation, are shaded by a fairly closed to very open canopy of native oaks, (*Quercus suber*, *Quercus rotundifolia*, *Quercus pyrenaica*, *Quercus faginea*). This definition indicates that there are many possible variations within this single term. Figure 1 shows some examples of variations of the *montado* system.

Mapping land cover requires mapping methods that differ when the scale of mapping differs. At a national or international level, a single designation as *dehesa/montado*, or a distinction between the four main life-forms in Mediterranean regions: trees, shrubs, dwarf shrubs and herbaceous vegetation maybe be adequate. However, when an area is mapped in more detail at a regional or local scale, with a minimal mapping unit (m.m.u.) of e.g. 1 ha, more divisions on the classification tree are desirable to represent subtle transitions in vegetation types. This is because small differences within the agro-silvo-pastoral systems in terms of tree density and shrub cover reflect important differences in the abiotic factors (Joffre 1999), the type of management in the past and present (Joffre 1999; Pinto-Correia 1993), and levels of biodiversity (Ojeda et al. 1995). These differences might also indicate different potentials for other complementary uses as hunting,

beekeeping, collection of natural products, recreation, and are thus of importance for landscape multifunctionality (Pinto-Correia and Vos 2004).

Visual interpretation of aerial photographs for landscape cartography carried out in agro-silvo-pastoral landscapes on regional level, are done by Fernandez Ales et al. (1992), Santos Pérez and Remmers (1997) and Plieninger (2004). In these papers one land cover category covers the agro-silvo-pastoral system, and the total number of categories often does not exceed seven. The number of categories is limited to enhance the legibility of the maps, despite the complex nature of the landscape. However, when comparing this approach to the heterogeneity and complexity of the system itself, using only one land cover class for agro-silvo-pastoral system in research carried out on regional to sub-local level, oversimplifies the real life situation and neglects important differences. This is especially true when land cover mapping is done aiming at identifying detailed landscape dynamics, making use of case studies that operate on a scale  $\leq 1:25,000$ . Moreover, in order to understand landscape dynamics and its associated factors, relations between land cover and land use have to be established. Small differences in land cover might indicate significant differences in land use and/or management regimes. Therefore a careful assessment of the land cover classification is required.

**Fig. 1** Different classes of *montado*, above: *montado*, between 5 and 10% tree cover and less than 20% shrub cover; middle: *montado*, 5–10% tree cover and 20–50% shrub cover; below: *montado*, more than 30% tree cover and less than 20% shrub cover



## Study area and materials

### Study area

The case study area, of 44 km<sup>2</sup>, is located in the southeast of Portugal (37°40' N, 7°47' E, datum WGS-1984), and is shown in Fig. 2. A gently sloping relief and a mosaic of varied land cover, with arable land, grassland, shrubs and open oak forest in varying mixtures characterize the landscape.

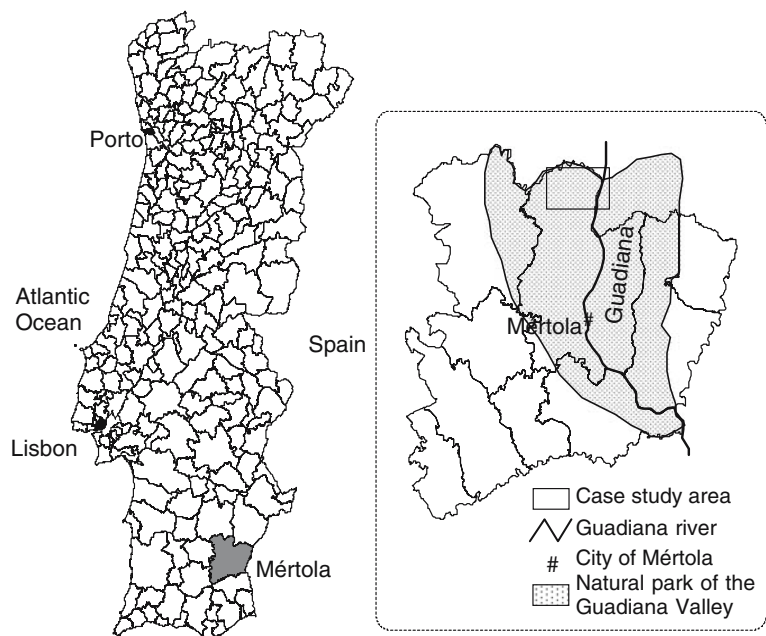
The dominant soil type is a poor and shallow litho-soil of non-calcareous schist (Roxo et al. 1998). The climate is typically Mediterranean, with most precipitation concentrated during the mild winter months, with on average 500–650 mm rainfall a year, followed by approximately 4 months of drought during the hot summer, when the temperatures often attain 30–40 degrees (Perez 1990).

In the past intensive cereal growing has taken place, as a result of a national policy searching for self-sufficiency in food-production, and reached a maximum of production in the first decades of the 20th century. This exploitation of the soil caused many problems with erosion and land degradation. Because of declining production and rural exodus cereal growing diminished from the 1950's, leaving behind highly degraded soils (Roxo et al. 1998).

Due to this severe soil degradation, the unfavourable biophysical conditions and socio-economical aspects, the land use is at present dominated by extensive farming systems. The main land use activities are livestock raising and some cereal production, mainly for fodder production. Most land owners normally practise a rotation cycle of 3 years, with 1 year of cereal growing and 2 years of fallow in combination with grazing. Others do not grow cereals and only have livestock. There are also some landowners who do not practise agriculture but use their land for hunting reserves or new forest plantations supported by legislations of the Common Agricultural Policy of the European Union.

The extensive use of the soil, in combination with heterogeneous physical conditions, has resulted in various densities of shrub cover, representing different degrees of the intensity and type of management. As a result, the borders between arable land, pasture, scrub and forest are fuzzy transitions rather than discrete edges and therefore not clearly visible. This gradient-like aspect is strengthened because some parts of the arable land, grasslands and natural pastures are covered with dispersed oak trees that are part of the land use system, the *montado* (Pinto-Correia 1993; Pereira and Pires da Fonseca 2003).

**Fig. 2** Location of the study area



## Material

Although the application of satellite images has become more common in landscape research, aerial photographs remain indispensable for detailed surveying (Fuller 1981; Longley et al. 2005). The pan chromatic aerial photographs of 1990 (Centro Nacional de Informação Geográfica 1990) were used to carry out the visual interpretation of the land cover. These photographs were made during the summer months (June–September). In this period pastures are dry, and appear as white fields, the trees appear as dark dots, as do the scrub formations, though the latter are more greyish. In this way tree and shrub cover contrast clearly with the understorey that makes identification easier.

The aerial photographs have a 1:25,000 scale. The hard copies were scanned, using 600 dpi, resulting in a pixel dimension on ground level of 1 m. Next, the visual interpretation was carried out on screen.

## Land cover classification and mapping

### Land cover classification

On aerial photographs one can interpret visually land cover categories (Lillesand and Kiefer 1994).

These land cover categories should be thematically consistent, not including land use or environmental conditions (Loveland et al. 2005). The composition of a land cover classification depends mainly on (1) the type of landscape, (2) the spatial scale, (3) the purpose of the study and (4) the available data sources. Because the tools for the adoption of a gradient approach for mapping land cover are currently unavailable, a discrete classification for land cover was adopted, using the patch-mosaic model of Forman (1995).

In order to relate land cover to land use in a later stage of the research the classes in the land cover classification should correspond to different management regimes, as far as the differences can be observed through the land cover. On basis the previous discussion, the local scale of the study, and previous work done in the area, a land cover classification has been constructed for the VISTA-project, which is displayed in Table 1, also showing the accompanying main land uses per land cover category.

The land cover classification consists of 14 categories and are mainly separated on the basis of physiognomy. Category 1, 2 and 3 are widely used and can be clearly recognized on aerial photographs. Categories 5, 6, 7 (*matorral*) and 9–14 (*montado*) are the land cover classes on which the paper focuses on.

**Table 1** Land cover classification used for the interpretation of the aerial photographs in the VISTA-project

Land cover classification	Land use
1 Hamlets/farm buildings horticulture/orchards/	Residential
2 Waterlines/reservoirs	Wildfire prevention, hunting, fishing, watering place for livestock,
3 Olive grooves	Production of fruit and vegetables for home consumption
4 Arable/grass land, s.c.<20%	Livestock grazing, cereal production, hunting
5 Low, scattered <i>matorral</i> , s.c. 20–50%	Livestock grazing, hunting
6 Middle, discont. <i>matorral</i> , s.c.50–75%	Hunting, honey production
7 High, dense <i>matorral</i> , s.c. >75%	Hunting, beekeeping, nature conservation
8 Forest plantations	Wood/cork production
9 <i>montado</i> , <sup>a</sup> c.c. <10% s.c. < 20%	Cereal growing, sheep and cattle grazing, hunting,
10 c.c. < 10% s.c. > 20%	Sheep and cattle grazing, hunting,
11 c.c. 10–30% s.c. < 20%	Cereal growing, sheep and cattle grazing, wood, acorn, cork production, hunting.
12 c.c. 10–30% s.c. > 20%	Sheep and cattle grazing, wood, acorn, cork production, hunting,
13 c.c. > 30% s.c. < 20%	Cereal growing, sheep and cattle grazing, wood, acorn and cork production, hunting,
14 c.c. > 30% s.c. > 20%	Sheep and cattle grazing, wood, acorn and cork production, hunting,

<sup>a</sup> c.c. = crown cover; s.c. = shrub cover

Category 4 arable/grass land includes those areas that are characterized by the absence of trees and shrubs and might correspond to arable land as well as pasture. The main agricultural activities are cereal growing in a 3–5 year rotation with fallow in combination with extensive livestock breeding of sheep, cattle and, less frequently, goats or pigs. Some dominant plant species in this land cover category are: *Agrostis pouretii*, *Carlina corymbosa*, *Tolpis barbata* and *Chamaemelum mixtum*.

Categories 5–7 are the categories of the different types of scrub, that are present in areas with less or no agricultural activities. Depending on the biophysical conditions and the type and intensity of land use the types of scrub vegetation differ in height and density of the shrubs and in species composition. Because local names of these different scrub types cause confusion we decided to apply the standardized nomenclature of Tomaselli (1981) for *matorral*. *Matorral* is defined as a shrubby formation of woody plants related to Mediterranean climates. Three categories of *matorral* are distinguished:

Category 5 is low, scattered *matorral* and corresponds to natural pasture where sparse shrub covers 20–50% of the surface. The shrubs have a maximum height of 0,6 m. and common species are *Lavandula stoechas*, *Genista hirsute*, *Carlina corymbosa*, *Helichrysum stoechas*. These areas are not subject to a rotational management. There is grazing but no crop growing, the area stays open through grazing but due to the low grazing intensity small shrubs can germinate.

Category 6 is middle discontinuous *matorral*. This type is between 0.6 and 2 meters high and the shrub cover between 50 and 75% of the surface. It a homogeneous formation of *Cistus ladaniferus*, but also *Quercus ilex*, *Lavandula stoechas*, *Genista hirsute* can be found. Middle, discontinuous *matorral* grows mainly on former cultivated lands or recently burned areas, since *Cistus ladaniferus* is an active pyrophyte. This type of *matorral* might represent an alternative stable state, which is highly persistent in the absence of human intervention, because seed establishment of *Quercus* species is difficult in this kind of scrub formation (Acacio 2005).

Category 7 is high, dense *matorral* (cat. 7), which can reach a height of more than 2 m., and can especially be found on the steep slopes along the waterlines. It is a heterogeneous formation, rich in species like *Arbutus unedo*, *Olea oleaster*, *Pistacia lentiscus* and *Quercus rotundifolia*. The structure of this type of *matorral* is more granular than the middle *matorral*, and thus as such recognisable on aerial photographs, since the vegetation composition is more varied and consists of bushes and small trees.

Category 8 includes the forest plantations, which are defined as areas where trees are recently planted or sowed in a process of forestation, or those areas where trees have been planted artificially less recently but still only have a forestry goal.

The selected species can be either native or exotic. In the first case it will be cork oak (*Quercus suber*) or holm oak (*Quercus rotundifolia*) and the forest plantation might develop into a *montado*. In the case of exotic species, the species that are selected for their wood and cellulose producing properties e.g. *Pinus* and *Eucalyptus*.

The land cover categories 9–14 deal with the agro-silvo-pastoral system, here after called *montado*. The *montado* distinguishes from the arable/grass land category and from the *matorral* categories, because of the presence of a tree cover of cork or holm oak trees of more than 5%. In the case study area the dominant species is holm oak (*Quercus rotundifolia*), but also patches of cork oak (*Quercus suber*) can be observed. The trees are visible as such on aerial photographs when they are more than 10-years-old.

The *montado* classification is set up as a combination between tree density and shrub cover, resulting in 7 categories, which should reflect different options and intensities of management. The tree density can be estimated in numbers of trees per hectare or in crown cover percentage. In recent studies dealing with *dehesas* and *montados* the number of trees per hectare is often used (Pereira and Pires da Fonseca 2003; Casimiro 2002; Joffre 1999) while international land cover data bases like CORINE and methodologies for habitat mapping like BioHab (Bunce et al. 2005) use the crown cover (c.c.)

percentage. A drawback of a classification based on the number of trees is that it does not take into account the difference between trees with large canopies and those with smaller ones, i.e. every tree counts equally. For this reason a classification based on the crown cover percentage was used.

Concerning CORINE and BioHAb (Bunce et al. 2005) the minimum crown cover for forest is 30%. For this reason those *montado* areas with a crown cover superior to 30% should be considered separately, since they represent ‘real’ forest.

The minimal tree density for the *montado* is in Portugal by law established at 10 trees ha<sup>-1</sup> (*Decreto lei no 11/97 de 14 de Janeiro*). In which way the number of trees is related to crown cover percentage depends on the crown perimeter of the trees. Figure 3 displays a detail of the aerial photograph of 1995 of the case study area. The black square represents 1 ha, within the square there are 23 trees, which are outlined in white. The total crown cover of the trees is calculated using the X-tools extension in ArcView and corresponds to 0.073 ha, which means the corresponding crown cover is 7.3%. So 20 trees ha<sup>-1</sup> might represent less than 10% c.c. To make a distinction between this very scattered type of *montado* and the more open forest type two classes were distinguished: the open forest class with a c.c. between 10 and 30% and the scattered *montado* with less than 10% c.c., but with a lower

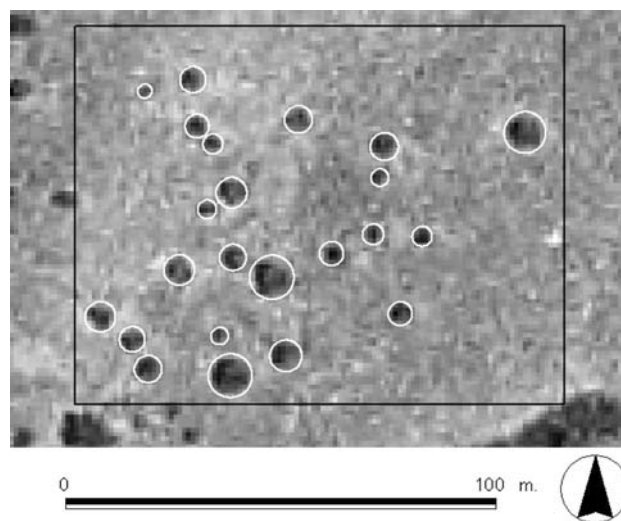
limit of 5%. These limits coincide with Bunce et al. (2005).

The second division within the *montado* classification is made on the type of understorey that is closely related to the type of short-term management and levels of disturbance. When the shrub cover (s.c.) is less than 20%, it is assumed that the area is frequently grazed and once in a while ploughed. A shrub cover of more than 20% corresponds to scattered, discontinuous or dense matorral and indicates much less intensive use of the soil.

#### Land cover mapping

Visual interpretation of aerial photographs is a qualitative approach that starts from the image characteristics as perceived on the printed version or on screen. Because it is a qualitative process there is no single “absolute” way to approach the interpretation process (Lillesand and Kiefer 1994). According to the same authors the basic characteristics of the aerial photo used when carrying out a visual interpretation are: shape, size, pattern, tone or hue, texture, shadows, geographic or topographic site and associations between features.

The interpretation and delineation started with most easy classes to identify, e.g. groups of houses, water courses and forest plantations,



**Fig. 3** Detail of aerial photograph with tree cover estimation

and subsequently the more complex ones like the different categories of *matorral* and *montado*. The minimum mapping unit (m.m.u.) varied with the type of land cover class. For reservoirs, groups of houses, olive grooves and waterlines it was 0.25 ha, for the other classes 0.5 ha.

The different types of *montado* according to crown cover and shrub densities were also relatively easy to recognize. In a couple of areas the crown cover was calculated as shown in Fig. 3. Because of efficiency reasons this was not done for the whole area but rather to develop an expert eye on estimating percentages of crown cover.

To avoid observer bias, resulting from differences in opinion about the delineation of the fuzzy boundaries, only one observer did the interpretation.

After this preliminary phase of interpretation, fieldwork was carried out in the spring of 2003. This was mainly when doubts were registered in the aerial photo interpretation. The objective was to check the photos because they were old and sometimes unclear. Based on the occasional fieldwork in combination with recent aerial photographs their information was corrected.

### Comparison with the national land cover database COS'90

#### Land cover data base COS'90

The VISTA land cover map has been compared with the land cover map of COS'90, which is the national land cover database (Instituto Geográfico Português 1990) on a 1:25,000 scale covering the entire continental part of Portugal. The database is widely used for monitoring land cover changes. The maps were produced through visual interpretation of false-colour aerial photographs, 28,000 in total, taken in the summer of 1990, using a m.m.u. of 1 ha (Instituto Florestal 1994).

Because of the national wide coverage and the detailed mapping scale, the land cover classification is comprehensive, and contains 78 categories. The *montado* areas are covered by a number of forest classes. These classes are composed of the combination of crown cover percentage and the

dominant tree species. Crown cover percentage is subdivided into four classes, ranging from less than 10% to more than 50%. The minimum limit of tree density for agro-forestry areas is considered to be 5 trees ha<sup>-1</sup> or 5% tree cover of the area. In terms of species, two types of trees are important: cork oak and holm oak. In total 16 classes of *montado* are used, which are exclusively based on the composition of the tree cover, without considering different types of understorey.

A comparison between the VISTA and the COS'90 categories for *montado* and *matorral* and some other land cover categories is displayed in the 1st and 3rd column of Table 2.

#### Comparison between the two land cover maps

Although the land cover classes of both approaches are slightly different, one can compare the differences in mapping by adapting both classifications to each other. Because COS'90 does not take into account shrub densities, we aggregated the *montado* classes of VISTA to 3 classes based on tree cover percentages: <10%, 10–30% and >30%. Because there was no further distinction in tree cover for >30% within the VISTA classification, the categories of COS'90 of 30–50% and >50% were aggregated. Also the sub categories of COS'90 on the basis of tree species (holm or cork oak), were aggregated. The final categories of the categories of *montado* and *matorral* to be compared are displayed in the 2nd column of Table 2. Because the COS'90 map only displays two categories of scrub (*matorral*) vegetation, it was decided to merge the classes of middle and high *matorral* of the VISTA-map. Besides the *montado* and *matorral* categories, which are characterized with fuzzy borders, 4 categories with clear boundaries were chosen for the comparison of the two land. So, in the end a comparison was made of the areas of arable land, horticulture, forestations, olive grooves, three categories of *montado* and two categories of *matorral*, see Table 2.

The consistency between the two maps can be evaluated according to the two basic errors of land cover maps: the misallocation of boundaries and the misclassification of areas (Longley et al. 2005). Since it is impossible to judge in this kind



**Table 2** The different classes of matorral and Montado of the classifications of VISTA and COS'90

VISTA		Categories for comparison	COS'90
Arable/grass land		Arable/grass land	Arable land, non irrigated
Olive grooves		Olive groove	Olive groove
Forest plantation		Forestations	Forest plantations
Low, scattered <i>matorral</i> , s.c. 20–50%		Low matorral	Low shrub
Middle, discont. <i>matorral</i> , s.c.50–75%		High matorral	High shrub and degraded forest
High, dense <i>matorral</i> , s.c. >75%			
<i>montado</i> , <sup>a</sup> c.c. <10%	s.c. <20%	montado c.c. < 10%	Arable land + holm oak c.c.<10%
c.c. <10%	s.c. >20%		Arable land + cork c.c.<10%
c.c. 10–30%	s.c. <20%	montado c.c. 10 – 30%	Holm oak (spontaneous)
c.c. 10–30%	s.c. >20%		Cork oak (spontaneous)
c.c. >30%	s.c. <20%	montado c.c. > 30%	Holm oak c.c. 10–30%
c.c. >30%	s.c. >20%		Cork oak c.c. 10–30%
			Holm oak + cork oak c.c. 10–30%
			Holm oak > c.c. 30%
			Cork oak > c.c. 30%
			Holm oak > c.c. 50%
			Cork oak c.c. > c.c. 50%
			Holm oak + cork oak c.c. 30–50%

<sup>a</sup> c.c. = crown cover; s.c. = shrub cover

of complex landscapes which interpretation is the right one, or which limit represents the 'true' boundary, they can rather be mentioned as *differences* instead of as *errors*. To assess the difference in misallocation of a boundary, a rule of thumb can be used, as recommended by Longley et al. (2005): features, patches, lines or dots, might be subject to errors of up to 0.5 mm on the map at a scale of 1:20,000 or smaller. So, if patch boundaries differ more than 0.5 mm on the map, they are significantly different.

The misclassification of areas was assessed by a systematic comparison of both maps. To make this comparison both polygon maps were rasterized with one raster cell representing 1 ha. A sample area of 22 km<sup>2</sup> in the centre of the case study area was chosen to carry out the detailed comparison between VISTA and COS'90. This was done by overlaying the two raster maps. Next, levels of agreement between the two land cover maps were assessed by applying the concept of the confusion matrix (Foody 2002). Normally, a confusion matrix is used to compare ground data and map data, for the purpose of this paper it was used to compare both land cover maps. Percentages of overlap of the categories for comparison (Table 2) on the COS'90 map in relation to these categories on the VISTA-map were calculated and listed in a matrix.

### Results of the VISTA land cover mapping and comparison between VISTA and COS'90

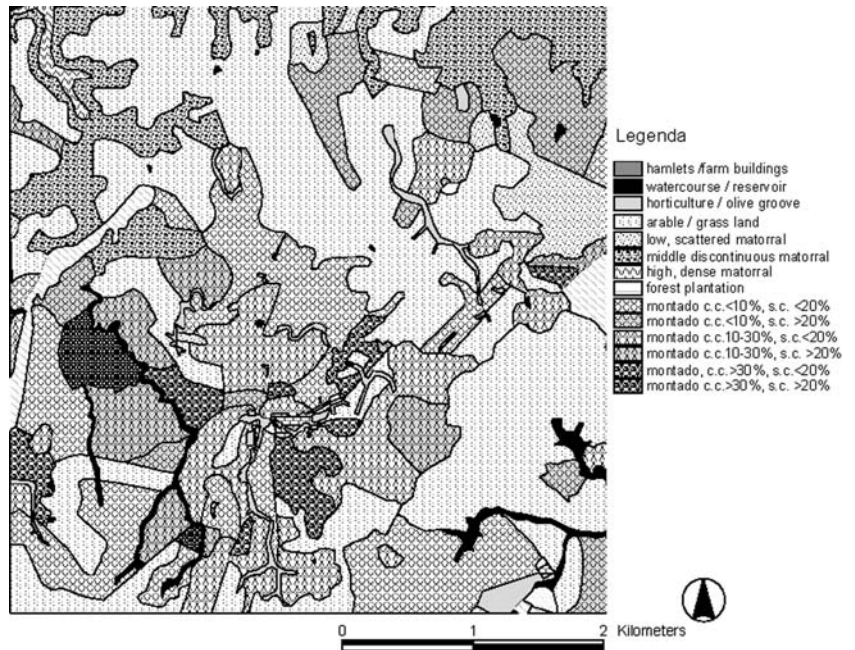
The VISTA land cover map and the COS'90 map

Figure 4 shows the results of the land cover mapping according the aerial photo interpretation carried out within the VISTA-project for the sample area of 22 km<sup>2</sup>. Figure 5 shows for the same area the COS'90 map. The *montado* is mostly concentrated around the settlements, while the arable/grassland, the forest plantations and the *matorral* areas are located in the periphery.

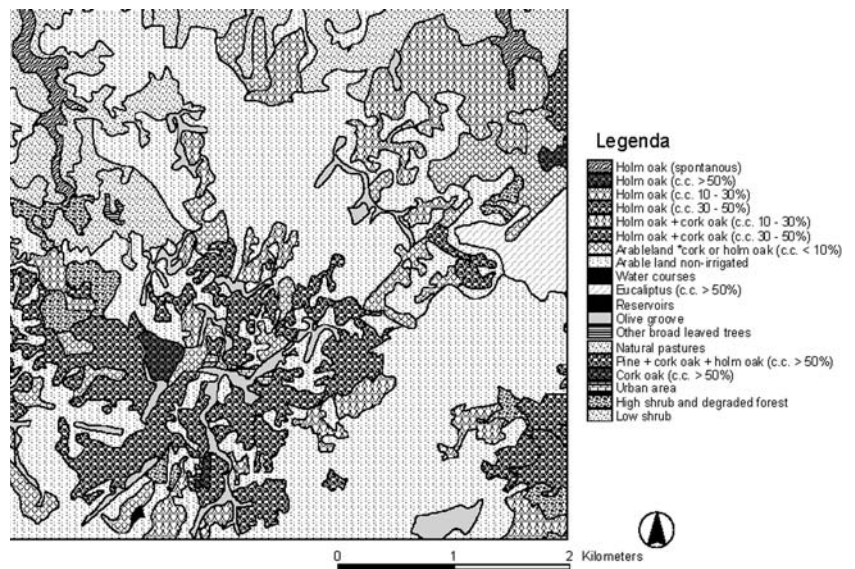
The differences between the proportion of land cover categories, as percentage of the total study area, of both land cover maps are displayed in Fig. 6. Clearly visible are the significant differences for the land cover categories of *montado* and *matorral*. The area of *montado* with >30% c.c. covers according to COS'90 14% of the sample area, while this is for VISTA only 4%. Almost the opposite ratio can be found for *montado* with <10% c.c. COS'90: 9% and VISTA 22%. More close but still distinct are the numbers for the *montado* with 10–30% tree cover, COS'90 11% and VISTA 17%.

Also for *matorral* there are large differences: according to COS'90 only 2% of the area is covered by high *matorral*, but the VISTA map

**Fig. 4** Land cover map elaborated within the framework of the VISTA-project



**Fig. 5** Land cover map according to COS'90



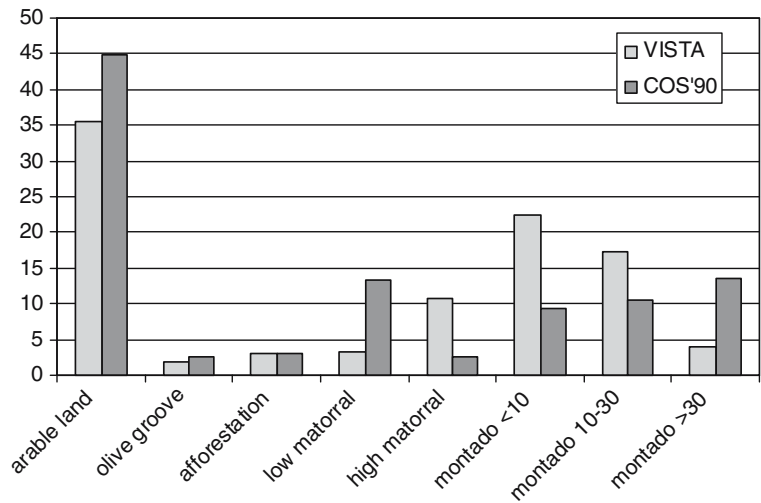
this is 11%. The category arable/grass land shows similar percentages of coverage, as well as the categories of forest plantation and olive grooves.

Differences in classification and delineation

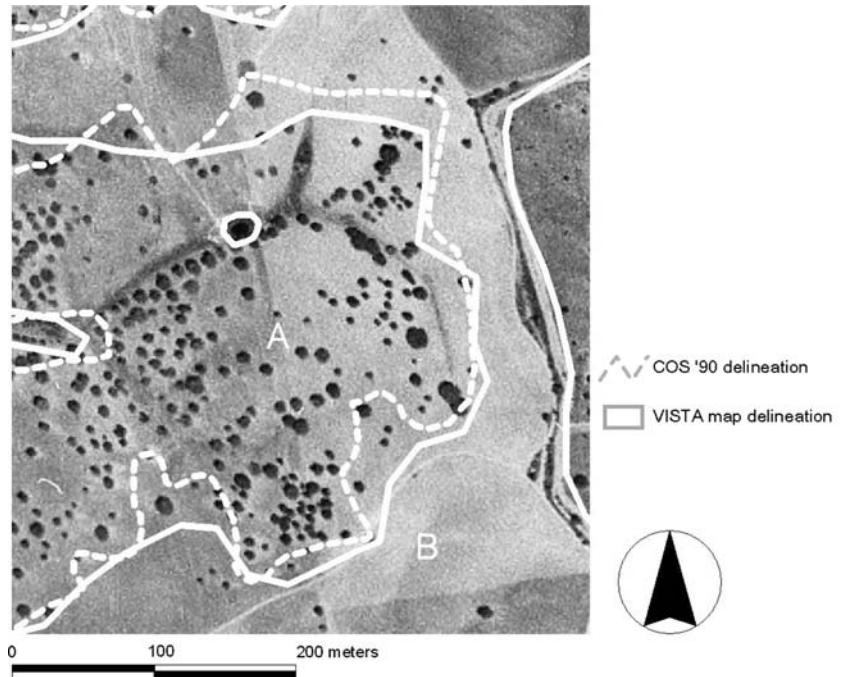
When comparing the aerial photo interpretation of COS with the interpretation carried out

within the VISTA project, the personal influence of the cartographer becomes clear. Figure 7 shows a detail of the aerial photograph of 1990 with the delineation between two land cover classes (A and B) for both land cover interpretations. The continuous line is the boundary between two patches identified in the case study, the stacked line is the boundary between two

**Fig. 6** Comparison between COS'90 and VISTA of proportions of land cover classes



**Fig. 7** Delineation of land cover classes according to COS'90 (stacked line) and photo interpretation work carried out within the VISTA project (continuous line)



patches identified by COS'90. Although the boundary is in a different place, the significance of this difference needs to be assessed.

The assessment of the misallocation of the boundaries has been done for the boundaries displayed on the detail of the aerial photograph of Fig. 7. With a scale of 1: 3250, the rule of thumb corresponds to a ground distance of 1.63 m. The differences in boundaries in Fig. 7 are larger than

0.5 mm on the map, in some cases even corresponding to more than 70 m. ground distance.

Except for the misallocation of an areas boundary, there are also differences in classification of land cover. For example, COS'90 classifies area A in Fig. 7 as holm oak forest with a crown cover of 35–50%, while the photo interpretation of the case study classified the area as *montado* area with 10–30% c.c.

The VISTA and COS'90 approach compared: percentages of agreement

Table 3 displays a matrix with the percentages of agreement between the two maps for the land cover categories that were selected for comparison. On the diagonal the percentages of agreement can be read, i.e. how many percent of the area of a land cover category on the VISTA map was mapped according to the same category on the COS'90 map. The values off the diagonal reflect the percentages that were differently classified on the COS'90 map.

The land cover categories with clear borders, like the forestations, olive grooves and arable land show high levels of agreement (>70%). This is also true for the *montado* c.c.> 30% category. For the *montado* category with c.c.<10% there is only 13% agreement. On the COS'90 map 24% of this category is mapped as *montado* with 10–30% crown cover or even as *montado* with c.c.>30% (14%). On the other hand, 39% of the category *montado* <10% c.c. is mapped in COS'90 as arable/grass land.

For the *montado* category with c.c.10–30% there is 16% agreement. Comparing with COS'90, 41% is mapped as *montado* c.c > 30%, while 22% of this category is mapped as arable/grass land.

According to the *matorral* categories the levels of agreement are very low, only 6% for low *matorral* and 4% for high *matorral*. The category of *low matorral* is on the COS'90 map for 47% classified as *montado* c.c.<10% and for 35% as arable/grass land. The category of *high matorral* is on the COS'90 map classified for 69% classified as *low matorral*.

## Discussion

Major differences exist between both land cover maps regarding the *montado* and *matorral* categories, while the categories with clear boundaries, as olive grooves and forest plantations show higher percentages of overlap. These differences between the VISTA land cover map and the one of COS'90 point out that the two approaches reflect different representations of the same reality and thus mean important imprecision. Both differences in classification and allocation are the cause of the observed differences between both land cover maps.

Differences in classifying the land cover as observed on the aerial photograph, are not only due to the application of different land cover classifications but also to dissimilarities in the estimations of crown cover by the different

**Table 3** Matrix with percentages of agreement between the land cover map of COS'90 and VISTA

COS'90	VISTA								
	Arable/ grass land	Olive groove	Forest plantation	Low matorral	High matorral	Montado cc < 10%	Montado cc 10–30%	Montado cc > 30%	Other
Arable/grass land	84	16	2	35	4	39	22	12	55
Olive groove	1	73	0	0	0	1	4	4	8
Forestations	1	0	71	0	0	0	3	6	5
Low matorral	8	4	9	6	69	4	4	0	0
High matorral	0	0	6	6	4	4	4	0	5
Montado cc < 10%	3	2	3	47	14	13	5	5	0
Montado cc 10–30%	2	3	3	4	8	24	16	0	5
Montado cc > 30%	1	0	6	1	0	14	41	74	18
Others	0	2	0	0	0	0	0	0	5
	100	100	100	100	100	100	100	100	100

interpreters. Differences also emerge because in the COS'90 classification no distinction is made between trees and shrub. The recognition of the understorey of the Montado in the VISTA-classification results in the distinguishing between montado 10–30% c.c. without shrubs and montado <10% c.c. with shrubs. In the COS'90 map it is likely that both land cover types are classified as montado 10–30% c.c.

Differences in allocation, location of boundaries, can be related to the fact that in this gradient rich landscapes, clear boundaries between the land cover types are hardly present. While it might be easy to recognize a type of *montado* in the core area, the identification on the boundary is more problematic. This results in problems in outlining the boundaries between two different land cover classes because these are not discrete edges but rather indeterminate boundaries, representing a gradual transition from one category of *matorral* or *montado* to another one.

Dealing with such a fuzziness, the aerial photo interpretation is rather intuitive and the result heavily depends on the point of view and personal preference of the cartographer. Especially because the borders of the patches are outlined in a qualitative way, every time questioning until what extent the spatial variation in terms of tree and shrub density within the patch could be ignored (Gustafson 1998). Within this respect the application of the m.m.u. is important. On basis of a priori defined m.m.u. the interpreter decides to include or exclude a couple of dispersed trees when outlining a *montado* area. Because of the irregular tree pattern of most *montado* areas, the influence of the size of the m.m.u. is considerable.

As we see, in the gradient rich landscape of the study area it is hard to define patches according to a discrete land cover classification. Rules for classification and delineation of land cover patches are hard to define and even harder to apply in practice. It is likely that both differences in allocation and classification, occur frequently in complex landscapes as the agro-silvo-pastoral ones. It is also likely that the occurrence of these differences increase when the map scale decreases and the number of land cover categories increase, because accuracy errors tend to increase when maps become more complex.

Differences in representation of the same reality do not have to be a problem if databases are used independently. However, in landscape research, different databases are often combined in order to trace landscape dynamics. In this way, dissimilarities in classification, interpretation and delineation between databases are likely to cause false differences or similarities in land cover and consequently one runs the risk to draw false conclusions about the tendencies of land cover change.

Concluding from the study presented, there are several issues to be dealt. In order to facilitate comparison among land cover databases of agro-silvo-pastoral landscapes of the Mediterranean, there should be comparability between classification and consistency in applying rules for delineating patches. In terms of classification, one of the efforts to be made is to create standardized rules and common criteria to classify the different appearances of the *montado/dehesas* systems. Standard categories of tree cover percentages should be introduced in combination with information about the vegetation of the understorey. In this point of view, the BioHab project developed a promising methodology to map habitats throughout Europe in a systematic way (Bunce et al. 2005). Though the methodology is designed for monitoring habitats through fieldwork and not primarily by aerial photo interpretation, its framework of classification might be useful to standardize land cover cartography.

The pan-European standardized land cover classification system CORINE is applied in Portugal (Instituto do Ambiente and IGEOE 2005), and causes confusion in identifying the agro-silvo pastoral systems. These are categorized into one class: 2.4.4. *Heterogeneous agricultural areas/agro-forestry systems*. Yet, class 3.1.1 *Broad-leaved forest*, 3.2.3. *Sclerophyllous vegetation* and 3.2.4 *Transitional woodland and scrub* might also cover some types of *montado* systems, but it is doubtful if they are likely to be recognized as such in databases based on CORINE.

In terms of allocation, the m.m.u. should be applied in a strict way in order to make clear decision about including or excluding trees on the border of the *montado*. However, whilst a concerted attempt can be made to maintain the

decision rules consistent, like the application of the m.m.u, the differences in interpretation can still be considerable (Loveland et al. 2005)

The observer bias of the qualitative interpretation of aerial photographs can be diminished by making use of automatic classification methods. They are only useful when just a few land cover classes for trees, shrubs and herbs are involved (Carmel and Kadmon 1998), but such methods are constantly improving and can be useful in the near future.

Other solutions can be found in advanced remote sensing techniques that are able to deal with real world fuzziness. These techniques are elaborated mainly in suburban areas of North West Europe (Zhang and Stuart 2001). Although developed in another context, it could be promising for mapping the *montado*. A central concept is a fuzzy map of land cover, on which a location can have partial or multiple memberships of all the candidate land cover classes (Zhang and Kirby 1997). The polygon boundaries are rather seen as a transitional zone with a degree of uncertainty. The degree of uncertainty decreases when moving to the centre of a patch and increases when moving to the boundary. In this way the probabilities of belonging to one land cover category or to another change. The pattern of change can be modelled by using a range of different interpolation methods. Application of such methods for detailed land cover mapping in the agro-silvo pastoral systems of the Mediterranean deserves further research, for further technical information we refer to (Zhang and Kirby 1997; Zhang and Kirby 1999; Zhang and Stuart 2001; Anderson and Cob 2004). However, within the scope of this paper, it is important to stress that such technical solutions could be way to solve the problems, but it will not result in the same representation of reality as in the more homogenous and simple landscapes.

Besides these considerations about standardized rules and common criteria to classify and map the *montado* and *dehesa* systems, one should take into account that the fuzziness of the presented landscape is an inherent part of the system. It is directly related with the characteristic extensive land use forms that permanently are being adapted by farmers to the resources

available in different patches of land cover. This complexity with its indeterminate boundaries corresponds to specific land use systems, and thus should be accepted and represented in the maps obtained. Therefore land cover databases dealing with this type of landscapes should not be compared in their construction or accuracy with databases referring to intensively used landscapes. They should be treated with care, and one should take into account the resulting inconsistencies when carrying out landscape analysis.

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