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A holistic approach to land system dynamics – The Monfurado case in Alentejo, Portugal

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ABSTRACT

Understanding land system dynamics is fundamental for policy-making from local to global scale. Land system is a combination of land use, land management and territorial practices. To attain such complete information about landscape structures is a challenging task. Aiming to deepen knowledge on land systems, we applied a methodology meant to achieve a broader understanding of dynamics in the *Sítio de Monfurado* (SM), a Natura 2000 site and holder of High Nature Value farming systems. To do so, we combined spatial analysis of land system changes with a participatory approach designated as Territory Game. While the spatial analysis shows little change in the SM land systems, the territory is perceived as fast-changing by the territorial actors (e.g., stakeholders with an explicit role in territorial development). At both scales, and in agreement with literature, we find trends of simplification and intensification in land systems, typically associated with the reduction of multifunctionality. The combination of both approaches contributed to the understanding of past changes, the drivers that induce such changes, how these are interpreted and, how to act upon them in the future. The proposed combined methodology can bring new useful insights for policy-makers, although scaling from local to broader scale remains a challenge.

1. Introduction

Land systems can be defined as the combination of land use and territorial practices (Turner et al., 2007), where social, economic and political flows meet biophysical constraints. Land systems are dynamic, resulting from interactions of the social-ecological systems that operate across spatial and temporal scales (Verburg et al., 2013, 2015). Over the last decades, the fast pace of social, technological and economic change lead to abrupt changes in land use and land cover (Jetz et al., 2007a; Verburg et al., 2015). These changes affected the composition, function, and services provided by ecosystems (Polasky et al., 2011; Lambin and Meyfroidt, 2011), with consequences for human well-being (Haines-Young and Potschin, 2010; Wu, 2013).

The Mediterranean Basin is characterized by poor and shallow soils, dry and hot summers with a limited availability of water, and mild wet winters (Caraveli, 2000). Nonetheless, the region has a long history of agricultural use and includes a large diversity of land use systems well adapted to its harsh conditions. Traditional Mediterranean land systems are often extensive and multifunctional (Blondel, 2006), such as silvopastoral and agroforestry systems, and provide several ecosystem goods and services on top of food production (Bugalho et al., 2011; Torralba et al., 2016). Some, but not exclusively, traditional Mediterranean farming systems fall under the concept of High Nature Value (HNV) farming, hosting a high diversity of habitats and species of interest (Pinto-Correia et al., 2018a). Moreover, these systems are also a type of cultural heritage, sources of traditional and quality products and rural employment (Moreno et al., 2018). These low-intensity farming systems, which are usually characterized by a small need of external inputs, continue to disappear in favor of more input needing systems, oriented to the global markets (Jepsen et al., 2015). This is leading to a detachment of farming systems from local needs, with an increased vulnerability of farmers (Cumming et al., 2014; Hamann et al., 2015), but also loss of cultural heritage (Plieninger et al., 2006), habitats, species of high conservation value and ecosystem functions (Bugalho et al., 2011). Therefore, it is urgent to enhance knowledge about the Mediterranean land systems, the changes that occurred, the drivers of

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change and ultimately which measures need to be taken to conserve valued systems that are dependent on human management.

Mediterranean land systems face a number of common challenges including the management of natural resources (Bugalho et al., 2011; Galli et al., 2015) under severe environmental conditions, which are expected to aggravate (Giorgi and Lionello, 2008), with consequences to the productivity and sustainability of agricultural and food systems. Debolini et al. (2018) argued that social and demographic factors, next to institutional and biogeographic, are determinants in the trajectory of change in Mediterranean land systems. Such factors of change are commonly linked with broad-scale processes (Lambin et al., 2001; Jetz et al., 2007b; Malek et al., 2018). Yet, how local actors and institutions interact with such broad-scale trends through their rules and decisions can influence outcomes, and in turn cumulatively influence global trends (Magliocca et al., 2018; van Vliet et al., 2015). Thus, people and their choices, guided by their perception, within their opportunities and constraints, significantly affect the system (Gorddard et al., 2016; Fernandes et al., 2019)

Recent studies have characterized main land system dynamics and their drivers, taking social-economic aspects into consideration (Debolini et al., 2018; Malek and Verburg, 2017; van Vliet et al., 2015). Yet, these regional-scale analyses tend to disregard how people perceive such changes and how they interact with their surroundings. Therefore, multiscale approaches that allow data collection at a broader and localized levels are needed to enhance understanding on the underlying drivers behind land system changes (Magliocca et al., 2018). Through participatory approaches it is possible to tap on the rules, values and knowledge influencing land system decisions (Gorddard et al., 2016), and gain a better understanding how these are influencing development trajectories.

This paper aims to arrive at a combined understanding of land use, land management, and territorial practices by integrating information attained using distinct methodologies. More specifically, this paper analyzes land system dynamics within a specific Mediterranean case study using two distinct sources of information (i) a temporal analysis of spatial data at the Mediterranean level, and (ii) the perception of territorial actors about the territory dynamics, drivers of change and future perspectives, collected through a participatory approach, the territory game. Through the combination of the two approaches, we sought to answer the following questions: 1) Which are the changes detected by spatial analysis and how do they relate to those identified by the Territory Game? 2) What are the driving forces of change? and 3) Are the changes towards a desirable future? And if not, 4) What actions must be taken towards land system dynamics moving the territory in a sustainable path?

With the results attained, we expect to provide not only a broader understanding of drivers of change at the case study level but also insights of how to manage change in the future.

2. The case study

The case study is the *Sítio de Monfurado* (SM) in the Alentejo Central region in mainland Portugal, within the municipalities of Évora and Montemor-o-Novo (Fig. 2). SM is a site from the Natura 2000 network, with a total area of 23,946 ha and a heterogeneous morphology, with elevation ranging from 150 to 420 m. There are 1469 residents within SM, distributed through small settlements and sparse housing (ICNB, 2000; PIERSM, 2010). The climate is Mediterranean, with dry and hot summers and cold and wet winters. The rainfall is above average for the central Alentejo region, reaching 900 mm annually (Silva, 2008). The landscape is dominated by *montado* silvo-pastoral system with a high tree cover of predominantly *Quercus suber* but also *Quercus rotundifolia*, and production of cattle or sheep in the understory. Other common land covers are olive groves, orchards, dry cereal fields and fallows. Both silvo-pastoral *montado* and the olive groove mosaics, although variable in their biodiversity value (Pinto-Correia et al., 2018a), can be generically considered HNV farming systems (Paracchini et al., 2008). *Montado* in particular, provides a good example of the main challenges faced by HNV systems. Despite its conservation value, both market mechanisms and public policies create pressures for simplification of the system through specialization and intensification (Almeida et al., 2013; Pinto-Correia and Azeda, 2017).

Livestock production and cork extraction are the main economic activities in SM. The site has a rich cultural and patrimonial heritage that dates to the pre-historic times and includes relevant Paleolithic and Neolithic edifications. There is a cave, the Escoural Cave, which remains the only grotto in Portugal where Upper Paleolithic rock art has been identified. Both natural and cultural values have been explored for tourism and recreation, with an increasing economic relevance of the sector, as the number of rural tourism units and restaurants grows. The proximity to the metropolitan area of Lisbon and easy accessibility adds to the attractiveness of the landscape (PIERSM, 2010).

3. Methods

Our focus is on land system dynamics and their drivers, how they affect local actors and what actions are needed towards desirable futures. These actions might be need at different scales, from local to global. To arrive at these results, we relate information from a multi-layer cluster spatial analysis of land systems changes at the Mediterranean Basin level with the knowledge and vision of stakeholders, collected through the application of the Territory Game methodology.

3.1. Land system changes at regional level

Land system changes were derived from the difference between two maps obtained for 2005 and 2015. The land system classification for the two years is based on a comprehensive database of the whole Mediterranean Basin (Fusco et al., 2018, 2019). This database has a spatial resolution of 2 km and for each pixel it includes data on land cover, biophysical factors data (morphology, soil quality, climate), agricultural production systems (livestock units, number of households, crop production system, protected areas) and population (see Appendix A for the databases used). The work of Fusco et al. (2018), (2019) combines data form several multi-temporal datasets, to assess land systems and their changes. The period for the temporal analysis was chosen to ensure a homogeneous time span for the whole Mediterranean Basin. The period between 2005 and 2015 encompasses relevant changes in political and agricultural settings and to provide useful information on ongoing changes and processes in Mediterranean land systems.

A 2 km resolution analysis is coarse for a local/regional scale; however, to the best of our knowledge no previous study presented a multi-layer analysis focused not on the state of a certain moment in time but on the changes between two different moments in time. Therefore, although coarse Fusco et al. (2018), (2019) provides a diagnosis of the main land system dynamics affecting the study area over the 10-year period. For this study, we focused on changes at the NUTS III level – Alentejo Central, to capture general trends affecting SM. The land system classification was obtained by coupling an expert-based classification approach with an unsupervised clustering process in a tree decision scheme (see Appendix A). Twenty land system classes were identified. The changes on land systems between 2005 and 2015 were evaluated through a confusion matrix. The database building and clustering process are described in Fusco et al. (2018), (2019).

3.2. Unravelling land system dynamics at the local level

At the case study level, our aim was to collect the perception of territorial actors regarding land systems dynamics and how they relate to the desired future development of the land systems. To arrive at these results, we use a participatory approach designated Territory Game. This technique allows a collaborative discussion between participants without losing a territorial dimension (Lardon, 2013). The game can be "played" by any type of actors. Our particular case focused on stakeholders with an explicit impact on territorial development. Following a set of rules, this method is described to diffuse possible tensions amongst different territorial actors (Lardon, 2013; Angeon and Lardon, 2008). Further, the negotiated reasoning at the "territory" level (defined area of interest) allows for a collective perception rather than the sum of individual perceptions.

The game is guided by a question, which was "Which land systems should exist in the *Sítio de Monfurado* to conserve biodiversity and secure local food systems?" in the present study. The game took place on the 12th of April 2018, with twelve participants, divided in two groups of six over two separate tables (from here on identified as Group A and Group B). The participants were technicians of Évora and Montemor-o-Novo municipalities, local development associations (Terras Dentro), regional administration (DRAPAL, CCDR Alentejo), and land managers, i.e. anyone in a position of making decisions over the management of a property. These actors work in institutions actively engaged in development initiatives and have a long-term knowledge of the area. The number of playing tables was based on the number of participants. The groups played in parallel and independently, presenting their results for each step, in plenary, discussing contrasts or similarities. Participants were chosen based on their knowledge and connection with SM and selected to ensure a wide representation of territorial actors. Their distribution through group A and B was made considering their affiliations to guarantee that most institutions were represented in each table.

The game is meant to be spatially explicit, using a map of the territory as a board (Fig. 1). It follows a set of rules and is played in three steps:

1) Diagnosis: The participants have to identify and draw the main dynamics of the territory. Each player is given two cards with succinct information on a topic relevant to the guiding question. In their turn to play, players must choose one of the cards they were given and share the information it contains, adding their own knowledge. Within each throw, it is only allowed to debate the topic of the thrown card. All the other players are encouraged to add to the topic. Once the selected information has been drawn on the map, it is the turn of the next player to throw a card.
2) Scenario: This is based on the previously identified dynamics, players have to imagine and draw a possible development for the territory on the long term. The scenario ought to be spatially explicit, and only consensual ideas can be drawn.
3) Action: The aim is to define a series of actions to be taken at the present time to meet the desired scenario or resist an undesired one. Actions should be feasible by the actors in the group and possible to implement at the present. Actions can suggest partners not present in the game, but with whom would be feasible to create a partnership (Lardon, 2013).

The cards were based on literature, regarding the case of SM (e.g., Ferraz-de-Oliveira and Pinto-Correia, 2017; PIERSM, 2010, Godinho et al., 2016b). The cards were designed to trigger and guide the discussion towards agriculture and biodiversity topics. The pairs of cards were the same on both tables, meaning player 1 in Group A had the same set of cards as player 1 in Group B, and so on. The distributed pairs of cards were: 1) Vegetation & Administrative limits; 2) Habitats & Population; 3) Decline of *montado* & Iniciatives; 4) Fauna & Landscape; 5) Social drivers & Cultural heritage; 6) Flora & Social drivers. Although all playing tables have the same cards, discussed topics may vary according to the prioritized cards, and the information added by the players. The cards purpose is to motivate a discussion that considers all dimensions of the overall question by providing snapshots of facts. Therefore, the Territory Game was select as: a) it allows a constant discussion at the territory level, and b) allows the inclusion of other sources of information that trigger and direct the discussion.

In each table, an animator guided the discussion and two note-takers followed the game and recorded the main discussion topics as well as the arguments used by participants concerning each card. Additionally, there was one voice recorder per table. The recordings were used to complete the notes produced during the game. The representations as drawn on the maps by the players during diagnosis and scenario steps have been transcribed into a digital format (in Figs. 3 and 4).

The data collected during the Territory Game were systematically organized in a table format that allowed the identification of recurrent themes that were consensual between participants or that induced a longer discussion without the achievement of a consensus. Data for each step of the game were organized and coded in separate. The results from the diagnosis and vision steps were compared to identify the common, disputed and complementary themes. The identified themes might by related to the topics presented in the cards used at the beginning of the game but not necessarily. The themes we will present in the next section are a result of the discussion between players.

The findings from the Territory Game are discussed together with the results from the spatial analysis of the land systems when suitable.

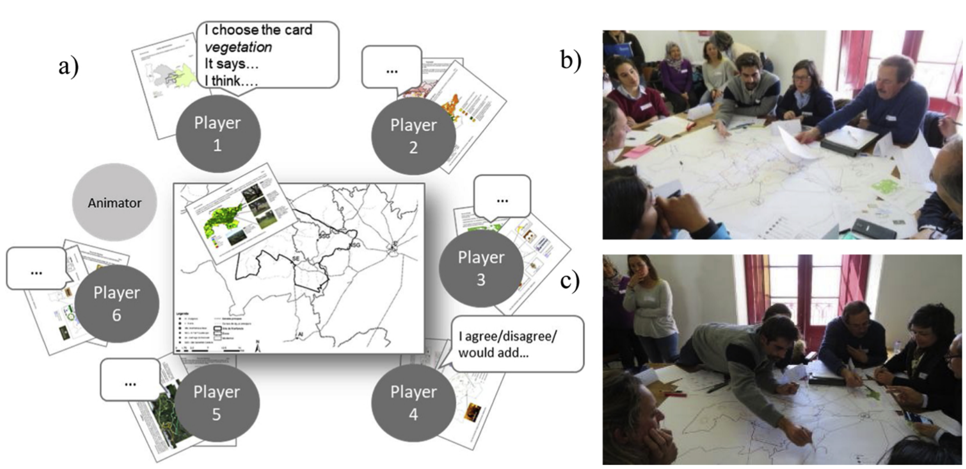

Fig. 1. a) Schematic representation of the diagnosis step. The game is played over a paper map of the territory. In the first round, each player must choose amongst its cards a theme to discuss (b). At the end of the throw, the selected information must be drawn on the map (c).

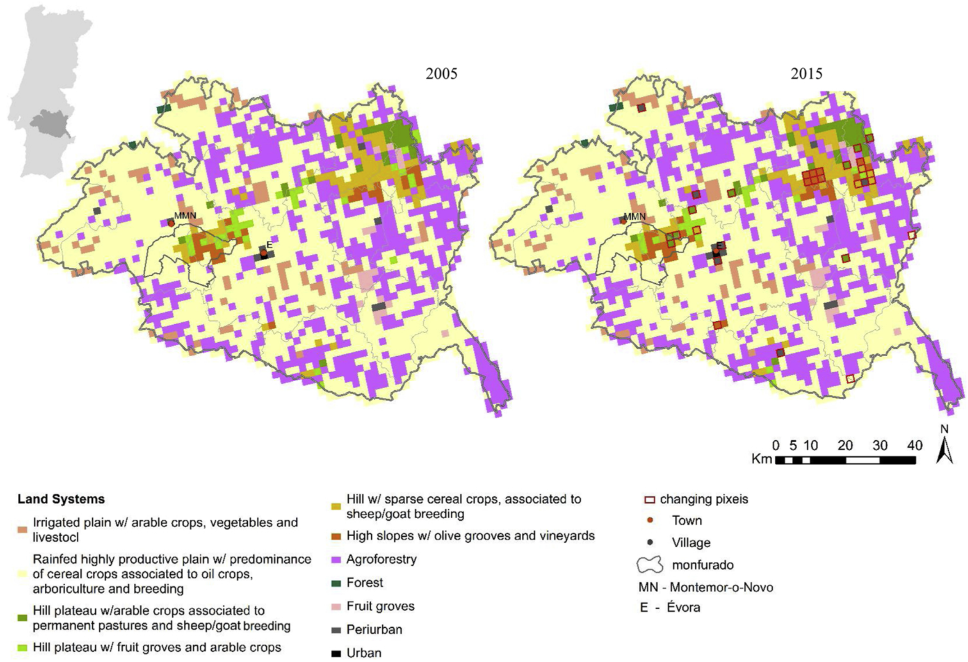

Fig. 2. Land systems in Monfurado and surroundings in 2005 and 2015. The pixels were significant changes was are outlined in red. The squares represent and area of 2 by 2 km. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

4. Results

4.1. Land systems dynamics – the spatial analysis

The results of the spatial analyses show little change to land systems in Alentejo Central between 2005 and 2015, with detected changes in 144 km2, that represent less than 2% of the area (Table 1, Fig. 2). We found a trend of intensification relating to arboriculture, with 32 km^2 of Alentejo Central changing from *hill sparse cereals crops associated with sheep/goats breeding* to *hill with olive and vineyards* (or other arboriculture). Loss of *agroforestry* was detected in 8 km^2, with conversion to to *rainfed plain highly productive with predominance of cereal*.

Trends of peri-urbanization (24 km^2), as expected, are found mainly near already urbanized areas. Also, pixels changing from *hill with olive and vineyards* to *hill sparse cereal crops associated with sheep/goats breeding*, were mainly found surrounding urbanized areas. Change from *Hill plateau with fruit groves and arable crops* to *Hill plateau with arable crops associated to permanent pastures and sheep/goat breeding*, as found in 36 km^2 of Alentejo Central implies the loss of the tree layer and increase of breading. This implicit loss of trees is the only change detected in SM through the spatial analysis (in 16 km^2).

4.2. Perception of changes by the territorial actors

Guided by the cards that were thrown during the game, the players described a changing and declining system. In a broad sense, the diagnosis incised over two major issues 1) the decline of *montado* and 2) changes on how humans relate to the system; being that these two are interconnected. Changes to agricultural practices decreased the availability of jobs, and the population tended to move to the nearby urban areas, contributing to their expansion. This exodus of population was feared to head towards the loss of traditional local knowledge, as well as the deterioration of habitats that need human intervention, including the landscape matrix of the silvo-pastoral *montado*. Counteracting this,

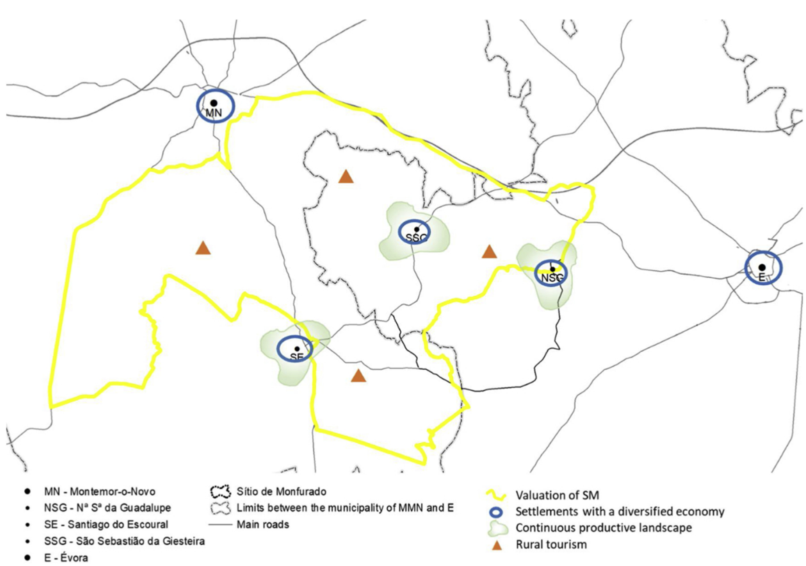

Fig. 3. Graphical representation of the common future decided by group A. This group focused on the need of valuation of SM, its products and people, highlighting the whole SM area. Tourism was considered an important tool, as well as investment in non-agricultural industry (concentrated in settlements as drown in blue on the map) and services, for local development. The idea of territorial management was expressed through the construction of a continuous productive landscape that would interconnect the territory. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

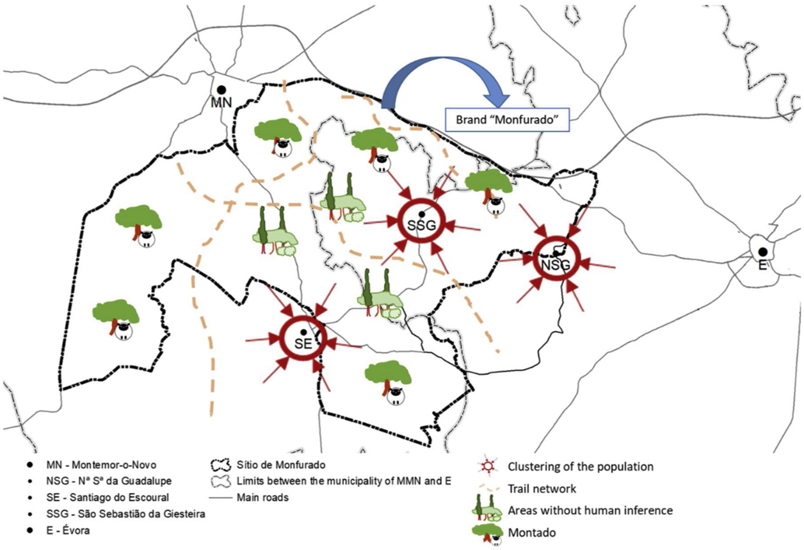

Fig. 4. Graphical representation of the common future decided by group B. The group envisioned SM maintaining montado as its main land cover, with a mosaic landscape including areas without human interference where vegetation would follow its natural succession. This was not spatially defined and should be managed and implemented at a territory level. Population would cluster in the already existing settlements, represented in the red arrows, and not be disperse through the territory. It was also agreed on the expansion of the trail network that would span across SM, increasing the attractiveness for hikers and visitors in general. Further, a brand "Monfurado" of the products of SM would increase valorisation of the products in the market and would account for externalities in its price. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

to a certain extent, is a commuting flow between SM and its surrounding urban areas, bringing people to and from SM. This enables activities, other than agriculture, to be established in SM such as tourism, leisure and agri-food industry.

The decline of *montado* was thought as a process that is driven by multiple factors. However, the intensification of livestock production was highly stressed as one of the main drivers. The current public policies scheme was criticised as producers are expected to choose the practices that generate the highest revenues, and the current subsidies encourage the increase of cattle, with consequences to the landscape and to the *montado* long-term sustainability. Table 2 details the dynamics as discussed in the game, organized by overarching themes.

Regarding visions for the future, both groups focused on the maintenance of the HNV farming systems currently existing, namely the silvo-pastural *montado*, together with socio-economic development based on the HNV values. The players were quick to agree on a common vision to the SM with *montado* as its main land use, preserving its cultural and natural patrimonial heritage and promoting economic dynamism. It was consensual that to achieve such vision both natural and heritage values of the SM need to be valorised. Such valorisation would allow for an equilibrium between economic development and preservation of the SM values, but would only be possible through external (e.g., political, economic) instruments. On this topic, it was mentioned the payment for ecosystem services and other mechanisms that would allow practices compatible with the landscape conservation. One player also expressed that implementation of greening measures should be mandatory not only within the SM boundaries but on all areas of *montado*. It was consensual that conservation measures should mostly be planned not at farm level but for all SM. Overall, it was expressed the need for rethinking the governance of the SM at different administrative levels to improve the preservation of the natural and cultural heritage. In group A, this was expressed through the envisioning of a continuous productive landscape, with no abrupt limits between settlements and its rural matrix, but with an integrated planning of activities across the territory (Fig. 3). Group B suggested an entity that would manage the territory as a whole, assuming a role of coordination that would be recognized by the different sectors and stakeholders.

Most players also emphasised that beyond conserving the *montado* silvo-pastoral system, local economy ought to be diversified (e.g., tourism and stronger agri-food industry), specially around the settlements. Both groups envisaged an increased dynamism of the settlements within SM, through the concentration of economic activities (Group A, Fig. 3) and of the population (instead of being scattered through SM in isolated holdings; Group B, Fig. 4), accompanied by an improvement of the existing services and infrastructures. The

Table 1
Detected changes in Alentejo Central by spatial analysis.

Land system	2015		2005		Δ 2015/2005 (km^2)
	km^2	%	km^2	%	
Irrigated plain with arable crops and vegetables	356	4.39	356	4.39	0
Rainfed plain highly productive with predominance of cereal	4716	58.11	4724	58.21	−8
Hill plateaux with arable crops associated to permanent pastures, sheep/goat breeding	156	1.92	120	1.48	36
Hill plateaux with fruit groves and arable crops	92	1.13	132	1.63	−40
High slope hill with olive and vineyards	136	1.68	124	1.53	12
Hill w/ sparse cereals crops associated with sheep/goats breeding	316	3.89	332	4.09	−16
Agroforestry	2176	26.81	2184	26.91	−8
Forest	12	0.15	12	0.15	0
Fruit groves	92	1.13	92	1.13	0
Periurban areas	60	0.74	36	0.44	24
Urban areas	4	0.05	4	0.05	0

Table 2
Major dynamics identified by the players during the diagnosis phase. The main topics of discussion, summarized on the right, are coded under "dynamic" and grouped per theme.

Theme	Dynamic	Details of the dynamics
Population	Decrease in inhabitants	It was agreed that population in SM has been decreasing. This was related to the lack of job opportunities due to a shift in agricultural production methods, but also to weak infrastructures and minimum available services within SM and its settlements.
	Small influx of new-comers	A small increase of new residents was mentioned, mainly attributed to second housing.
Economy	Intensification of cattle production	It was consensual that SM is facing a generalized intensification of animal production, motivated by Common Agricultural Policies (CAP) and its subsidies for cattle.
Landscape	Decline of High Nature Value farming systems, its goods and services	It was identified a clear trend of decline in the *montado* within SM, yet not as strong as in other areas in southern Portugal. The intensification of cattle production, together with climate, political and socio-economic factors were agreed to contribute to the decline of *montado*, noticeable in the reduction of canopy density with the opening of clearings in the canopy. These were thought to affect the quality of the landscape. It was also noted, that the canopy tends to be denser in the centre of SM, while signs of degradation are more noticeable in the periphery. The ability of SM to preserve areas of dense *montado* was related to its status in the Natura2000 Network, but also to the area's climatic and topographic conditions.
Governance	Change in human management	Human activities were considered necessary to maintain the habitats of interest in SM. However, it was also noted that certain practices can be harmful, such as the intensification of cattle production and mechanic soil mobilization [turning the soil for the purposes of soil aeration and increase permeability]. These have been linked with soil compaction and damage of the tree roots. It was agreed that short-term reasoning prevailed over long-term planning, and partially related to the land managers not being the land owners. It was also emphasized the difficulty of managing the SM as an area of public interest as it is mainly owned by privates. The present structure of payment schemes, which is coupled with the number of animals, and higher for cattle than smaller ruminants, was said to have contributed to the decline of *montado*, as it was found to favour short term economic goals rather than incentivizing managers to define strategies that favour the system *montado* as a whole. It was also agreed that land managers tend to choose management strategies to maximize revenue, and that there should be public support measures in place that promote good farming practices that would ensure the conservation of the existing natural values

development of a brand "Monfurado" was discussed in both groups. One group agreed it would be a tool for valuing SM products and a source of funding for its management and conservation through the inclusion of externalities in the products price. While in the other group, the idea was contested as some players were uncertain of the willingness of consumers to pay for it and the little dimension it would have. The landscape was imagined with the prevalence of the mosaic of land covers, including areas without human intervention, where vegetation could follow its ecological succession. The investment in a trail network and in tourism points were thought as to increase attractiveness of the area and add or highlight its value beyond production.

The actions defined by the groups (Table 3) meet these visions of conserving HNV farming systems through the emergence of new ways to value SM and management of a cohesive territory. It was agreed that public measures need to support the recovery and maintenance of HNV systems, diversification of the economy sectors with the existence of funds for enterprises to establish and develop in rural areas. The emphasis on "extensive production" also fits with the negative perception over intensification trends and shows the desire to counteract it.

In a revision of efforts already made in SM area, Group B recalled the intervention plan for SM, which was co-constructed and largely discussed with a variety of stakeholders - PIERSM (2010). Identifying the difficulties on the implementation of the intervention plan, the group suggested the creation of a dedicated action group. This action group would focus on the implementation of the necessary actions to achieve the goals already defined, including the articulation of preservation and production activities.

5. Discussion

5.1. Land system dynamics – global trends and actors' perceptions

It is important to underline the different spatial scales applied to the analysis: while the land system classification considers the whole Mediterranean Basin and uses a 2 km spatial resolution, stakeholder's perceptions were collected at a local level, with a focus in SM. Caution is needed when combining such disparate scales. Yet, more than seeking a precise characterization of the area under study, we examine how dynamics at both scales relate. This is a relevant discussion as decision-making at regional, national and trans-national levels are developed with the available cartographic data that often does not provide sufficient detail on the dynamics at the different levels that such decisions affect (van Zanten et al., 2014).

The results of the spatial analysis at the NUTS III level show land system changes in SM and its surroundings (Fig. 2, Table 1), providing a grasp of the global trends affecting the study area. In particular, the

Table 3
Actions defined by the groups.

Actions	Who will implement it?	Where will it be implemented?	With the help of whom?
Recovery of *montado,* valuing the understory with improved pastures and extensive livestock production	Producers	In SM	Public Policies
Diversification of activities	Finance Minister	In SM	Privates [producers, local enterprises]
Creation of a territorial-based action unit	Municipalities, councils, associations, University of Évora, Specific Human resources	In SM	Producers, Companies, Residents, University of Évora, tourism, consumers, visitants.

multi-dimensional character of the dataset provides information on dynamics related with changes in land system functions without changes in land cover (unseen changes in the sense of Pinto-Correia et al., 2018b). While the spatial analysis shows little change in the territory over the 10-year study period, insights from the territorial actors describe a dynamic territory. Nonetheless, it is possible to find agreement between the two data sets, with local perceptions adding detailed information to better contextualize the observed large-scale dynamics. *Montado*, the dominant system in SM, is a resilient system. The dominant trees (cork and holm oaks) are under a special protection and cannot be cut without permission (Santos and Thorne, 2010; Godinho et al., 2016b). Thus, changes in *montado* tend to be not abrupt, but scattered in both space and time (Godinho et al., 2016a, 2016b). Further, there is a low social, institutional and bureaucratic flexibility to allow rapid transformative trends (Pinto-Correia et al., 2017; Guimarães et al., 2019), which may explain the stability depicted in the regional analysis.

The aging of trees and the lack of natural regeneration are, in general terms, the main problems affecting *montado.* These systems gradually lose diversity in the spatial distribution of trees age, increasing their vulnerability to ecological disturbances such as drought (Camilo-Alves et al., 2017), fire (Guiomar et al., 2015), pests and diseases (Camilo-Alves et al., 2013) or due to the cumulative effect of different disturbances (e.g., Acácio et al., 2009; Catry et al., 2017). These dynamics are very slow and might not be captured through traditional methods of analysis of landscape change based on bi-temporal maps. Yet, signs of the simplification and of reduction in tree density were the main trend described by the actors in SM. According to other studies focused on *montado* dynamics, this can be related with an increase in grazing intensity (e.g., Godinho et al., 2016b; Almeida et al., 2016). Intensification of livestock production was also described by the territorial actors as a widespread phenomenon within SM. This trend has become common in *montado* areas, as CAP schemes in Portugal favor an increase in livestock and a shift from the traditional sheep and free ranging pigs to cattle (Guerra et al., 2015; Pinto-Correia and Azeda, 2017). Consequences of this practice are soil compaction, which in turn hinders natural regeneration (Costa et al., 2009; Dinis et al., 2015) contributing to the fragmentation of *montado* (Almeida et al., 2016), also identified by the players. Moreover, more fragmented patches shows higher probability of shrub encroachment (Guiomar et al., 2015), dealing, in turn, with multiple recruitment limitation (Acácio et al., 2007).

Through the spatial analysis, we found an increase of the urban areas in Alentejo Central. The displacement of rural population to cities, also found in our study area, contributes to the growth of urban and peri-urban areas (Antrop, 2004). Rural abandonment is not a localized problem, but a wide-spread phenomenon. With the modernization of agriculture and introduction of technology such as disc plows and seeders, that reduced the needed labor intensity, people sought for new employment opportunities in urban areas (Pinto-Correia et al., 2014). Although, rural abandonment was perceived as negative by the players, it was argued that the concentration of people in larger settlements, within or nearby SM, has a positive outcome. Traditional housing in Alentejo is scattered in isolated houses through the territory, which offers greater challenges in terms of management and supply than organized settlements. We also found a trend of less labor-intensive systems, such as breeding, replacing vineyards and olive yards. In other studies, this was found to be a preamble of land abandonment (Debolini et al., 2015). Given its tendential proximity to urban and peri urban areas, this could mean further urban growth.

Considering the 2 km resolution, it is possible that some ongoing dynamics are not still “visible” on the 10 years’ analysis and they need a longer temporal lag to be detected. Thus, despite a useful tool to detect general trends, the land system analysis alone cannot capture potentially important signs if below a certain threshold. It is also worth reflecting on the land system classifications used in this study. As the focus of the land system analysis lays on its dynamics and not a precise characterization, specific parameterizations might have been overlooked, as exemplified by the non-classification of *montado* as *agroforestry* in SM. At the same time, the existing trends observed at the local and global scale are coherent, and in agreement with literature, supporting the interest to use the combined methodology. Further, we argue that the Territory Game approach has revealed itself as a useful tool when aiming to link global and local dynamics. Guided by topic cards, ranging from more general to site-specific data, the territorial actors could reflect on how these affect SM, and what are the underlying drivers. Having all players discussing and then agreeing on the final result enabled a self-validation mechanism. We have found that players have some difficulties in the spatialization of certain subjects. Other studies have successfully used game-based participatory approaches to build up on a territorial context to examine local knowledge, with the possibility to scale up (Ornetsmüller et al., 2018). In sum, the combination of the spatial analysis with the Territory Game seems to provide an opportunity to match global dynamics with local ones, enabling to find underlying drivers at a local scale. The implementation of the approach described in the present study to other areas of the Mediterranean Basin is under development within DIVERCROP project[1] . Such expansion will hopefully contribute to enrich our understanding and characterization of global dynamics.

5.2. Future implications for the system and actors

We have found that territorial actors’ welcome activity diversification for SM. This contrasts with more conservative perspectives collected from other studies focusing mainly on producers (Surová and Pinto-Correia, 2009; Pinto-Correia and Azeda, 2017). According to these studies, producers tend to have a more productivist perspective, placing livestock production above other functionalities of the system, yet still valuing the traditional *montado* and agreeing with the need of its preservation (Pinto-Correia and Azeda, 2017). The players of the territory game identified a lack of follow up on the planning of the farming activities and sometimes of technical support to the producers, as well as a need for more dialogue between universities and research centers and producers. Considering all these, and that much of the land in SM is privately owned and under low productivity regimes in general, our case study supports the call for new ways of linking science and practice that contribute to sustainability solutions (Verburg et al., 2015; Fernandes et al., 2019).

There is a growing interest in maintaining HNV farming systems, which although marginal are estimated to cover 30 % of the European Utilized Agricultural Area (Paracchini et al., 2008). The persistence of HNV farming systems is dependent on an appropriated intensity of management (Lomba et al., 2014). Fischer et al. (2012) argues that new links between humans needs and their environment are possible and desirable, and there is a need to create a supportive environment in which communities can actively work toward establishing those new links. The same argument was identified in the present case study. The activities in the territory should be diversified and mechanisms that foment “good practices” amongst producers put in place. The territorial actors find that to achieve conservation goals in the SM as they know it, there has to be a change to how the system is being managed. In this context, the valorization of ecosystem services and the valuation of these “external” benefits is critical (Plieninger et al., 2014). However, there is still a gap in the operationalization of “alternative” schemes. The collective development of the action plan PIERSM (2010) is a clear example how collecting insights from diverse actors in terms to support decision making can be a starting point (Shove, 2010), but identifying

[1] Land system dynamics in the Mediterranean basin across scales as relevant indicator for species diversity and local food systems: https://divercropblog.wordpress.com/blog/.

tools to operationalize collective decisions is equally important. Despite civic and non-governmental organizations efforts, without an appropriate enforcing mechanism, attempts for drawing new development paths fall short (Maeillo et al., 2013). The land system dynamics found in this study echo those found in other HNV systems and silvo-pastoral systems through Europe, that do not necessarily have the same statutes and value recognition than SM (Oñate et al., 2007; Ribeiro et al., 2014; O'Rourke et al., 2016). Thus, conservation mechanisms concerning systems dependent on human intervention, should not be site-specific, but imbedded into political schemes that recognize the value of these systems as a whole and not with separate "productive" and "to preserve" components. In particular, we suggest the need of coordination between the different landowners and managers to distribute the onus of maintaining a multifunctional system, a good communication channel between research and managers to co-produce useful and applicable knowledge, and a link between users and policy makers to draw well-adjusted measures.

6. Conclusion

Traditional Mediterranean systems arguably provide a good model on how to find a balance between its human and natural components. However, the land systems changes detected and discussed in this study show that such traditional systems are at risk. Policy drivers, mainly with the implementation of CAP, were identified as major contributors to this undesirable change. Simultaneously, the lack of capacity to implement desirable changes and adequate policy instruments that support such systems were found to be the current challenges.

The spatial analysis developed considering the Mediterranean level as proven useful to detect the major changes occurring at the case study level. The territory game allowed a deeper understanding of these changes and how they perpetuate before and after the time frame used in the spatial analysis. In addition, the tool was found useful towards an operational analysis of land systems changes since visions were shared and action defined.

Although SM case study was a pilot test for the overall work in development in DIVERCROP project, the results indicate that such combination is promising. The territory game allowed the identification of the drivers of change, and generated discussion over feasible collective actions to promote the desired changes and prevent unwanted changes. Nonetheless, it does not imply that the defined actions are implemented, and this remains a challenge.

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CRediT authorship contribution statement

Catarina Esgalhado: Investigation, Visualization, Writing - original draft. **Helena Guimarães:** Conceptualization, Writing - review & editing. **Marta Debolini:** Formal analysis, Writing - review & editing. **Nuno Guiomar:** Writing - review & editing. **Sylvie Lardon:** Methodology. **Isabel Ferraz de Oliveira:** Resources, Writing - review & editing.

Appendix A

The DIVERCROP database gathers various types of information from many different sources, mostly stemming from global-scale databases. The different types of variables and their original sources are listed below.

The methodological approach can be consulted in higher detail in Fusco et al. (2018), (2019) (Table A1).

Table A1
Sources for the spatial database used to model Mediterranean land systems.

Variable	Original database	Original data link
Land use/land cover	ESA/CCI database	https://maps.elie.ucl.ac.be/CCI/viewer/
Crop production systems	MAPSPAM	http://mapspam.info/
Number of holdings, cultivated areas and livestock	National censuses	
Livestock	Gridded Livestock of the world	http://www.fao.org/ag/againfo/resources/en/glw/home.html
Terrain	Global Digital Elevation Model	https://webmap.ornl.gov/ogc/wcsdown.jsp?dg_id = 10003_1
Bioclimatic	WORLDCLIM	http://worldclim.org/version2
Soil types and quality	Harmonized world soil database	http://webarchive.iiasa.ac.at/Research/LUC/External World-soil-database/HTML/SoilQuality.html?sb = 10
Population	LANDSCAN	https://landscan.ornl.gov/
Rural & Urban Population	HYDE	http://themasites.pbl.nl/tridion/en/themasites/hydendex.html/i
Protected areas	World database on protected areas	https://protectedplanet.net/

The land system classification was developed through 2 main steps: 1) expert-based classification, and 2) cluster analysis.

A preliminary expert-based classification was needed before performing any unsupervised classification, for two main reasons: 1 the heaviness of the dataset 716105 lines x 88 columns prevented any classification algorithm from being run on R software; 2 the unsupervised classification was not reflecting some typical site-specific Mediterranean agricultural systems.

The expert-based classification was done by aggregating non-agricultural land, and of lesser interest to this study, into broad classifications as forest, wetlands, urban, peri-urban and bare soils, and mobilizing expert knowledge to define classification thresholds. This was also done for complex multifunctional land systems (agroforestry and arboriculture), that would require a large data and statistical effort to have a homogenous and consistent classification through the basin using the same variables as used to characterize the other land systems (Table A2).

After the expert-based classification, the remaining pixeis were divided into 6 sub-data sets based on the topography of the area (Table A3) to prevent topographic variables from hiding others in the classification process. The unsupervised classification was done using the method CLARA – Clustering LARge Applications (Kaufman and Rousseeuw 1986, 1990), available in the R package cluster (Maechler et al., 2018).

Table A2
Land use and agricultural thresholds chosen to perform the expert-based classification.

Expert-based classes	Conditions
Forest	> 95 % forests
Wetlands	> 60 % wetlands
Urban	> 80 % urban
Periurban	> 15–80 % urban
Bare soils	> 95 % bare soils
Agroforestry	> 25 % mosaic croplands (> 50 %) associated to natural vegetation (< 50 %)[a] AND > 50 % mosaic natural vegetation (> 50 %) associated to croplands (< 50 %)[a]
Arboriculture	MENA[b] region: > 50% rainfed croplands with tree or shrub cover OR > 10 ha temperate fruit growing[c]; Other regions: > 50 % rainfed croplands with tree or shrub cover;

[a] The values in brackets are relative to the landcover at the 300 m pixel, whereas the numbers at the beginning of the sentence are relative to the generalization at the 2 km generalization. See Fusco et al., 2018 for a better understanding of the upscaling process.
[b] Middle East and Northern Africa region.
[c] Based on data from MAPSPAM. All other thresholds in the table are based on LU/LC data from ESA/CCI database.

Table A3
Detailed description of the 20 Mediterranean land systems.

Topographic subset	Land system		Detailed description of the land system
Irrigated or flooded plain	1	Predominance of arable crops (maize, cereals and oil crops) alternated with vegetables, livestock	Most of the surface is dedicated to irrigated croplands (73 %), in particular oil crops and cereals (corn). Vegetables are also well represented. Temperate climate, high population density.
	2	High population density and intensive cattle breeding	Most of the surface is dedicated to irrigated croplands (92 %) alternated with urban areas (6%). The population density is very high and cattle breeding is predominant.
	3	Predominance of corn associated with vegetable and cattle breeding	
Rainfed plain	4	Highly productive plains with a predominance of cereal crops combined with oil crops, fruit groves and livestock	Arable crops are predominant (45 % of the land use), in particular wheat (29 ha), oil crops (26 ha) and corn (4 ha) associated with temperate fruits (7 ha) and vegetables (2 ha). Intensive livestock.
	5	Semiarid plains with sparse vegetation and bare soils, pulses	Very low amount of rainfall (150 mm/y) and 13 % of land use occupied by bare soils. Sparse vegetation is also well represented (15 %). Among the crops, pulses are important, associated with cereals.
Hill plateau	6	Arable crops, mainly cereals associated with permanent pastures and sheep / goat breeding	Wheat is the predominant crop (average 67 ha/4km^2) associated with pulses and vegetables. Grasslands represent 5% of the land use. High presence of sheep and goat breeding.
	7	Fruit groves associated with arable crops	High presence of temperate fruits (around 6 ha) associated with oil crops and cereals (half of the surface than in the previous class). 20 % of the surface dedicated to sparse herbaceous cover.
Hill	8	High slopes characterized by olive groves and vineyards associated with natural vegetation (trees and shrubs)	Fruit groves associated with natural vegetation (forest is 25 % of the surface and sparse tree and shrublands 13 %). Average slope around 8%.
	9	Sparse crops, mainly cereals associated with livestock, mostly sheep / goats	Arable crops (31 % of the land use), in particular wheat and other cereals associated with oil crops. Average slope 5%. Intensive sheep and goat breeding.
Mountain plateau	10	Sparse natural vegetation and bare soils, residual agriculture, mainly cereals	Low rainfall (around 400 mm/y), 10 % of the surface occupied by bare soils or sparse vegetation (18 %). Cereals are the main crops (75 ha) and the average altitude is around 1000 m.
	11	Arable crops (cereals and oil crops) with high presence of sheep / goat breeding	Intensive cereal and arable crops (84 ha of cereals and 12 ha of oil crops). Low rainfall amount (460 mm/y).
Mountain	12	High mountain permanent pastures (sheep / goats) alternated with sparse natural vegetation	The average altitude is around 1700 m a.s.l. with very high slopes (15 %). Grasslands occupy 17 % of the land use associated with natural sparse vegetation. Extensive livestock systems.
	13	Grasslands alternated with arable crops (cereals and pulses). Sheep and cattle breeding	The average altitude is around 1000 m a.s.l. with high slopes (10 %). Grasslands are alternated with cereals and pulses. Extensive livestock systems.
Other agricultural classes	14	Agroforestry	25 % or more of the cell's LU/LC are mosaic croplands associated with natural vegetation. Sheep breeding is predominant.
	15	Fruit groves	50 % or more of the cell's LU/LC are rainfed croplands with tree or shrub cover and temperate fruits are around 24 ha
Non-agricultural classes	16	Bare soils	95 % or more of the cell's LU/LC are bare soils
	17	Forest	95 % or more of the cell's LU/LC are forests
	18	Periurban areas	Around 34 % of the cell's LU/LC are urban areas. Cereals are the most common crop, associated with temperate fruits and vegetables.
	19	Urban areas	Around 92 % of the cell's LU/LC are urban areas
	20	Wetlands	> 60 % of the land use is wetlands

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