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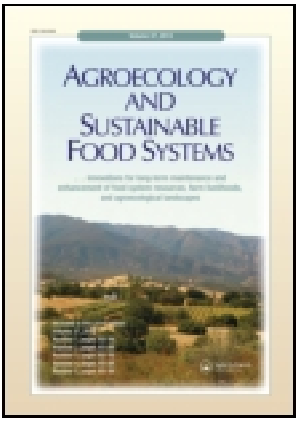

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Exploratory Landscape Metrics for Agricultural Sustainability

Eric Vaz [a b], Teresa De Noronha [b] & Peter Nijkamp [c]

[a] Department of Geography, Ryerson University, Toronto, Ontario, Canada

[b] CIEO, University of the Algarve, Faro, Portugal

[c] Faculty of Business and Economics, VU University, Amsterdam, the Netherlands

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Exploratory Landscape Metrics for Agricultural Sustainability

ERIC VAZ,[1,2] TERESA DE NORONHA,[2] and PETER NIJKAMP[3]
[1]*Department of Geography, Ryerson University, Toronto, Ontario, Canada*
[2]*CIEO, University of the Algarve, Faro, Portugal*
[3]*Faculty of Business and Economics, VU University, Amsterdam, the Netherlands*

Socioeconomic growth and urban change have been an increasing concern for decision makers in recent decades. The monitoring, mapping, and analysis of agricultural land use change, especially in areas where urban change has been high, is crucial. The collision between traditional economic activities related to agriculture in tourist areas such as the Algarve and current demand for tourism infrastructures in urban regions is also leading to loss of economic activity. This article uses a combined geographical information system approach with CORINE land cover datasets to perform a Shannon's diversity index quantifying changes in agricultural areas. The article then expands on the nature of the agricultural changes observed, and offers a multi-temporal assessment by means of landscape metrics in order to understand the shifting land use patterns for the Algarve in land use planning and regional economic equilibrium: a) forest regions become transformed into agricultural areas and agricultural areas become urban; b) areas that are initially agricultural become scattered residential regions created by economic investors; and c) agricultural land use changes have a cyclical nature in which—in the course of the economic recession—such dynamic effects brought about a decrease in tourism and focus on traditional sectors.

KEYWORDS agricultural land use change, sustainable agricultural development, landscape metrics, agricultural land loss, geographical information systems

© Eric Vaz, Teresa De Noronha, and Peter Nijkamp
Address correspondence to Eric Vaz, Department of Geography, Ryerson University, 350 Victoria Street, Toronto, ON, M5B 2K3, Canada. E-mail: evaz@ryerson.ca

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1. INTRODUCTION

While urban areas have become a cradle for economic growth, urbanization processes do not necessarily signify economic prosperity and growth (Henderson 2003). These processes have also been shown to be associated with important trends in the sustainability of urban regions and their carrying capacity (Wackernagel and Rees 1996) and the degradation of the traditional historical identity of landscapes (Antrop 2005), due to excessive and often uncontrolled economic and population dynamics, leading to loss of traditions as well as local knowledge (McCune et al. 2011). Urban areas reflect a proportionally growing output of population growth and economic change (Boserup 2005). The economic impact of urban growth has led to fundamental questions related to the environmental sustainability (Campbell 1996; Giddings et al. 2002) that cities offer, and to whether urban settlements currently offer the best solution for future economic and ecological stability in view of their unprecedented anthropogenic costs at the broader spatial level (Deal and Schunk 2004). While the future expansion of urban regions and continued sprawl is adversely affecting our environment and natural rural landscapes (Gar-On Yeh and Li 1999), the sectors of activity that determine the form of the city are undermining the most sustainable options, given the demands of these sectors. This has led to a greater occurrence of leapfrogging, (Heim 2001), loss of agricultural land (Fazal 2000) and an increase in commercial, industrial, and complex patterns in urban-rural environments (McDonnell et al. 1997). Decision making is, however, influenced by the need to make a choice that articulates the consequences not only for economic growth but also for the planning and infrastructures of the city. While urban sprawl leads to the amelioration of important aspects of the urban environment, artificial land use types tend to concentrate, causing severe consequences for ecosystems and the existence of less profitable land use and land cover types (Alberti 2008). This is especially felt at the local and regional level, where changes in the land use patches often lead to severe ecological imbalances (Zipperer et al. 2012). As land use has a specific externality function given the region's economic output (Alessio 1973), urban regions are rapidly changing and weaken as a consequence certain land use types that tend to be less adhering to economic growth (Fujita 1976). However, from an evolutionary perspective, the dynamics of land use have become much more complex than traditional Cobb-Douglas function estimates (Goldberger 1968). In this sense, novel assessment methods are often possible at the desktop level (Batty 1998), and allow much more elaborate land use transitions to be tracked over time and assessed than those proposed in neoclassical economies. Agricultural land, for instance, becomes scarce in areas where a service sector is more predominant, while urban regions tend to swallow up agricultural land that does not seem to be relevant for the production function of the positive externality of the city. These

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concepts of combined and often compatible land use dynamics are lost in traditional economic visions, where the diagnosis of the ecological spectrum of spatial impacts often fails at different administrative levels, hindering the possibility of local and regional analysis. However, from an evolutionary perspective, an appreciation of the complexity of these relationships over space (Frenken and Boschma 2007) allows us to gain a better understanding of anthropogenic influences in the face of irremediable changes; for instance, a) soil properties are changed irreversibly; b) historical and unique characteristics of the landscape become forever lost; c) biodiversity and ecological equilibrium in the area stagnates (Eppink et al. 2004). While more sustainable options should be considered, the economic crisis offers the possibility for a conceptual rethinking of economic paradigms based on downscaling, such as the restriction (Schneider et al. 2010) of the growth of urban regions; local agricultural production could offer the prospect of some renewed equilibrium through coevolution with the ecological and socioeconomic systems (Saifi and Drake 2008), avoiding excessive pressure on the landscape and reducing the need for excessive land consumption (Kallis 2011). In this sense, land use change models allow impacts to be assessed by means of an integrative scenario-based approach, in particular in geographical and economic regions with similar characteristics (Bajocco et al. 2012). The current consequences of the economic crisis observed in southern Europe, provide, in some sense, a unique opportunity at the regional level to assess spatial changes, while accepting the past impacts and to promote a more ecofriendly and sustainable future. In this context, the CORINE Land Cover (CLC) data set is a useful tool to assess land use changes for Europe since the early 1990s. The existence of three rounds, called CLC 90, CLC 2000, and CLC 2006, enable a multi-temporal projection of path tendencies of land use change between CLC 90 to CLC 2000, and accurate assessments of the predicted results for CLC 2006. If the model can provide an interesting interpretation of what the land use changes were (e.g., adapted through stochastic models), it becomes possible to project our land-cover change to a future time. The integration of nonlinear methodologies—or more spatially clear frameworks to model land use transitions—allows geographical information systems (GIS) to become a valuable tool to assess land use change, as well as to identify what are the necessary future responses that decision making may give to mitigate the impacts of land use change in general. These methodologies have been widely accepted in the framework of urban growth models, where land use changes are measured in terms of multi-temporal changes in urban areas over series of temporal frames. These spatiotemporal changes are, however, not limited only to urban growth modeling, but, much more than this, may be used to create change matrices that show the consequences of the rate of registered land use change for other land use types, such as forest areas, agriculture, wetland systems, vegetation types, and other land-cover categories, ranging from a more specific land use type to a more

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coarse level, depending on whether the analysis output deals with results concerning local, regional or international land uses. The combination of this information with existing national data makes it possible to have a complex decision system where land use change may be analyzed and assessed using a GIS. The use of the Reserva Agrícola Nacional (RAN) for Portugal is a good example of a national repository dealing with agricultural land for Portugal. The RAN has become a tool for territorial management, covering those areas that, due to their morphological, climatic and social conditions, are most suitable and have the greatest potential for the development of agricultural activities. Essentially, the areas contained within the RAN are those which are more fertile, but many have a greater tendency to be converted to urban use. However, local patterns of agricultural activity, typical in the rural areas of the Algarve, have lost their traditional positive externalities, leading to the augmentation of negative externalities brought by nonsystemic production sectors. This led in 1976 to the "Law of Land Use" (Decreto Lei n. 794/76, November 5), which brought urban development control policies, and the forecasting of agricultural activity. However, urban and population pressure, as well as the current concentration on the secondary and tertiary sector threaten the sustainability of agricultural land, and increase urbanization and agricultural abandonment in Portugal. The present study: a) provides a combined analysis of the impacts of agricultural land changes in the RAN; b) and demonstrates the link that tourism growth has had on these changes. While tourism does provide an interesting opportunity for economic growth, it is fundamentally important to integrate tourism within the traditional agricultural activities of regions, in order to avoid future change that might bring irreversible adverse consequences, from a spatial perspective, for the land, and even for economic growth. In line with the importance of understanding the sustainability of regions, it is of utmost significance to consider the sustainability of agricultural land, in particular, in quickly changing regions, where economic growth is put forth in detriment of sustainable choices and the harmony of agricultural and ecological land. The balancing of natural resources with urban land and the sustainability of agricultural systems, must as such consider the impacts on land use changes and land dynamics, to envision a more sustainable agricultural future.

2. STUDY AREA

The southernmost region of Portugal is called the Algarve, which has a total size of 5412 km^2. Nowadays, it is one of the most well-known regions in the country, given its prosperous tourist sector. The region has a unique wetland landscape (Vaz, Walczynska, et al. 2012), and a rich historical past dating back to Roman civilization. The Algarve (Figure 1) is the region of Portugal,

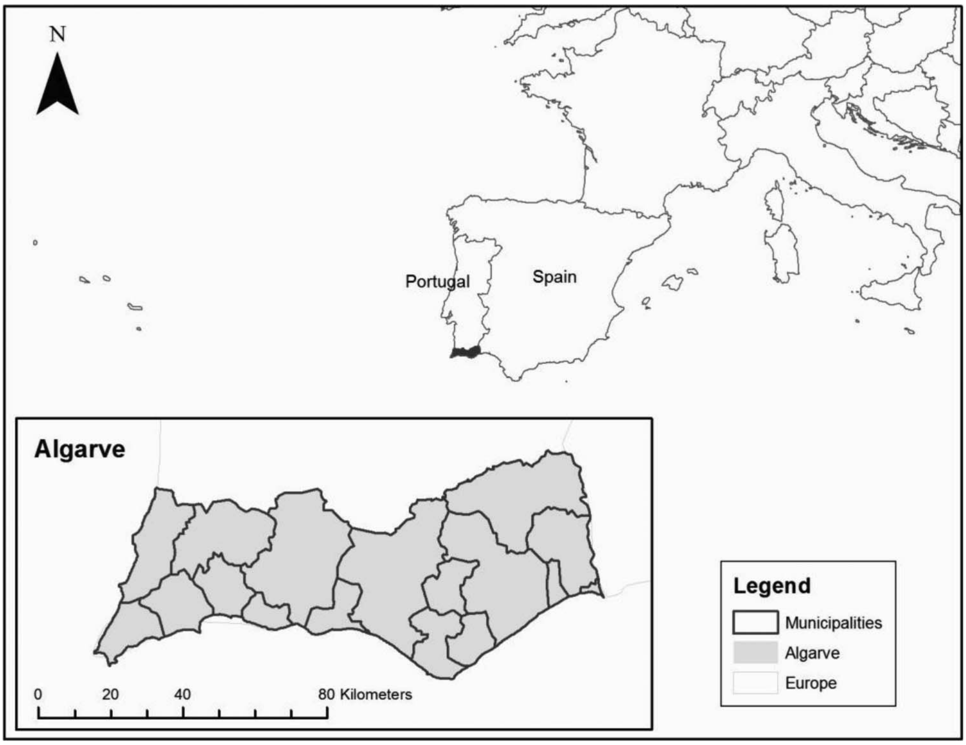

FIGURE 1 Location of the Algarve in Europe and administrative municipality divisions.

which has the highest Moorish influence. It is, thus, well endowed with the artistry of the Roman, Moorish, and Christian civilizations.

The influences of these different cultures on the environment have led to a distinct architectural landscape, but also to a unique type of ecological landscape, formed by anthropocentric activity since antiquity, and current economic growth generated by the mass tourism industry. It is, therefore, an ecological landscape of contrasts, which is protected in the continental network of conservation habitats (79/409/CEE). The Algarve consists of three quite distinct regions: *Interior, Barrocal*, and *Litoral*. In the Algarve there is a marked asymmetry between the Interior (located on the northern part of the region) and the Litoral (the coastal area of the Algarve). It is within the coastal area that the land tends to be more fertile, and converging ecosystems in the southeast area together create the Reserva Natural da Ria Formosa, known for its many different types of edaphic species. With most of its southern area being part of the NATURA network, the Algarve has an interesting combination of agricultural land and wetland systems (Vaz, Noronha, et al. 2012). The synergy between both these elements provides the region with rich biodiversity, appreciated by many birdwatchers and tourists worldwide. Close to these wetland systems, sandy beaches extend along the

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coast of almost the entire region, and have been successfully exploited since the 1970s, changing a transition economy led by the rural agricultural sector into an urban service sector, where infrastructures have been built mainly to support tourism demand and economic growth. According to the 2009 Census, the Algarve had an estimated population size of 450,485 in 2010. Faro, the district capital, has one of the three major airports, and the region is divided into 16 municipalities and two zones on either side of the municipality of Loulé: the *Barlavento* (in the east of the Algarve) and the *Sotavento* (in the west of the Algarve).

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3. MATERIALS AND METHODS

3.1. Materials

3.1.1. Corine land cover

The Corine Land Cover (CLC) survey, presently in its third round, constitutes a highly important data set for understanding land use changes and transitions at the European level. The project itself began in 1985, with a particular purpose as a tool to address the state of and changes witnessed at a spatially explicit level in the environment, under a common agenda of reporting the issue of natural hazards concerning toxic substances and their impacts on fauna and flora (European Environmental Agency 1995). What started out as an experimental project in the 1980s, has grown into a spatial database containing a land use inventory for the entire European Union, where a multi-temporal understanding of land use changes has become possible since its second round in 2002, called CORINE Land Cover 2000. The succeeding round, CLC 2006, allowed for a more complex multi-temporal analysis. The complexity added, given a third moment in time, is strongly linked to the capabilities of manipulating and calibrating the results of scenarios based on the two preceding land covers, in an attempt to model with more accuracy the land use dynamics in 2006. In its third round, the CLC survey has thus become an indispensable tool for future land use modeling based on a scenario and speculative approach with regards to future possible changes in the socioeconomic, natural, and anthropogenic environment at local, regional, and European level.

3.1.2. Reserva Agrícola Nacional

The RAN is a Portuguese tool for land management, which covers those areas which, on account of their favorable morphological, climatic and social conditions, are considered to have the greatest potential for the development of agricultural activities. Essentially, the areas included within the RAN are more fertile, and, thus, would be a serious loss if appropriated for urban

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areas. Nevertheless, local patterns of agricultural activity, typical of the rural areas of the Algarve, have lost some of their traditional positive externalities, leading to an increase in negative externalities generated by nonsystemic production sectors. As already explained in the Introduction, this led in 1976 to the "Land Use Law" (Decreto Lei n. 794/76, November 5), which brought policies for urban development control, and the planning of agricultural activity. However, urban and population pressure, as well as the existing concentration on the secondary and the tertiary sector, have led to further agricultural abandonment, and inevitable urban growth in Portugal. A special framework of legislation was conceived in 1982, which expressed the concerns about agricultural land loss, and thus the RAN (Decreto Lei n. 451/82, November 16) was created, with the main objective of recovering lost agricultural and abandoned land and protecting vulnerable agricultural areas. The RAN is divided in two distinct classes (A and B), based on physical and geographical characteristics (Decreto Lei n. 196/89, June 14). The RAN land is systematically decreasing, while urban areas are registering a steady increase (Vaz, Cabral, et al. 2011).

3.2. Methods

3.2.1. Regional geographic information system

The implementation of a GIS is crucial to manipulate and understand spatially explicit data in a multi-temporal environment: in particular, the integration of regional characteristics reflected in the spatial dimension of land use transitions, specifically concerning non-sustainable land use choices (Peña et al. 2007), as well as allowing both the creation of regional response systems to assess the adaptive capacity of land and the collection of information on the typology of the land use changes observed (Verburg et al. 2010). The incorporation of socioeconomic, natural, and administrative data in such a system permits: different criteria, to be assessed using integrative multi-criteria evaluation techniques (Jankowski 1995); the handling and manipulation of results, in order to make better decisions about the best preventive measures in the short, medium, and long run; and the possibility to progress as a legitimate scientific field in its own right (Wright et al. 2004). The functional and applied capabilities of a GIS can provide data handling solutions possible at desktop level, which also facilitate decision making at more precise spatial scales, leading to advances in other decision making tools, for example, concerning transportation systems (O'Sullivan et al. 2000). For the Algarve, the administrative boundaries were used in order to form subsets of the available data sets of the CORINE land cover survey and the RAN. The embedded information in a vector polygon shapefile, allows data to be aggregated and edited in a georeferenced manner, thus, adding to the local and regional importance of visualizing the results derived by the provision of spatial information. In the case of the Algarve, this corresponded to a

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complete data set of 16 municipalities, and the integration of agricultural land changes from the RAN inventory, as well as the integration of two timeframes (1990 and 2006) from the CORINE land cover survey at the administrative level. The different land use classes were then converted into a grid format, allowing more advanced spatial calculations to be processed in order to compare both the effects of the transition of land use changes in time and the additional spatial dynamics over the entire region.

3.2.2. Landscape metrics

The advantage of landscape metrics for analyzing agricultural and socioeconomic changes is strongly linked to the possibility of understanding the geomorphological and topologic transitions observed from a quantitative description of the often complex and heterogeneous dynamics of land use (Antrop and van Eetvelde 2000). In this analysis, the extension and typologies of different areas are considered, forming a functional land use mosaic allowing the assessment of diverse quantifiable patterns, regarding the composition of the landscape as well as its configuration (Farina 2006). These distinct dimensions have an effect not only on a discrete spatial surface such as an entire region and contribute to understanding the fragmentation of existing habitats (Hargis et al. 1998), but are also extremely effective when related to established administrative boundaries, where there is the possibility of assessing different land use consequences, given that different socioeconomic and policy actions have been implemented over time. This is spatially expressed by quantification relating the diversity of land use, the areas with a specific type of land use per administrative territory, the morphology of the shape of the land cover and its control with respect to the total proportion of land use within a specific administrative boundary. Comparison of the distinct results at the administrative level, allows their assessment to be facilitated within the regional geographic information system (RGIS). For local and regional decision making, this is of the utmost importance, as it allows an explanatory framework of the registered land use changes to be developed, while maintaining a consistent spatial dimension at the administrative level, and understanding which subsets of land use have changed, and what may be expected in the future. This supports a socioeconomic analysis of land use change at the spatial level, enabling the identification of phenomena such as loss of agricultural land to urbanization in recent decades in the Algarve, and permitting the RGIS to have not only analytical capabilities with regard to regional change in land use, but also visual possibilities for rapid assessment and result sharing. Several spatial statistical analyses were conducted to understand the changes in land use and the consequences for agriculture. The clear difference between the interior of the Algarve and the rapid changes witnessed in the littoral region, led us

TABLE 1 Variation in Shannon's Diversity Index between 1990 and 2006

Municipality	1990	2006	Variation in SDI
Albufeira	1.77	1.96	0.19
Alcoutim	1.6	1.56	−0.04
Aljezur	2.02	2.01	−0.01
Castro Marim	1.91	2.12	0.21
Faro	2.21	2.32	0.11
Lagoa	1.94	2.34	0.4
Lagos	2.31	2.39	0.08
Loule	2.11	2.26	0.15
Monchique	1.28	1.34	0.06
Olhao	2.16	2.36	0.2
Portimao	2.47	2.6	0.13
SB Alportel	1.47	1.61	0.14
Silves	2.16	2.19	0.03
Tavira	1.9	2.05	0.15
Vila do Bispo	2.1	2.06	−0.04
VRSA	2.41	2.48	0.07

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to assume that there would be considerable effects on agricultural land use, in particular given the changes registered in the RAN.

3.2.2.1. Shannon's diversity index and spatial auto-correlation. A Shannon's diversity index (SDI) was generated at the administrative level. In this sense, SDI provides a definition of "variety," that is, the existence of different types of land use within an administrative boundary. The richness of the patches existing at the municipal level permits us to understand whether there have been significant changes over time in the land use and land cover. The total diversity is calculated at the level of each cell as follows:

$$\mathrm{H}' = \sum_{i=1}^{S} \left[\left(\frac{n_i}{n} \right) \ln \left(\frac{n_i}{n} \right) \right], \tag{1}$$

where n_i represents the number of patches within the administrative boundary and n is the total number of land use classes found there. The calculation of this index allowed the richness of the diversity of different land use types to be evaluated. A predominant increase in diversity was evident throughout the years concerning this landscape analysis with the exception of a decrease in the diversity of patches for Alcoutim, Aljezur, and Vila do Bispo (Table 1). In a visual assessment, rural areas reported a lower SDI, while the coastal region, in particular the more urbanized areas, showed more change in the SDI. At the spatial level this shows clear evidence of the loss of certain agricultural land types.

3.2.2.2. Total landscape changes and sustainable economies. Total changes in the landscape were calculated by means of studying the distribution of changes in patches at cell level. The total changes in patches corresponded to a percentage value of the difference between the two years

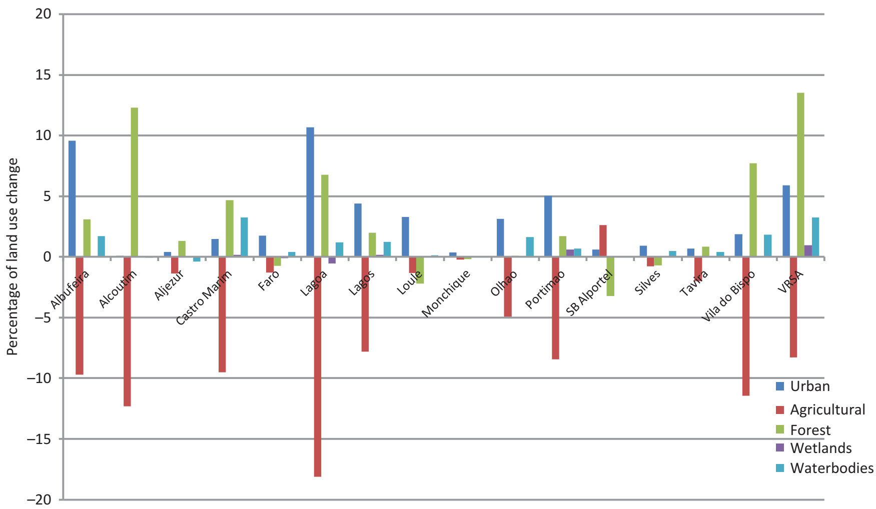

FIGURE 2 Transitions of land use classes per municipality 1990–2006 (color figure available online).

per main class. An increase of urban land of 50.2% had occurred over the preceding decades, while simultaneously 94.88% of total agricultural land was changed from their original land use types in the early nineties. This overwhelming loss of agricultural land was also found to have direct spatial repercussions in terms of the increase of the total forest cover of 47.03% between 1990 and 2006. The changes in agricultural land (Figure 2) suggests an alarming scenario, particularly given the variations in the geomorphological and landscape characteristics of these areas, and the steady increase still being observed in new urban surfaces. A closer look at administrative level shows that the regions with the highest agricultural variation are predominantly more urban and located along the Algarve coast where tourism is abundant. The combination of these results with the RAN clarifies that there is not only an underlying pattern of increased agricultural land loss, but also a predominant tendency to use this land for urban activities hand in hand with agricultural abandonment. At the economic level these results tend to be quite dire, as one of the main advantages of the region is its scenic beauty and ecological landscapes. The high concentration of NATURA 2000 sites in this area is witness to the ecological importance of these landscapes, and presents a unique opportunity for sustainable tourism. One of the main advantages resides in the adaptive properties of sustainable tourism (Hunter 1997). The spatial analysis performed with landscape metrics, in line with adaptive strategies for sustainable tourism, also indicates the importance of using the wetland systems of the Algarve as a unique ecological tourism resource. Wetland systems are one of the most ecologically productive regions of the world, with unique breeding grounds and habitats

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for marine species and in particular, marine birds. Given, in general, the low structural changes of most of the wetland systems at present, a unique cluster for bird-watching tourism could be fostered. In line with measures to combat the economic recession, the existing landscapes and natural biodiversity of these tourism types, allied to traditional sectors of agricultural activity, as well as to the unique landscape characteristics of the Algarve, could allow tourism in the Algarve to be reshaped without compromising a sustainable future. The application of spatial information, in particular landscape metrics, suggest that the agricultural land and wetland systems currently at risk, present a unique economic opportunity for economic activity that does not cause excessive urbanization or environmental degradation contrary to what is happening in the traditional tourism sectors.

4. DISCUSSION AND EXPLANATION OF LANDSCAPE CHANGES

The increasing agricultural land loss described above is explained from the ever increasing tendency to use this land for urban activities, as well as by the unusually fast dynamics in the agricultural sector, leading to a transformation of agricultural landscapes in Western Europe (Meeus 1993). These combined phenomena put at risk not only the Algarve's traditional heritage (Vaz, Cabral, et al. 2012), but also its environmental ecological equilibrium (Newton and Mudge 2003), and therefore the underlying causes should be further investigated, and combined with quantitative methods borrowed from landscape ecology (Riitters et al. 1995) and economic rationale, complemented with integrating spatial methodologies. In general, the Western economic growth pattern is characterized by a slow decline of many agricultural activities which, having become more mechanized and intensive, reduce labor and, eventually, the share of rural areas used exclusively for agricultural purposes. Such areas are frequently located on the peripheries of small cities and, nowadays, include new functions characteristic of the modern urban world, such as new tourist activities (rural tourism, festivals, traditional production, local arts, exploration of archaeological sites, etc.).

In Portugal, however, the data show a drastic increase in the loss of agricultural land, which is being replaced by forestry and urban constructions. In our view, at least, three distinct factors have contributed to this: 1) the unusually large extent of protected areas, defined by land use regulation, result in an artificial pressure on the rest of the territory—such a situation generates artificially increasing land prices, including in agricultural areas which have in many cases become residential quarters or have been used to locate public facilities; 2) population increases, which have imposed a permanent growth of urban areas, often in the form of urban sprawl; and, finally, 3) the rapidly decreasing importance of most of the agro-food activities (both agriculture and the food industry) as active participants in the regional economic activities. A more detailed overview of each of these factors helps to better understand the results of the previous section:

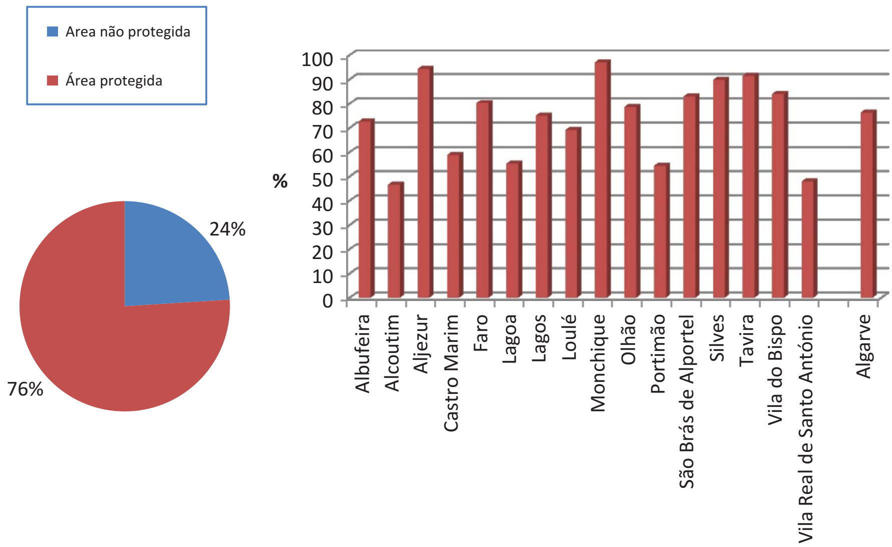

FIGURE 3 Protected areas in Algarve (adapted from: CAOP e SIG CCDR Algarve) (color figure available online).

1) Land Use Pressures

One of the reasons for the strict legislation defining so many protected areas is to safeguard land from the invasive nature of mass tourism. However, such rigid decision may have brought perverse results: The Algarve has three quarters of its territory classified as protected areas, under one of the following classifications: RAN, REN, Rede Natura, and Área Protegida.

Figure 3 shows that, with the exception of Alcoutim and Vila Real de Santo António, all the municipalities have more than half of their surface classified as a protected area, eight of them having about 80% of the land under such legislative restrictions (Aljezur, Faro, Olhão, Monchique, São Brás de Alportel, Silves, Tavira e Vila do Bispo). Altogether, only about one quarter of the Algarve area does not impose limitations of any kind on construction and urban growth. Considering that the Algarve registered the second highest growth rate in the country, it should be questioned whether this policy has served to contain urban growth and urban sprawl and whether public agents can succeed in resisting the strong pressures that tourism and related activities have imposed. Most probably, they have been able to overcome such restrictions, by finding out legal ambiguities, and facilitating more flexibility to serve economic and political interests. What is certain is the continuous rise of property prices up to excessively high levels. As expected, in the current economic crisis, these strongly speculative prices led to a sudden crash, with a severe impact on regional investment and growth. The severe impact has additionally been felt mainly by existing obsolete infrastructures whose functionality has diminished as tourist demand has substantially shortened.

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Meanwhile, infrastructures are becoming abandoned leading to additional constraints on regional environmental systems, with high ecological value, and where sounder specialized agricultural production systems used to be present in decades prior to the construction and mass tourism.

2) Urbanization Trends

The permanent growth of urban areas, also in the form of urban sprawl, is the next factor which needs to be explained. We should set out this explanation by defining that continuous urban areas are related to urban land that is intrinsically connected, while discontinuous urban areas are more prone to leapfrogging activity and tend to have other land use types in between. This has raised much concern regarding the nature of urban sprawl, and sustainability of landscapes and agricultural areas. The region shows that land used for urban purposes increased at a speed significantly above the average for all Portuguese regions. In fact, in terms of the rate of change, the extent of the urbanized area more than doubled between 1990 and 2006. This picture of growth is reinforced by examining the built-up urban area as a proportion of the total surface. In 16 years, this share has risen from 1.9% to 3.9%, a tendency recorded in most of the country. While, between 1990 and 2000, its growth rate was significant, it then decreased between 2000 and 2006, in line with the latest developments for Portugal as a whole.

On the other hand, between 1990 and 2000, the discontinuous urban growth in the Algarve region has increased faster than that in mainland Portugal as a whole, but it slowed down between 2000 and 2006, indicating less dispersion in the evolution of the urban built-up areas for that period, compared with the situation in Portugal as a whole. Thus, development is in line with the strategy advocated in the PROT Algarve (Plano Regional de Ordernamento do Territorio), to increase the scale of the regional urban system, through the development of economies of agglomeration.

The Algarve also has a special position in relation to the land occupied by sports and leisure. More than a quarter of the area occupied by sports and leisure in Portugal as a whole is found in the Algarve. It is also significant that in 1990 the land devoted to sports and leisure represented 0.5% of the territory of the region, rising to 0.8% in 2000, and reaching 1.3% in 2006. These calculated values contrast with the 0.1% growth recorded for mainland Portugal as a whole in 2006. This rapid development recorded in the Algarve for the 16-year period of 1990–2006 confirms a growth of developed areas (urban land used for sports and leisure) of 2.5 times. The proportion of land occupied by sports and leisure in the Algarve is a disproportionally large share (1.3%) of the total land occupied by these activities in mainland Portugal as a whole (4%). The Algarve's substantial share is explained by the very high concentration of golf courses in the region.

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3) Agriculture

The fast decreasing importance of most of the agro-food activities (both agriculture and food industry), as active participants in the regional economic activities, is the last factor to be considered. Traditionally, and because of its a mild and sunny climate, the Algarve has centered its extensive agricultural production mostly in citrus fruit, almonds, olives and wine. Besides this, it also produced intensively and frequently under partial hydroponic conditions other horticultural products such as early season strawberries. However, throughout the last few decades the production level has decreased. The main cause was that the distribution channels no longer pass through local channels, as they are determined by multinational firms whose acquisition interests are based on the price-quantity bargaining abilities of their partners. Most of the small or medium-sized farms producing traditional agricultural products face increasing difficulties in meeting the distribution requirements of big farms, and do not have the necessary capacity to capture any sort of market share. With increasing labor costs determined by the demand of the tourism sector, farmers have faced huge pressure from increasing costs and market quota reductions; land abandonment has been the only alternative for most of them.

5. CONCLUSIONS

Landscape metrics have mostly been applied to landscape ecology. However, the main rationale for the landscape metrics has predominantly been the research interest in tracking changes in biodiversity and natural habitats. Little attention has been given so far to the combination of regional support systems and socioeconomic change in the light of landscape metrics applied to the anthropogenic environment. The anthropogenic environment is, however, strikingly complex, and understanding the interactions at the land use level, especially taking into consideration the effects at the administrative level, also allows the understanding of both a subset of policies that mitigate the risk of losing fragile environments and what might be the best economic options for a sustainable future. This article has shown that landscape metrics can be used to understand from an economic perspective the loss of agricultural land in the Algarve to the mass tourism industry. The increase of agricultural land loss, despite the presence of strong legislative controls, indicates that economic growth is leading to unhealthy effects on the anthropogenic ecological landscape. The differences between the economies of the north of the region and the south are self-explanatory, and lead to the conclusion that restrictive strategies should be applied in more urban areas, by fostering support systems for traditional agricultural production and implementing new tourism opportunities such as sustainable tourism. The Algarve, as a unique region of Europe, faces the same challenges as most anthropogenic environments: a conflict between excessive economic growth, loss of sustainable areas, and balanced decision making for sustainable development. A combination of GIS at the regional level combined with landscape metrics approaches allows these problems to be tackled more successfully and in particular enables the quantification of these issues over space, permitting advanced spatiotemporal analysis, which may help decision makers to initiate more appropriate actions for sustainable economic growth.

NOTE

1. Leapfrogging´ may occur when developers reject expensive city center sites in favor of cheaper land on the periphery of cities, or beyond the "Green Belt."

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