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LAND-USE CHANGES AND ENVIRONMENTAL DEGRADATION: A LONG-TERM ANALYSIS IN COASTAL SARDINIA/BASILICATA, ITALY

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SOMMARIO

Land degradation affects land suitability for agriculture thus reducing the wealth and economic development of nations. The causes of land degradation are mainly anthropogenic and agriculture-related, and include physical losses of agricultural land due to conversion to artificial land, unsustainable cropping practices (related to land clearance, wrong crop and cultivation choices, misuse in irrigation resources e chemicals) and land abandonment. The focus of this study was on desertification risk land degradation in coastal areas of the Mediterranean, where the environmental and socio-economic spheres interact closely: Sardinia and Basilicata (Italy). It analysed the impact of LULC changes that occurred from 1975 to 2000 compared to the possible changes in the level of land sensitivity to degradation over the period 1990-2000. The results demonstrated that there are two main factors affecting the land vulnerability of the study areas: (i) land abandonment and (ii) the conversion from natural, semi-natural and agricultural areas to artificial areas. These two factors represent the primary LULC transformations that led to an increase of the land sensitivity to degradation. It is hoped that these evidences can effectively contribute to raise awareness on these specific land degradation processes and help devising management policies capable of preserving the environmental quality of coastal areas in the Mediterranean.

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1 Introduzione

In developing and developed countries the expansion of urban areas and infrastructures is encroaching on productive land and natural habitats. Resolution of land use conflicts is essential for sustainable development. Identifying the causes of land-use change requires understanding both how people make land-use decisions (decision-making processes) and how specific environmental and social factors interact to influence these decisions (decision-making context). It is also very important to understand that land use decisions are made and influenced by social and environmental factors across a wide range of spatial scales - from household level decisions that influence local land use practices to policies and economic forces that can alter land use regionally and even globally.

It has been largely studied and demonstrated (Thornes, 2004; Kosmas *et al.*, 2000; Symeonakis *et al.*, 2007) that, during the last decades, the Mediterranean region has been subjected to major changes in Land Use and Land Cover (LULC) as a result of the relocation of people to coastal areas, forest fires, the abandonment of farms and grazing land, the rapid expansion of tourism-related activities, and the intensification of agriculture. Many studies demonstrated that LULC changes have led to an acceleration of desertification and land degradation processes (Thornes, 2004; Drake and Vafeidis, 2004).

The definition of desertification we are using in this paper is the one from the United Nations Convention to Combat Desertification (UNCCD, http://www.unccd.ch/), where "desertification" means land degradation in arid, semi-arid and dry subhumid areas resulting from various factors, including climatic variations and human activities. Overgrazing, for example, leads to trampling and compaction of the soil, which reduces the water infiltration and thus increases runoff. Deforestation due to wildfires or clearcutting also leads to increased land degradation because it removes the vegetation cover, thus favouring soil erosion.

The magnitude of the environmental and social consequences of soil erosion and land degradation in semiarid areas of the Mediterranean region has long been recognized and studied. Although a number of EU-funded projects, such as MEDALUS, ERMES, EFEDA, etc., have looked into the link between LULC changes and desertification (Thornes, 2004), rarely the researchers have addressed the context of desertification as a dynamic process (Hawkes, 2004).

Actually it is of basic importance to assess trends of change in various categories of land use systems and to determine levels of land degradation in these systems in order to know how land use changes lead to Land Degradation (LD) (Symeonakis *et al.*, 2007). Currently there is no methodology on how to use land use change analysis to assess changes in land degradation. The work presented here is intended to contribute to this deserving need.

The main aim of this research is therefore to study the interrelationship between LULC change and land degradation in two Mediterranean coastal areas using multitemporal land use cartography (1975-2000) and land sensitivity data (1990-2000) in a Geographic Information System (GIS) framework. Maps portraying LULC and their changes with time capture the combined effects of environmental and socio-economic policies on the territory and allow the characterization of artificialization and urban pressure, therefore being an essential indicator for integrated coastal zone management (ICZM) and land quality assessment over time (Freire *et al.*, 2009).

In particular, this paper focuses on the coastal belts of Sardinia and Basilicata regions (Italy), characterized by several natural and anthropogenic challenges, including lack of effective planning and management, pollution, coastal erosion, pressure from population growth, tourism and urbanization. These problems and pressures are often inter-related, as illustrated by the distribution of the human settlements close to the shoreline which are being threatened by coastal erosion.

The results identified potential degradation hot-spots where mitigation measures should be taken to prevent further degradation. As illustrated by this study, a readily implementable methodology based on modest data requirements, is a useful tool for land use change and land degradation studies and strategic planning for environmental management from catchment to regional scale.

2 Area di studio

The study area encompasses the coastal area of Sardinia region and the area of Basilicata region, both in southern Italy.

Sardinia is the second largest island in the Mediterranean Sea, with an area of roughly 24,000 kmq. The island shows a complex geography with 1,840 km of coasts and a prevalently hilly topography. Sardinia’s climate is predominantly Mediterranean. The mean annual temperature ranges from 11 to 17└ C, while rainfall varies from 400 to 1,100 mm depending on the elevation.

Basilicata region is located in southern Italy and covers a surface area of 9.992 Km267 . It is the steepest region in southern Italy: 47% of the land is covered by mountains (Apennine mountains that cross the Eastern area of Basilicata from the North to the South), 45% by uplands and only 8% by lowlands. The region shows a marked elevation gradient accounting for several micro-climate types. Climate along the coastal belt is typically Mediterranean: precipitation is evenly distributed during the year (450–500 mm), with a peak in autumn-winter and annual temperatures averaging 17°C.

3 Materiali e metodi

The datasets available for the analysis were (a) historical LULC change maps, from LaCoast (LC) and CORINE Land Cover (CLC) projects, (b) a Land Degradation (LD) sensitivity map derived according to a procedure developed by Brandt (2005). Each of the above mentioned datasets were resized over the areas of interest. The mentioned land cover products are comparable both in terms of nominal scale (1:100.000) and nomenclature. They therefore allow a coherent change detection over the period 1975-90 (LC) and 1990-00 (CLC).

The sensitivity map to LD was elaborated according to the Environmentally Sensitive Area (ESA) framework. The parameters selected to build the ESA Index (ESAI) refer to four themes: climate, soil, land cover, and human pressure (see Table 1).

Table 1. Variables used to derive the ESA Index (ESAI), unit of measure, and statistical sources.

Theme	Variable	Scale	Unit of measure	Source
Soil quality	Soil texture	1:500,000	Sensitivity class	Ministry of Agriculture, European soil database
	Soil Depth	1:500,000	mm	Ministry of Agriculture, European soil database
	Available Water Capacity-AWC	1:500,000	mm	Ministry of Agriculture, European soil database
	Slope	1:25,000	%	Ministry of Environment
Climate quality	Annual mean rainfall	1:500,000	mm	Meteorological statistics
	Aridity index	1:500,000	mm/mm	Meteorological statistics
	Aspect	1:25,000	Angle	Ministry of Environment
Vegetation quality	Fire risk	1:100,000	Sensitivity class	CORINE Land Cover
	Erosion protection	1:100,000	Sensitivity class	CORINE Land Cover
	Drought resistance	1:100,000	Sensitivity class	CORINE Land Cover
	Plant cover	1:100,000	Sensitivity class	CORINE Land Cover
Land management quality	Population density	1:500,000	People km-2	Census of Household
	Population growth rate	1:500,000	%	Census of Household
	Agricultural intensity	1:100,000	Sensitivity class	CORINE Land Cover

Four partial indicators, depicting environmental quality in terms of climate (Climate Quality Index, CQI), soil (Soil Quality Index, SQI), vegetation (Vegetation Quality Index, VQI), and land management (land Management Quality Index, MQI), were estimated as the geometric mean of the different scores for each parameter. The ESAI was subsequently estimated for each i-th spatial unit and j-th year as the geometric mean of the four partial indicators (Basso et al. 2000) as follows:

$$ESAI_{i,j} = (SQI_{i,j}*CQI_{i,j}*VQI_{i,j}*MQI_{i,j})^{1/4}$$

The ESAI values range from 1 (the lowest land sensitivity to desertification) to 2 (the highest sensitivity to desertification). Based on ESAI values, it is possible to identify four classes of land sensitivity which refer to the most used classification thresholds (Basso et al. 2000; Brandt 2005): (i) areas unaffected by LD (ESAI < 1.175), (ii) areas potentially affected (1.175 < ESAI < 1.225), (iii) ‘fragile’ areas (1.225 < ESAI < 1.375), and (iv) ‘critical’ areas (ESAI > 1.375). Intermediate and final maps were produced after the different elementary layers were registered and referenced to a pixel (e.g. MMU) of 1 km2 (e.g. Basso et al. 2000; Salvati et al. 2008). According to the described procedure, two ESAI maps related to the land quality status of the study area during 1990 (ESAI90) and 2000 (ESAI00) were derived.

4 Risultati e conclusioni

An analysis of changes in LC and CLC shows that, according to the first CLC level, in both transition periods (1975-1990 and 1990-2000), the major transitions concerned the land conversion from agricultural to artificial areas, and from a type of agricultural use of the territory to another, mainly from non-irrigated fields to more complex cultivations (e.g. permanent crops, rice fields, heterogeneous cultivations). On the contrary, the conversion from natural and semi-natural areas to artificial areas, frequently practiced during the 15-years from 1975 to 1990, has been appreciably reduced in the decade 1990-2000; while the LULC change from crops to shrubs and vegetation dominated by grasses strongly increased from 1975-1990 to 1990-2000, expression of a progressive land abandonment especially in the last decade.

We have deepened the evidence obtained with the previous investigation adding the information related to the land vulnerability and considering the second CORINE level of detail. The results obtained from the analysis of the mean ESAI values for each LULC change class occurred in 1975-90 and 1990-00 showed that the most critical land use conversions are those from crops to heterogeneous agricultural lands, from permanent cultivations to crops, from permanent cultivations to heterogeneous agricultural lands, from heterogeneous agricultural lands to industrial areas, from heterogeneous agricultural lands to grasslands/shrublands, and finally from grasslands/shrublands to mines, pits and dumps.

A document published by the European Environment Agency (EEA 2006), “The Changing Face of Europe’s Coastal Areas”, draws attention to the fast increase in the use of coastal space, mainly stimulated by the touristic and leisure industries. It also indicates that this

represents a serious threat to the delicate balance of coastal ecosystems. According to this report, the population's density in coastal zones is, on average, 10% higher than inland, reaching 50% in some countries. Even more worrying is the rate of conversion of natural coastal areas into artificial ones, this being faster than the increase of population density (Alves et al. 2007). In Italy, and especially in the southern regions, these processes are evident, as it is the consequent impact on dryland landscapes. This is becoming a major concern from both an ecological and a socio-economic perspective, due on one hand to the resulting loss of natural areas, the reduction in biodiversity, the fragmentation of the landscape, and the impoverishment of the soil and, on the other hand, to the consequent decrease in land productivity and quality status (Salvati and Zitti 2007).

This study focussed on two coastal areas in Sardinia and Basilicata (Italy). It analysed the impact of LULC changes that occurred from 1975 to 2000 compared to the possible changes in the level of land sensitivity to degradation (1990-2000). The results demonstrated that there are two main factors affecting the land vulnerability of the study area: (i) land abandonment and (ii) the conversion from natural, semi-natural and agricultural areas to artificial areas. These two factors represent the primary LULC transformations that led to an increase of the land sensitivity to degradation.

Identifying the major LULC conversion trends of a territory during time and knowing how the observed LULC change trajectories are associated to land vulnerability allow to detect the most "risky" LULC changes in terms of LD. The detection of where certain LULC changes occur, the type of change, as well as how the associated land quality status is changing, can support decision-makers to develop short to long-term plans for the conservation, sustainable use and development of natural resources. Such information represent the basis for policy interventions in rapidly evolving landscapes aimed at mitigating the effects of land mismanagement; for instance, directing land-owners' choices towards ameliorating LULC typologies, regulating the land use destinations on the basis of the environmental characteristics of a specific territory, monitoring land vulnerability dynamics through time.

In conclusion, we believe that the evidences emerged in this paper can effectively contribute to give more insight in land degradation processes and targeted management policies aiming at preserving environmental quality in the coastal areas.

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