Monitoring Changes in Coastal Areas. From the socio-economic to an integrated approach*

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ABSTRACT

This paper aims at presenting the dynamics of land cover changes in coastal areas. These dynamics were identified, Coastal Alentejo (Portugal), by the application of an integrated methodology that associated the land cover data with the socio-economic data. The use of Geographic Information Systems made possible the association of land cover data and socio-economic data using different levels of analysis.

Being land cover and land use changes one of the main issues integrating the large debate on sustainable development, its analysis demand clearly an integration of spatial / landscape data with the socio-economic data, which has been recently widely recognised. The question is how this integration is possible, and how can it best being achieved to understand the change. Moreover, the land use changes studies must be a contextualised analysis centred in the individual inside the context where he acts. This departing point assumes that the individual induces land use changes but he also reflects these changes, which were made by him or by other agents that intervene, directly or indirectly, in the land use. Thus we must consider and analyse the impact of external driving forces such as the national and international policies and regulations, being necessary, therefore, an effort to make this kind of analysis at Regional, Local and Individual Level.

The coastal areas are special focus given the increasing importance that they had assumed in the global frame of the present economic development. The number and diversity of agents that are searching for space in coastal areas increases the needs for an integrated management in a way to minimise the negative impacts of the increasing number of activities conflicting in these areas. The nature and distribution of human activities on coastal areas result from the action of a range of driving forces – demographic, institutional, commercial and market, cultural and technological. The impact of these forces explains the land use changes and the way in which the coastal resources are affected.

Toward the identification and understanding the environmental problems of coastal areas it is important, therefore, to analyse the efficacy of the administrative structures at the level of the formulation of the legislative frame and its practice giving possible to understand the articulation, at distinct levels of the institutional dimensions. Moreover the institutional frame, given the integration of Portugal in the European Union since the middle eighties, is in part the reflection of the problems and needs, which are perceived also at the international level. In Portugal the responsibility of management of coastal resources is distributed by several administrative structures that intervene at different spatial levels (national, regional and local levels). This intervention present some contradictions caused by the different objectives of the planning tools, which frame those administrative structures

In what relates to the methodological design, this study is based in an integrated perspective that aims at understand the processes of land use change. The association of different scientific approaches and levels of analysis will accomplish this posture of integration. However, this multi-disciplinary integration cannot be faced as a superimposition or assembling of divers empirical approaches. It represents an articulation between the different scientific domains and levels of spatial or time analysis. The time analysis it is a significant element of the methodological design. If this studies aim at understand the processes of land use change, it is required to analyse different periods, besides the study of different rhythms or cycles of the phenomena. The accurate study of these different moments must contemplate the changes of the biophysical and social frames. The land use change is, therefore, the reflection of the practices of the different agents conditioned by the changes in the global frame of each period. In order to articulate these spatial and temporal levels of analysis of the georeferenced data it was implemented a GIS. How to articulate information from different sources and natures, different scales into the system of analysis is one of the main challenges of the work carried on.

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LAND-USE CHANGE STUDIES

Generally speaking, the effects of changes in land use on global change are still little known in much the same way as the factors, which are behind those processes, are not fully understood. There are difficulties in defining methods of intervention in the regions and in obtaining support instruments for decision making which are fundamental to managing, understanding, monitoring and assessing the (environmental and social) changes resulting from modifications in land use.

The land use study involves both the manner in which the biophysical attributes of the land are manipulated and the purpose for which the land is used: forestry, parks, livestock herding, urban areas, suburbia, and farmlands (Turner *et al*., 1995). The chosen classes denote intent or purpose of use, so knowing this purpose and intent is a manner to understand the trends of change.

However, some of the most profound changes in the landscape have arisen from direct decisions by man concerning land use, and these have affected both the quality of environmental resources, such as soils and water, and the sustainability of food production. Land use decisions are based on opportunities and constraints affected by both biophysical and socio-economic drivers. Predicting future land use change requires methodologies that integrate the understanding of the processes affected by these drivers. Because the dynamics of land use and land cover can have biophysical, social, economic or ecological drivers, we must use a cross-disciplinary approach to analyse the different problems. Nevertheless the work departing from the disciplinary perspective of traditional land use studies it must maintain the specificity of each science (Lourenço; Correia; Jorge; Machado, 1999).

Aside from a more integrative approaches for human / environmental syntheses, which must put for a better understanding of the biophysical and social driving forces, it is of prime importance to push further from land cover to land use in a way that it is far more significant to understand the processes of change then the patterns of occupation of a territory.

COASTAL AREAS

The importance of coastal areas as a study object has emerged in recent times. This increasing significance is due to the complex activities that are present in those regions. Moreover different scientific research domains contemplate this complexity. Therefore it is of great importance to fix the limits of what is considered as *Coastal Areas* (Lourenço; Jorge; Machado, 1998).

For the natural researchers the coastal areas are related to the influence of the presence of the sea. This conception of coastal areas frames a region, with variations in large of its limits that include the coastal plain, the coastal cliff and the coastal plateau. In the immerse area the limits could also comprehend the continental shelves. Therefore, it is a demarcation very related to the influence (present or past) of the sea in the shaping of these areas.

In the frame of this paper the coastal areas are considered as the regions, located near the sea, where we can notice **rapid** and **intense** socio-economic and environmental changes. These kinds of changes are demanding for **fast** and **appropriate** policy responses as well as they act as important driving forces over hinterland regions. They can be considered as "*Hot Spot*" areas in the sense that they are one of the most dynamic and intricate areas of the planet. This complexity involves significant process of population dynamics, which are expressed in population growth, demographic stress and in rapid and intense migrations (hinterland-coast, rural areas-coastal areas).

METHODOLOGICAL APPROACH

At the moment, both the scientific community and the policy makers perceive the convergence between economic viability and environmental protection as being an important step towards land use sustainability. However, the accomplishment of this perception and its development into a coherent research strategy is not easy. Integration underpins the success of the policy-making process, as well as aiding the definition of research priorities relevant to policy decisions. Furthermore, this process needs to involve the stakeholders operating within the landscape: for example, landowners and agricultural managers, local and national regulators, planners and governments, local and national pressure groups, the private and entrepreneurial sector, and the wider public.

However, the majority of studies tend to concentrate on the effect and impact of man’s actions on the environment, dedicating little attention to the consequences of those changes on human activity. Studies on

the role which humanity plays in global change are often carried out within the concept of an *analysis of the human dimension*. Thus, they loose the systemic perspective, which considers society as a sub-system interacting with the natural sub-system within the far-reaching and integrated framework, which is the global change system (Mesarovic *et al*., 1996).

This systemic perspective allows the complexity of the interactions defined by the social and natural systems to be incorporated in the analysis and shows that they interact through logic of reflexivity. In other words, the social systems are changed at the same time as they modify the natural system, *i.e.* the impact of human activity on the environment and the consequences of the latter's deterioration on human activity cannot be considered separately since they are related in real time (Lourenço; Correia; Jorge; Machado, 1999).

Sociological and political structures analysis can help to identify the decisive elements that influence the decision-making process as it affects land use change. For example, constraints, which depend on agricultural structures, may be at the level of education or the level of regional agricultural consultancy. One of the most significant elements is the agricultural system created, in Europe, by the Common Agricultural Policy (CAP). The CAP, with its market regulations, has until now dominated production and markets for the most important agricultural products.

Another issue relevant to this kind of analysis is the integration of different level analysis. Understand the problems related to scale analysis must be a key issue in the study of the interactions nature / society. The different human activities must be evaluated or measured according to the different levels of the spatial and temporal scales (Gibson, C.; Ostrom, E.; Ahn, T., 1998). Thus, if we search for answers at local level we must not forget the external driving forces in other levels of intervention, i.e. the regional and the global framework that influence the local or the individual level.

However, for the integration of the socio-economic perspective in the study of land use changes, it is not enough to collect data of socio-economic type and to present its spatial pattern of distribution, or even its combination with spatial data. The integration of different disciplines requires the close collaboration between these disciplines, already at the stage of defining the datasets needed. The information to be collected depends on the questions each scientific perspective has to the same object, i.e. land use change, and also on the scale of analysis. The process is not a simple one, and it is not possible with the work of a single scientific perspective, even if well motivated.

The significance of GIS in the study of land use changes

The GIS allows a whole set of data analysis operations spatially referenced at diverse levels, which constitutes one of the most important principles of the methodology presented in this work. The constitution of a geo-referenced database with information collected should render possible the association of biophysical and socio-economic data and their intervention at different levels of analysis, this being one of the main objectives in using the GIS in this kind of studies. What makes these GIS even more relevant is the fact that they permit the construction of dynamic models of geographic reality that makes it possible to reach alternative representations for the production of information to support decisions.

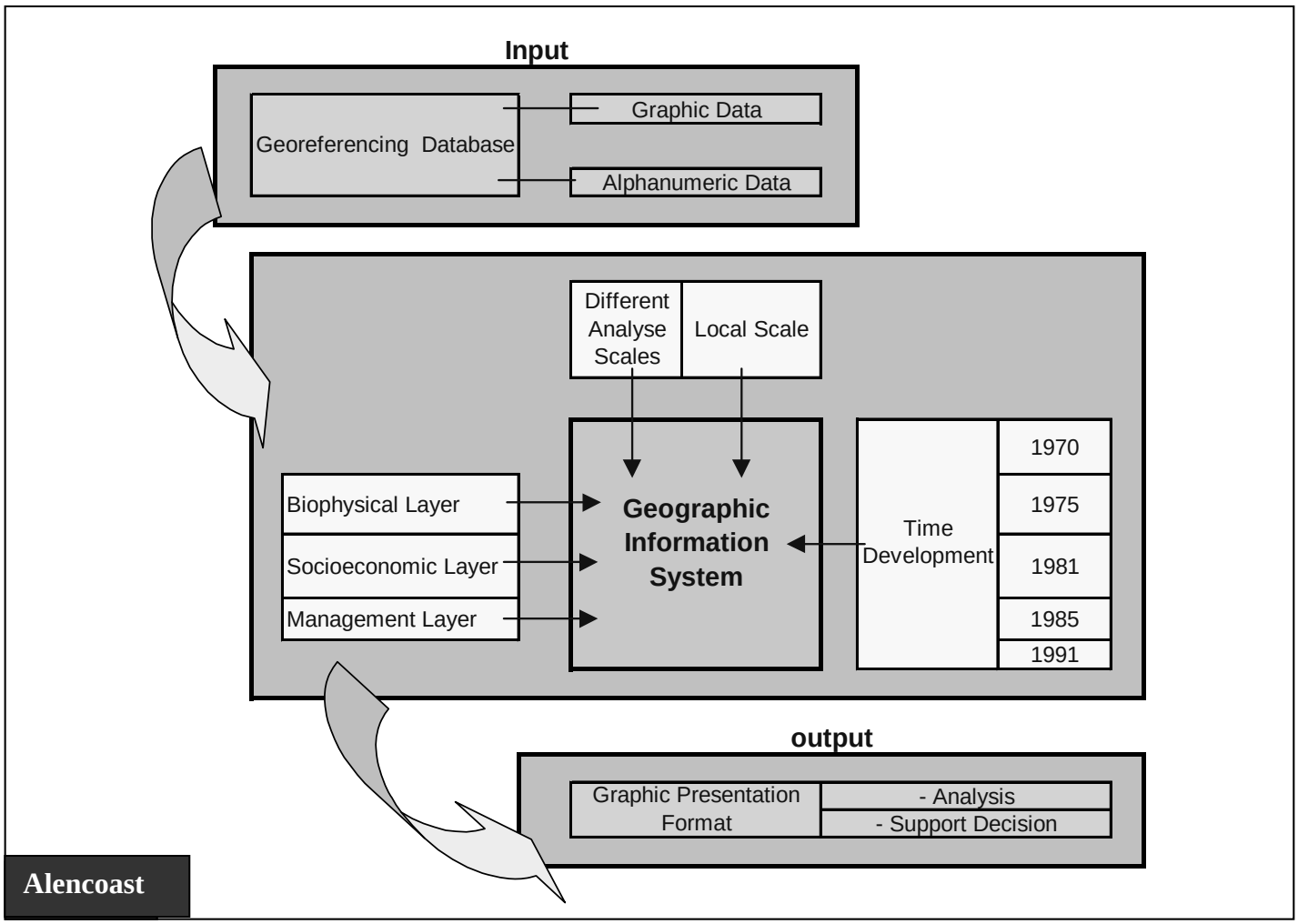
In effect, the use of these *socialised* GIS has already been defended in previous studies (Lourenço *et al*, 1997 and Lourenço, Jorge and Machado, 1997) as indispensable tools in monitoring land use and land cover dynamics, as mentioned above. Aside from the characterisation variables of the various intervening actors in a designated territory, *socialised* GIS, when associated to adequate techniques of sociological analysis, likewise permit the integration of information relative to attitudes and expectations of the individual actors. In this manner, they become essential tools in the construction of systems that monitor and assess policies impact on land use.

THE METHODOLOGY TO THE LAND USE CHANGE ANALYSIS IN COASTAL AREAS

This paper refers to a study carried out on Alentejo (South Portugal). At regional level, the analysis was based on information obtained with instruments for remote detection (satellite images and aerial photographs), which permit the collection of information on land cover in the coastal area and the identification of its main dynamics. These instruments also made possible to obtain data for different periods and to carry out an evolutive analysis of the most significant changes in land use. On this level, official statistics were also analysed to collect socio-economic information, which is fundamental for describing the region's general framework. At local level, an analysis was made of the social actors and of the factors for change identified at regional level.

These two groups of data were introduced into the Geographic Information System making for a spatial reading of the information (Fig. 1). The effort of compatibility between the different kinds of data made possible the integrated analysis. Moreover the GIS software makes possible the quick adaptation of the analysis to the questions that rise during the course of the research.

Fig. 1 – Structure of the Geographic Information System

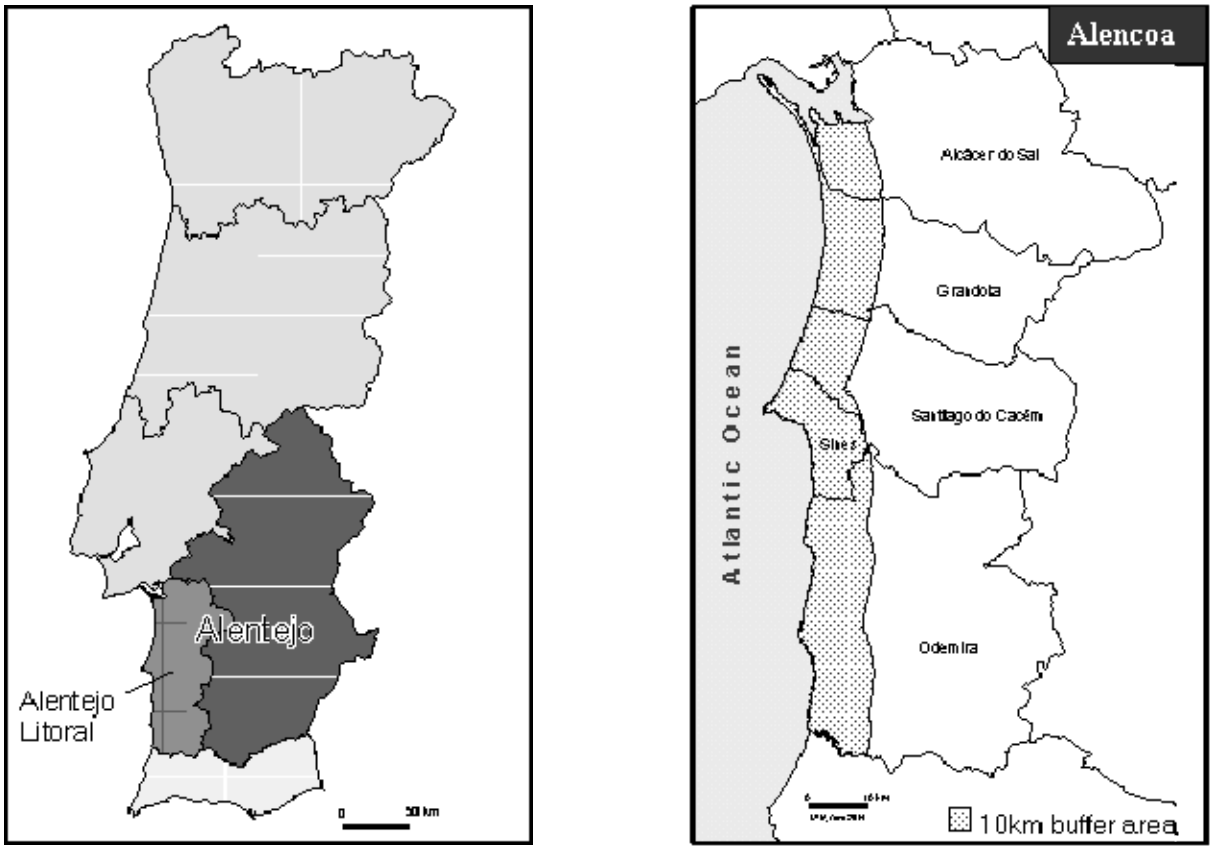


Source: Lourenço, N.; Jorge, R.; Machado, C.R.; Rodrigues, L. (1999)

The Coastal Alentejo

The Portuguese mainland coast (832 km) can be broadly divided in two sections: west coast and south coast (Algarve). The coastal sector located in the region of Alentejo is characterised by a low population density, dominance of the agricultural activities and services, and by a recent increasing urban pressure in consequence of tourism activities. A sandy shore on the north and steep cliffs on the south defines the coastline that constitutes, with the adjacent areas, a Natural Park. The problems related to the pressure on this area, mainly due to tourism activities, could damage the present ecological balance. The main institutional constrains to the land use change, causing some interest conflicts between the different social actors, are imposed by restrictive ordnance measures and by the existence of the Natural Park. In this region the industry, which is concentrated around the industrial harbour of Sines, causes the main environmental degradation.

Fig. 2 – The region of Alentejo studied



Source: Lourenço, N.; Jorge, R.; Machado, C.R.; Rodrigues, L. (1999)

Questions arising from the Regional Analysis: the main societal driving forces

The Alentejo (Fig. 2) is a region that has been undergoing since 1970 a process of depopulation and ageing of its population. At the same time, there is a strong decrease in importance of the activities in the primary sector, accompanied by the reinforcement of the weight of the tertiary sector, essentially of a social nature. This is a region where the absence of economic activities alternative to agriculture and capable of fixing the population, is causing the population to leave for other regions of the country. Nevertheless, certain municipalities in the *Alentejo Litoral* (Sines and Santiago do Cacém) reveal some capacity to attract labour, mainly due to the economic dynamism stimulated by the industrial pole of Sines.

The main problems of territorial management are related with:

- Intensive agriculture in more or less 2 000 ha (Irrigated Perimeter of Mira Basin) which lead to the extinction of some plant species;
- Marine and atmospheric pollution originated in the Sines Industrial Compound;
- Urban and seasonal tourism pressure over the coast;
- Inadequacy of some forestry projects;
- Random opening of access roads to the coastal zone;
- Illegal fishery and hunting;
- Arson and unintentional forest fires.

Resulting from its geographic situation, landscape diversity and reduced human pressure, the Portuguese Southwest Coast accommodates a rich natural patrimony that justifies the creation of the Natural Park of the Southwest of *Alentejo* and *Costa Vicentina* that aims at preserving the environmental balance of this territory. Therefore, the Park is one of the factors of change that must be considered in the analysis of land use

change. However the present and the expected pressures can lead to the disturbance and destruction of coastal habitats, and also to the degradation of beaches by coastal erosion.

Coastal Band

In this study the coastal area of Alentejo was the territorial unit of research. This fact is justified by two main reasons. In the same region we can identify a remarkable diversity of activities and uses of the territory: the agriculture at north and south; the industry in Sines municipality; and the tourism related with the existence of small, and almost wild, beaches. It is also a region where the environmental degradation is, for the time being, restricted to the areas near the industrial harbour of Sines. Nevertheless the increasing pressure over the land towards a higher tourist expansion could, if not well planed, damage the environmental balance expressed by the existence of the Natural Park of Alentejo Coast.

This area consists of a 10 km-wide band, stretching along the coastline (Fig. 2). The Sado River estuary borders it to the north and the Odeceixe River, to the south. Another significant river in this area is the Mira River that crosses this coastal band in the area to the south of Sines. The landscape of this coastal area, especially to the north of Sines, is also marked by the presence of divers lagoons that result from the geomorphologic evolution of the coastline.

The study of this territorial unit is conditioned by the availability of sources of information. In fact, the primary source of data was the project Land cover Change in European coastal zones - LACOAST[1], which consists of the inventory of land use / land cover changes obtained from the comparison of two CORINE Land cover (CLC)-type databases of a 10-km band from the coastline for ten European countries. This data was an important effort to make a quantitative assessment of land cover/land use changes in European coastal zones (a 10 km large ribbon) especially those due to human activities. This land cover data corresponds to digital maps (scale 1:100 000) obtained from satellite images (1975, Landsat MSS; and 1985, Landsat TM).

Data Treatment and Modelling

The data related to the land cover was manipulated in three main phases. First it was necessary to organize the legend to the objectives of the study. Therefore it was made a land cover classification from the CORINE legend (third level). Secondly this vectorial information was rasterised constituting a grid of pixels with a coverage resolution of 1 ha. Thirdly it was made a map algebra operation to identify the land cover changes. The socio-economic data were taken from the Population Census of 1981 and 1991. It was introduced in this analysis, after place / square kilometre area conversion, from which resulted a grid comprising small squares of 1 km². These squares show the socio-economic characteristics of the population, such as the resident population, the present population, the age structure, the level of instruction, the sector of economic activity, and inactive population. As for buildings, data on the year of construction, characteristics of the main resistant element (concrete, wood, etc.), and living conditions of housing, were collected.

Data modelling is one of the most interesting forms of data use in GIS since it is fundamental in the obtaining of results. The simplest form of original data modelling allowed the characterisation of biophysical and socio-economic features, the data being processed from the classification of variables, or of sets of crossed variables. The identification of hotspots is directly related to the most major changes in the coastal band throughout the period studied. These changes may be of a socio-economic and/or biophysical nature. Locating these areas is fundamental in determining the classification thresholds for each variable in order to distinguish a particular point.

Finally, the development of empirical models that allow us to cross all information is one of the objectives of the mastery of the methodology, that can only evolve insofar as it can integrate a more significant modelling component sustained by spatial statistical techniques, aided by spatial analysis functions of GIS.

LAND USE AND SOCIO-ECONOMIC DYNAMICS. PROCESSES OF CHANGE

The land cover in this area is chiefly characterised by agricultural areas (45%) and by forest and semi-natural areas (52%). Other types of land cover are remnants occupying less than 3% of the area studied (Table 1). A quantitative analysis of the land cover changes reveals a very low rate of change between 1975 and 1985.

[1] The Lacoast project was launched by the Agriculture and Regional Information Systems (ARIS) unit of the Space Applications Institute of the Joint Research Centre, and was funded by the Centre for Earth Observation (CEO) programme Workpackage AS3200 (Application projects in support of the European Commission Services).

However, it is possible to identify some significant land use dynamics associated to different processes of change. Although they are small rates, the urban and industrial areas underwent some of the most significant changes between 1975 and 1985.

Table 1 – Land cover classes in the coastal area

LAND-COVER CLASSES	1975		1985	
	ha	%	ha	%
Artificial surfaces	1421	1,2	2129	1,8
Agricultural areas	53540	45,4	52638	44,6
Forests and semi-natural areas	61891	52,5	61839	52,4
Wetlands	665	0,6	665	0,6
Water bodies	456	0,4	789	0,7
TOTAL	117973	100	118059	100

Source: Lourenço, N.; Jorge, R.; Machado, C.R.; Rodrigues, L. (1999) Lacoast, 1975; CORINE, 1985

These low rates of change are certainly related to the weak socio-economic dynamism of the area. The study of many socio-economic indicators denotes that the Alentejo is one of the most peripheral regions of Portugal (Jorge, 1977 and Lourenço; Jorge; Machado, 1998). In the areas of the Alentejo previously studied by the authors, there are generally no significant changes in the landscape (Lourenço *et al.*, 1997). In recent years, the processes of change in land use have been characterised by the increase of the extensive use of available land, particularly in the increase of the area of natural pastures, the conservation of the *montado,* and use, with little expenditure, of areas, which had been previously used for cereal growing.

However, it is possible to identify some patterns of change in Coastal Alentejo (Fig. 3 and Table 2). These ones are particularly related to the expansion of the industrial harbour in Sines since 1978.

Table 2 – Processes of Change in the Coastal Band of the Alentejo

Processes of Change
Dynamics in Urban Areas
Non-irrigated arable land decreasing
Dynamics in Industrial Areas
Areas with complex cultivation patterns decreasing
Mixed forest areas decreasing
Dynamics in Agricultural Areas
Arable land decreasing
Areas with complex cultivation patterns decreasing
Agro-forestry areas increasing
Dynamics in Forestry Areas
Cycle of forestry production
Forestry areas increasing

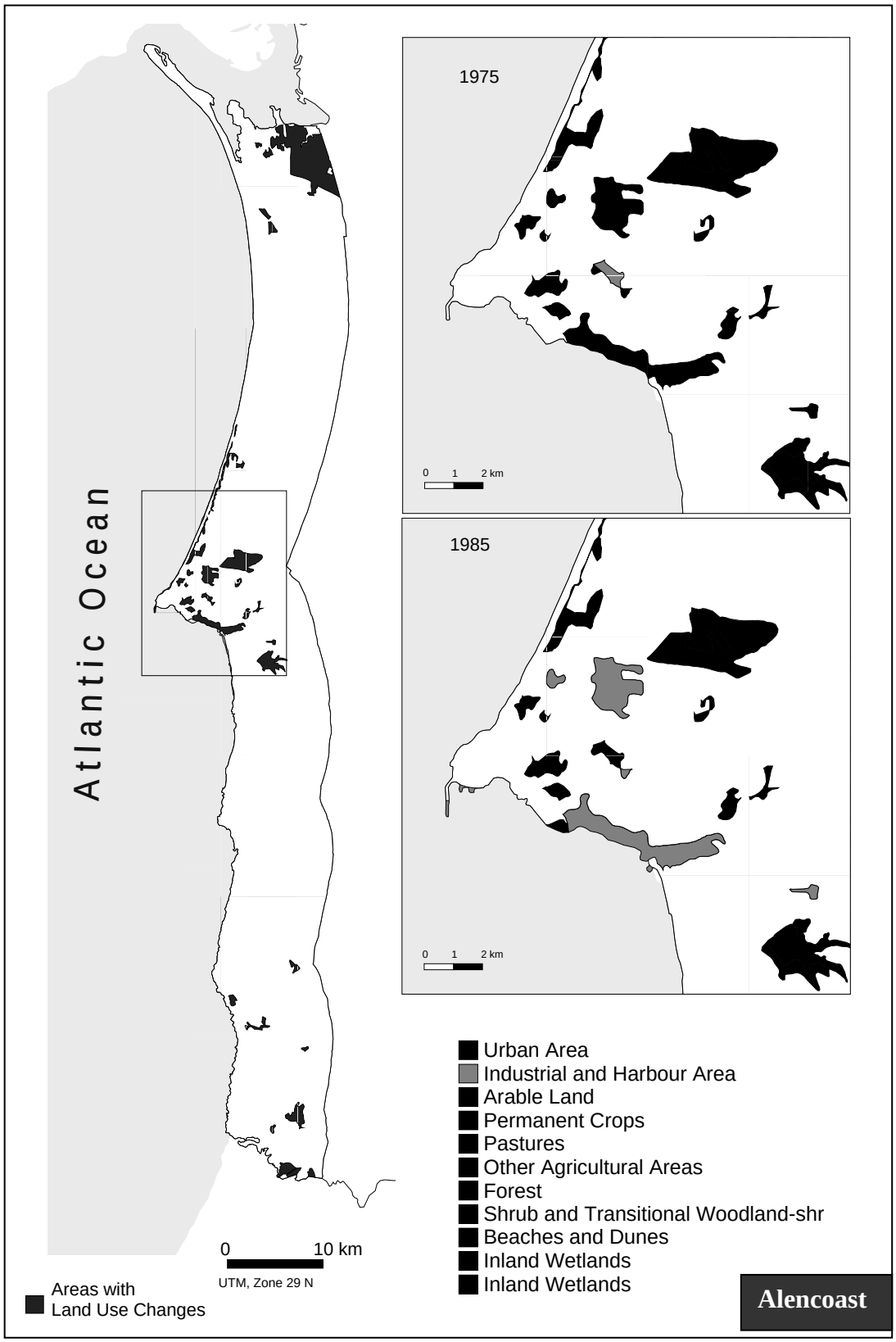
Source: Lourenço, N.; Jorge, R.; Machado, C.R.; Rodrigues, L. (1999) Lacoast, 1975; CORINE, 1985

Dynamics in Urban Areas

The dynamics in the urban areas of the coastal band of the Alentejo are characterised by a significant increase in areas of population agglomerations. However, for the period studied (1975-1985), this growth is visible only in Sines. In this urban centre, the continuous urban fabric registers an increase of 76 ha, and this growth is related with the decrease of non-irrigated arable land.

Nevertheless, it can be noted that a significant growth of the urban fabric occurred also after 1985, or in other words, after the date of the CORINE. This growth is visible, with the help of ancillary sources of information such as the 1995 aerial photographs, particularly on the villages situated near the coastline.

Fig. 3 – Land Cover Changes, 1975-1985, near Sines



Source: Lourenço, N.; Jorge, R.; Machado, C.R.; Rodrigues, L. (1999), Corine Land Cover (1985) and Lacoast (1975) Databases

Dynamics in Industrial Areas

In general, the surrounding area of the expanding urban centre of Sines seems to be the most dynamic. It is here where the land use changes are more significant (Fig. 3). These changes result from the expansion of the industrial harbour, the construction of an electric power plant, and the installation of an oil refinery that was a significant focus of attraction for the population of the hinterland (Lourenço *et al*, 1998).

Therefore, in the recent years this industrial centre has been an important infrastructure responsible for the main land use changes observed in this region. These land use changes are expressed in the increase of the urban and industrial areas of Sines and in the enlargement of the harbour facilities. The extension of these areas results in the reduction of the more or less complex patterns of agricultural land use (360 ha), which is evident in the 1975 maps. Likewise, a significant decrease in the area of mixed forest (279 ha) was registered.

Dynamics in Agricultural Areas

The dynamics in agricultural areas of the coastal band of the Alentejo is typified by a net reduction in the area of arable land (irrigated and non-irrigated) and complex cultivation patterns, as well as in the significant increase in agro-forestry areas.

The decrease in area of non-irrigated arable land seems to correspond to an important land use change, given that approximately 70% of the area came to be used in 1985 for forestry or agro-forestry purposes. A land use change is therefore being witnessed.

As for areas with an agricultural use, a significant decrease in complex cultivation patterns is registered as well. In fact, it can be noted that 80% of these areas came to be used for industrial purposes in 1985. This land use change can be seen in the area of Sines in places where we find the thermoelectric power plant, the refinery, the industrial units related to petroleum derivatives, some sewer and residual water treatment stations, and not to mention the new access roads to the Port of Sines.

Dynamics in Forestry Areas

The dynamics in forestry areas in the coastal band of the Alentejo seem to be typified by two processes; one corresponding to the actual increase in forestry area, and the other related to the land use change associated with the forestry production cycle.

In this manner, only around 40% of the areas that registered in 1985 a change to forestry cover seem to indicate an actual increase in the forestry area. This process of increase in forestry area corresponds to the use of non-irrigated arable land (243 ha) and complex cultivation patterns (52 ha) for forestry production, mainly Eucalyptus. However, this increase in forestry is very slight, corresponding to approximately 0.7% of the forestry area in 1985.

As mentioned above, other changes perceived in the area that seem to point more to a cycle of forestry production than to an actual increase in area of forestry in the coastal band of the Alentejo. This type of change seems to follow a cycle that begins with the clearing of cultures in a particular parcel. This leads to a parcel where the rocky substratum (in the area studied, essentially sandy) crops out to the surface. Next, trees are planted and a shrubby layer, sometimes very thick, naturally develops. This contributes to the protection of young trees and the fixation of nutrients in the soil. In a third phase, the trees grow and give rise to a productive forest until they are cut, beginning the cycle once again.

Socio-Economic Pressures on Land Use

Four indicators of pressure on land use were formed based on the analysis of socio-economic variables. This was possible for the coastal band of the Alentejo due to the existence of data disaggregated at the level of the locality and available in the form of a kilometric grid. Triangulated Irregular Network (TIN) data models were created as a cartographic representation of tourist, urban, industrial, and agro-forestry pressure indicators. These models are based on the possibility of attributing a third dimension to the various phenomena. It consists in the interpolation of data relative to the points (localities / grids) in order to create a set of areas determined by their triangular form.

The above-mentioned data modelling made way for the formation of the following indicators: Urban Pressure, Industrial Pressure, Tourist Pressure, and Agro-Forestry Pressure. The variables selected in these

indicators are weighted equally, so that the number of variables present in each locality evaluates socio-economic pressure. Thus, the more variables present in a given locality, the greater the pressure will be.

Urban Pressure

Four variables were used to form this indicator:

- Active population in the tertiary sector in 1991, equal to or more than 50 %;
- Growth rate of the active population in the tertiary sector between 1981 and 1991, equal to or more than 100%;
- Active population in the primary sector in 1991, less than 10%;
- Localities with more than 100 inhabitants and with more than 50 % of its buildings constructed after 1970.

The cross-referencing of these four variables using the Geographical Information System developed for this study resulted in the Urban Pressure Indicator (Fig. 4).

The analysis of this map shows the heavy urban pressure that is felt in the area located between Sines and Santo André. To this area, where the five selected variables are present, the following areas can be added: Tróia, Vila Nova de Milfontes (and mainly localities that are developing in the surroundings of this urban centre, such as Alagoachos), Zambujeira do Mar, and Azenha.

Tourist Pressure

Four variables were cross-referenced to form this indicator:

- Active population in the tertiary sector in 1991, equal to or more than 50%;
- Growth rate of the active population in the tertiary sector between 1981 and 1991, equal to or more than 100%;
- Localities where the number of secondary households is superior to the number of normal habitations;
- Localities with more than 100 inhabitants and with more than 20% of its buildings constructed between 1985 and 1991.

It was not possible to integrate a variable related with the number of hotels into the Tourist Pressure Indicator, given that this data is aggregated with collective buildings[2]. As such, the indicator essentially reflects one of the dimensions of tourist pressure, resulting from secondary and weekend households.

However, the map (Fig. 4) is very clear with respect to pressure existing mainly in localities next to the coastal line. Thus, the following manifest higher figures of tourist pressure: Tróia, the area adjacent to Lagoa de Santo André, Porto Côvo, Vila Nova de Milfontes, and the coast located between Zambujeira do Mar and Praia de Odeceixe.

It is interesting to note the differences between Vila Nova de Milfontes and the localities developing in its surroundings when this indicator is compared with urban and industrial pressure indicators. While Vila Nova de Milfontes reveals significant tourist pressure, the locality of Alagoachos is subject to greater industrial pressure.

Land Cover Change Associated to Urban and Tourist Pressure

The urban and tourist pressure that is felt in some localities in the coastal band identified in the analysis of socio-economic indicators is not related to any type of land cover change in the coastal band between 1975 and 1985. This is a reflection of the fact that these socio-economic changes occurred for the most part, after the last date of land cover analysis. However, these pressures, which are related to the growth of urban areas, reflect changes observed in the 1995 aerial photograph, and at present, on field[3].

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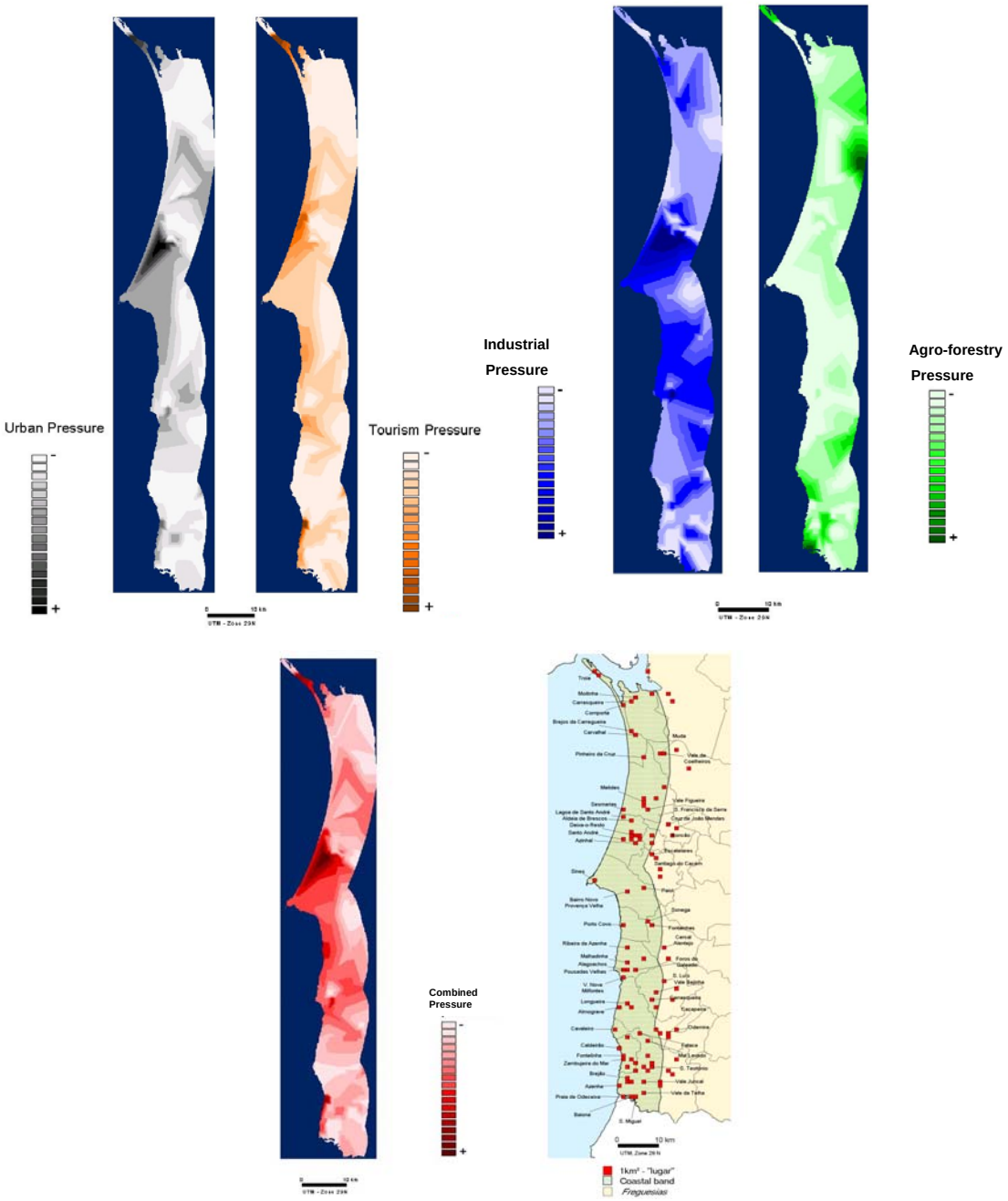
[2] A set of premises intended for a large group of people subject to an authority or a common administration, linked by a common objective or common personal interests. Social welfare, educational, health, religious, military, prisonal, and work institutions, are included in this group.

[3] While this analysis has not been quantitatively integrated into the study, is a valuable qualitative contribution to the understanding of the more recent land cover changes.

Fig. 4 – Socio-economic pressures on land use, 1981-1991 in Coastal Alentejo



Source: Lourenço, N.; Jorge, R.; Machado, C.R.; Rodrigues, L. (1999)

Nevertheless, it can be noted that the areas with the greatest tourist pressure are the beaches, lagoon areas (estuary of the rivers Sado and Mira, and the Santo André lagoon), or the rocky coast marked cliffs. These areas, which constitute a Natural Park, should be preserved, given their landscape aesthetic value, the existence of a unique flora and fauna, and the scarcity of human occupation. Thus, since it is foreseeable that the increase of tourist pressure in this coastal band shall continue to be felt in places located next to the coastal line, the main land cover changes that will probably occur are related mainly with the increase of urban and the decrease of agricultural areas.

This scenario corresponds to pressure exerted in this region by various private investment plans that have emerged in recent years with a view to building tourist ventures. Their establishment has however been until

now stopped by restrictions enforced by the different territorial planning tools such as the Coastal Fringe Ordinance Plans and the Coastal Alentejo Natural Park Ordinance Plan.

Industrial Pressure

The following variables were used for this indicator:

- Active population in the secondary sector in 1991, equal to or more than 30%;
- Growth rate of the active population in the secondary sector between 1981 and 1991, equal to or more than 100%;
- Localities with more than fifty inhabitants.

This indicator shows (Fig. 4) that the areas under the greatest industrial pressure are, once again, located between Sines and Santo André, and likewise the locality of Alagoachos, located in the surrounding area of Vila Nova de Milfontes.

In addition to this, in a vast area of the coastal band the localities show two of the variables selected to form the Industrial Pressure Indicator. This fact is certainly related to both the small industries and activities related to civil construction.

The land cover changes observed in the area of Sines and Santo André, which basically correspond to the expansion of urban and industrial areas, are related to strong socio-economic pressures, particularly due to urbanisation and industrialisation. It is obvious that there is no clear spatial overlapping of these dynamics. However, it is important to note that it is in these places that the two types of dynamics are most intense. The relationship between the expansion of industrial areas and the growth of the resident population and the active population in the secondary sector likewise provide some clues that help to understand the relationship between these two types of dynamics.

Agro-forestry Pressure

This indicator was based on the cross-referencing of three variables:

- Active population in the primary sector in 1991, equal to or more than 50%;
- Growth rate of the active population in the primary sector between 1981 and 1991, equal to or more than 50%;
- Localities where the retired population is more than the active population.

The cartographic representation of the Agro-Forestry Pressure Indicator (Fig. 4) clearly shows the contrast among the indicators above. The areas with the greatest pressure are found far from the coastal line. The following areas are exceptions to this general distribution: Praia de Odeceixe and Zambujeira do Mar. Here, fishing activities must certainly take a more considerable weight in the context of the activities in the primary sector.

The areas located in the extreme north and south of the coastal band have land cover dynamics related to agricultural and forestry use. It is also in these areas that there is the greatest intensity of the socio-economic indicator agro-forestry pressure. The analysis of socio-economic dynamics and land cover at the level of the coastal band explained how the main land cover changes are related to the various socio-economic pressures identified. However, a more detailed analysis and understanding of these processes of change can only be undertaken at the local / individual level of analysis.

At the local level it would be possible to understand, and mainly as far as agricultural land use is concerned, the adequacy of land use strategies regarding biophysical factors such as the slope of the topographical surface, the nature of the soils, and the exposure of slopes. In addition, it would be possible to clearly identify the land use projects that were regulated by regional or local policies and the institutional context, making possible in turn an analysis of their degree of efficiency in the process of sustainable development.

Understanding the link of these biophysical factors with the socio-cultural characteristics of individuals, their capacity to manifest in markets (local, regional, national, and supranational) and in land use policies (national and supranational), and their investment capacity, is valuable in understanding the real reasons behind land use change.

Understanding the factors affecting change: integration of socio-economic and nature dimensions

The analysis of these four indicators of socio-economic pressure on land use shows that there is a sharp contrast between the combined pressure from urban, industrial, and tourist dynamics on the one hand, and agro-forestry pressure on the other (Fig. 4). While the combined pressure of urban, industrial and tourist growth is felt mainly next to the coastal line, the agro-forestry pressure is more evident in the interior of the Alentejo coastal band.

Among the places subject to a greater pressure from socio-economic dynamics related to land use change are the following: Tróia, located in the extreme north of the coastal band; the area next to the coastal line between Santo André lagoon and Vila Nova de Milfontes; and the coast between Zambujeira do Mar e a Praia de Odeceixe. These places are greatly affected by the growth of tourist activities in this coastal band. In addition to these places, the vast area located between Sines and Santo André must be mentioned, where urban growth is related to the development of the Industrial Complex of Sines.

As has been mentioned before, it is not easy, if at all possible, to find cause and effect relations between land cover changes and socio-economic dynamics. Aside from theoretical factors that prevent the establishment of cause and effect relationships between these two dimensions, other factors rendered the cross-referencing of information difficult, such as the time lag between the dates to which the different types of data refer. Therefore, we sought to understand how these two types of dynamics are related.

The land cover of this coastal band is mainly characterised by its agricultural and forestry nature, not having suffered great changes in terms of expansion or reduction of this type of land use between 1975 and 1985. The main changes are of a localised nature and are related to growth in urban and industrial areas.

As mentioned above, this is an area with a low rate of land cover change between 1975 and 1985. The main land cover changes in this coastal band are recorded in three sectors: in the north, next to the estuary of the river Sado, in the centre, next to the area of Sines / Santo André, and in the south, next to the coastal band limit. The main processes of change can be expressed by the following:

- Changes in agricultural and forestry uses of the land
- Urban concentration
- Industrial areas expansion
- Growth of the areas with tourism use

These changes will have impacts on the landscape and can negatively affect both the quality of environmental resources, such as soils and water, and the sustainability of food production. Therefore, this methodological approach can be an important tool to answer and to support the need of a correct territorial planning and the landscape preservation.

CONCLUSION

The fundamental objective of the now-completed study, "Land use change: A Methodological Approach to Understanding the Nature/Society Interactions in Coastal Areas", was the development of an integrated methodology for analysing land use changes in coastal areas.

The study of land use changes (in coastal or non-coastal areas) thus appears to be an essential contributing factor to the understanding of Global Change. In fact, while the problems that these changes cause are diverse, they have one aspect in common: they can put the sustainable development of a region at risk. Thus, in developing countries that have high population growth rates, there is a need to increase and intensify agricultural production, in competition with urban and industrial occupation of the territory, causing serious problems in terms of arboreal vegetation and soil degradation (by erosion and pollution).

On the other hand, in industrialised countries (and in Europe, in particular) where there are low population growth rates, the problems resulting from land use change have a diverse nature. The tendency in the European Union for agricultural areas to decrease, brought about by the Common Agricultural Policy, has been accompanied by the expansion of land use stimulated by urban growth and tourist activities. In certain regions, this type of land occupation has had a very rapid growth, and without thorough territorial planning,

has contributed to the degradation of natural resources and the landscape, putting at risk the economic development model itself.

However, land use changes can only be understood in depth through the understanding of the decision-making processes of the various agents of change present in a given territory. In such a way, the following phase of analysis unfolds at the local or individual level and attempts to find out how people make decisions. As such, the GIS is once again a fundamental tool in the expression and association of a large amount of biophysical and socio-economic data collected at the local level or from the various agents of change.

In this manner, the GIS has shown to be a powerful tool not only because it allows for the expression of large amounts of data of a diverse nature (biophysical, socio-economic, and institutional), but also for the survey of various levels of analysis, thus supporting integrated analyses. As mentioned above, the relation between land cover and land use and the socio-economic data are rarely direct. Nevertheless, the association of these types of data is crucial to a methodology of study of land use changes, insofar as it allows us to make a first reading supported by the processes of change at a given regional scale. The socialisation of the GIS, however, is only fully developed with the creation of a local level of analysis, where it may serve as support for structuring enquiries for agents of change, thereby putting forward more detailed and founded explanations of land use changes.

Hence, the usefulness of this methodology lies in the construction of scenarios of change or vulnerability, by attempting to identify the critical areas of land use change (present or future), and understanding and evaluating the vulnerabilities of those areas relative to those changes. In addition to this, it becomes likewise possible to construct models from the methodology developed for the evaluation of the impacts of national and supranational policies, thereby contributing to the evaluation of the real effects of these policies on land use change and the balanced occupation of the territory, or in other words, on the sustainable development of a region.

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