Land Planning through GIS, RS and multicriteria decision analysis. A case study in Sardinia.

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Abstract

During the last few years researchers and environmental planners have carried on their preliminary studies following an interdisciplinary approach. One of the main issues in this approach is the sustainability of economic development. As a matter of fact, the importance of the studies related to the distribution and the limits of natural resources is widely recognized. This can be accomplished more easily than in present by the use of extremely powerful computer application.
The purpose of this contribution is to demonstrate the usefulness of an integrated approach of the GIS and of the RS to planning in complex problems of decision making. Many GIS applications are suited to the input of remote sensing and the integration of these techniques is now accepted in landscape planning. By means of GIS and RS, environmental information can be integrated with administrative, political, social and economic data. GIS, RS and fuzzy logic techniques are used to assist environmental compatibility studies and decision making.

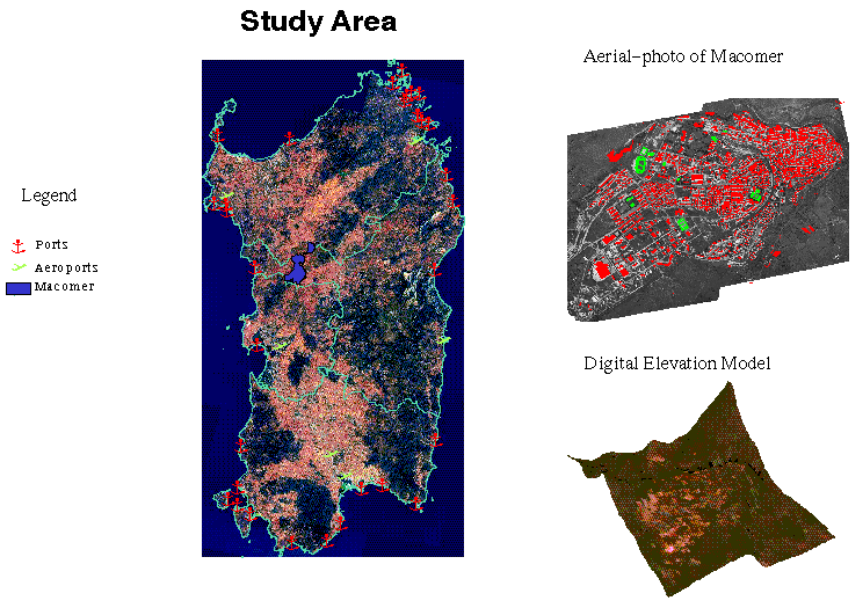
As a case study, an area located in the central part of Sardinia is analyzed. This area is especially interesting because of the presence of industrial and agricultural resources and infrastructures.

1 Introduction

The relative weakness of the Sardinian economy is the basis under which the European (EU) considers Sardinia to be a "lagging behind region - objective 1". Many measures of economic strength have demonstrated the disparity between the Sardinian economy and the greater Italian and European economies. Even today it is clear that the weakness of the Sardinian economy can be attributed to this geographic separation. The high cost of transportation to and from the island, as well as within the island itself is the most pressing problem to be addressed when factory location decisions are being made.

1.1 The crucial geographic position of Macomer

The primary road crossing the island of Sardinia is State Highway (S.S) number 131, also known as Carlo Felice, which links the capital city - Cagliari - in the south to the other major population and industrial center - Sassari - in the north. The town of Macomer is located at the intersection of the S.S. 131 and another important artery - known as the Sardinian Central Way - which links the larger centers on the western side of the island, such as Bosa, to the interior eastern regions in the Nuoro's Province. This geographic situation is ideal for those industries that choose to minimize transportation costs: the immediate access to the main highways of the island constitutes a positive externality and generates economies of scale. For this reason Macomer's economic development has been based mainly on industrial settlements. A model of industrial development includes the development of medium and small sized factories producing a wide variety of products, such as textiles, dairy-products, food, garments, and structural steel. This "soft" model based on a strategy consisting of the diversification of production is descriptive of Macomer's industrial complex. Considering that the hard industry is currently in a state of crisis, and is now being re-constructed with respect to its organization and means of production, the soft model of Macomer in its industrial zone "Tossilo" seems to guarantee a higher level of output and of employment.



1.2 Urban and environmental planning procedures

The Commune of Macomer in the 1970's showed a population of more than 10.000 residents. According to the main urban planning national law n. 1150/42, in 1975 its General Regulatory Plan (P.R.G.) was approved. In 1995 the Commune of Macomer, according to landscape and environmental requirements set forth by the main regional law number 45/89, published the executive summary of the new P.R.G., called the Urban Communal Plan (P.U.C.). All of the aforementioned documents focus on the development of industrial plants as an important economic opportunity for the territory. In large part, they describe the industrial expansion in Bonurtau and at the new site Tossilo.

1.3 Sector planning and general strategic indications

Throughout the period of the 1960s and the 1970s, sector planning in Sardinia has influenced the entire system of planning procedures for the territory as a whole. Specifically, the Territorial Coordinated Plan (P.T.C.), provided for by the national law n. 1150/42, corresponds closely to the plan of the Middle Sardinia Industrial Development Area (A.S.I.).

In other words, that regional economic strategic plan is largely composed of the local industrial development scenarios.
The relatively new field of landscape planning and environment protection procedures asserts that the diversification of land use is a crucial element of successful economic development. However, the importance of a well chosen site for a particular industrial settlement, and the access of that site to transportation routes is universally accepted as the most influential element in a successful territorial land use plan.
In spite of the recent trend away from mono-cultural development, the newest developments in the study region are, without exception, expansions of the industrial zones in the commune of Macomer:
1. Under the plans described above, the first settlements were located at the periphery of the town, in close proximity to the existing urban infrastructure;
2. A second an industrial "D" zone was planned at Bonutrau in the western part of the territory of Macomer;
3. Thirdly the industrial zone of Tossilo was settled in the southern part of the territory of the commune.
As the importance of the system at Tossilo grew rapidly, the number of industrial settlements at Bonutrau have diminished. As a result, the local planners have indicated that the expansion zone should be located between Bonutrau and Tossilo, and in the area of Bonutrau itself, through a special renewal plan known as a Recovery Plan (P.d.R).

1.4 Population forecast and industrial settlement

Employment and population forecasts serve two particular purposes. First, they are the basis for estimating future space requirements. Space requirement for housing are estimated by converting population forecasts into the number and types of households demanded by that population. The second application of population and employment forecasts is the projection of the need for transportation infrastructure and service, community facilities, and public services.
The changing geographic distribution of the population of Macomer has reflected regional trends. The 1981 urban area population was 11.083, and the most recent census established that there were 11.395 urban residents. There has been virtually no urban population growth. This trend is common to all the island towns, with few exceptions. This trend reflects the attraction and migration to the largest regional centers, accompanied by a regional decline in the birth rate.

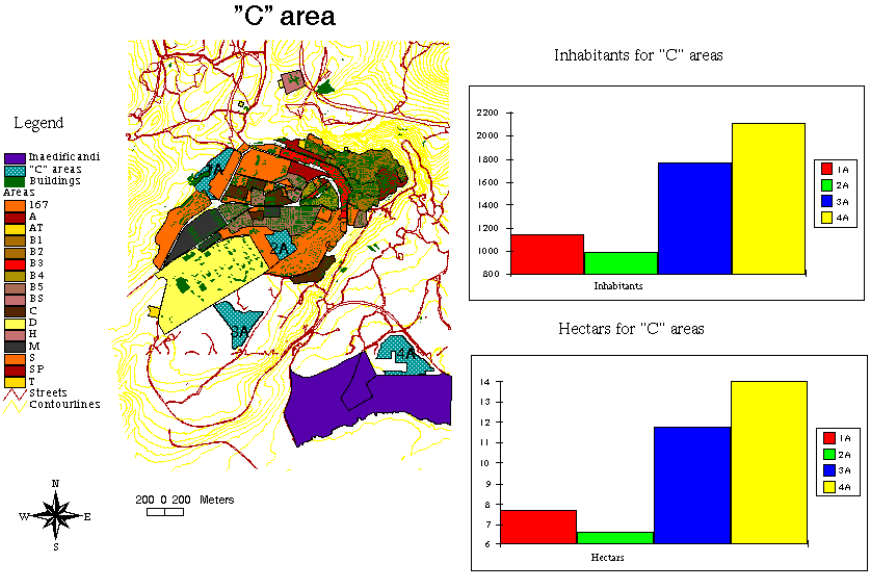
Population trends may also be recognized through qualitative analysis. One method of doing so involves an assessment of the varying styles of buildings in different geographic regions. In Macomer a natural division exists between the traditional or historic city center and the urban-rural fringe surrounding the city. Macomer is divided into two parts by the railway, and by the main street, represented by the former highway (ss131). The historic area is a mixture of architectural styles reflecting a variety of different cultures and economic classes. This area is well restored and the employment rate is high. In an attempt to cope with the lack of housing in urban areas, recent urban planning efforts have promoted the concept of residential area delineation. The 1979 P.R.G. defined three expansion areas. The large majority of the land within these areas has been dedicated to the construction of the popular building. More recently, however, the P.U.C of 1995 includes a new expansion area.

The renewed interest in local authority accountability has placed issues of resource allocation firmly back on the political agenda. The local councillors have to consider three principal characteristic of population and economy, especially relevant for land use planning purposes; size, composition, and spatial distribution.When determining the size or population number, it is necessary to apply a forecast approach. The forecasting method used here is a joint economic-population technique. This approach projects population and employment in a coordinated procedure. The population projection is based on employment analysis, and the economic projection is based on labor force-population indicators.

The industrial settlement of Tossilo shows many signal of employment growth. The consortium controlling the industrial area has received many requests from firms which would like to locate inside that industrial area.

The renewed industrial strategic plan makes a provision for 158 ha, assigned to new installations, but - in actuality - the land use plan has assigned substantially less area (approximately 90 ha), than what was estimated by the plan. The average size of the new industries that would like to locate in this area, is approximately 10 ha. Considering this dimension of each free area, the ratio between the area available and the average size for new enterprise gives the number of new plants (equal to 9 new industries). Assuming that these new firms will employ an average of 200 workers, multiplying the number of the new plants times the number of workers, results in the amount of population increase for the city. Considering the unemployment ratio (around 15%), 300 workers

should be absorbed by new industries, but the remainder must find new housing - ideally close to the work place.
An assessment of the “Composition” of the population is made by determining the size of specific age groups, households types, and socioeconomic levels. Moreover, economic activity may be distinguished by industry and type of firm. The largest group of employees is composed of labour-workers.
The spatial distribution of population and economic activity must be considered. Italian law has defined several criteria to calculate the potential size area for expansion; the regional law “decreto Floris”, fixes for each person, a volume of 100 mc. Consider that the expected new employment will increase the city population by 1500 workers. These workers will likely bring their families with them. The average Italian family is composed of two members. Multiplying this factor by the number of new workers, results in a total city population increase of 3.000. However, it is reasonable to assume that not all of the families will live in Macomer, and it is expected that 30% will live close to - but out of the city limits of - Macomer. Subtracting this percentage and the number of unemployed persons absorbed by the new employment, the resulting population increase is approximately 1.500 persons. Multiply this number by 100 mc for each person, and the result is 150.000 mc. This value is divided then by the edification index (1.5 mc/mq) to obtained a residential space requirement of 10 ha.



2 Description and construction of the alternatives

To find out an alternative fitting the requests of the environment and politics, it has been carried out a suitability analysis. The suitability analysis identifies location within the planning area that are best suited to locate the "C" area.
The following is a list of some criteria that ought to be considered when setting out to derive a fair assessment of "C" are:
Natural endowed value, Polical geography value, Slope, Increasing population, Soil, Distance, Landuse, Political Agenda, Topography, Sentiment.
Doing this analysis it has been built an environmental inventory. It is a coordinate "package" of information on individual environment features. This package generates a suitability scores for all sites within the planning jurisdiction for a "C" area.
The two alternatives have been built by computer calculation, while the others two come from the town's plan of the '79.
The procedure to build the two alternatives is the following:

- Creation of a map containing the percent degree of slope
- Reclassification based on a value of slope.
- Creation of a map of landuse.
- Reclassification based on the natural resource. From the landuse, derived from the TM and aerial photos classification, it has been extracted a suitability score map. The scale arises from one to five.
- Overlay summing procedure has been carried out to obtain a suitable map. Firstly the town boundary has been clipped from the result overlaid map; after having created a buffer of rivers, inaedificandi area, streets and railway (mostly taking into account the law constraints), these have been clipped too. The sum of the values can tell how many positive factors occur at the location. In this case the highest value shows the best allocation. The area whom belongs to a value higher than five, should be a good solution for location of the "C" area. After having reclassified the area with a value higher than five, it has been searched an area bigger than 10 hectares. The GIS software mapped out two areas.

2.1 Identification of the "C zone" and multicriteria evaluation

The major steps in developing and using a model of this type for multiple criteria evaluation are:
1.identification of the alternatives to be evaluated.

The alternatives to be considered are represented by the "C" area, those already in the urban plan of 1979, and the new area, created by the computer's calculation and designed by an urban planner.

2.Identification of relevant criteria and structuring a hierarchy of criteria.

It has been also identified a number of relevant criteria, thus establishing a base for evaluation:

♠ neighbourhood to "B" area
♠ nearness to principal street
♠ population dynamics
♠ square meters for "C" area
♠ land price for the passage from "E" to "C" area
♠ slope
♠ landscape fruition
♠ visual impact

Having identified the above collection of criteria they need to be structured in an appropriate way. The structure is a hierarchies of criteria.

3) Evaluation of alternatives with respect to criteria (scoring).

The aim of scoring is to assign values to each alternative reflecting their performance on each criterion. The function is an utility function. For the criterion neighbourhood to "B" area the scale is quantitative. So less is the distance better is the performance of the criterion. The second criterion is the real distance from the principal communication way (ss131). The population dynamics is a quantitative criterion. A growing number of person is a positive aspect, because, as explained before, means a raising economy and industrial development. It's related to the number of person that should be allocated inside the area. The square meters is also a quantitative criterion linked directly with the above criteria. The cost for a new area is calculated by "Naples's Law" (market value + income from agricultural land / 2). The two last criteria should be included into one criteria "quality of life". The landscape position is strictly linked with the position of the area "C". The area worked by computer out is in a wonderful area, very interesting for the nature and beautiful visual impact. The country around the new area is green and colorful during the spring. A high quality level of vegetation is present there. The scale is between 1 and 8 where 8 is the best performance. Slope is a quantitative criterion. A scale from 1 up to 5 has been scored, where the value equal to five is the best while 1 is the worst. One is the slope over 5%, 3 is between 2 and 5%, and 5% is between 0 and 2%.

4.Evaluation of the relative importance of criteria (weighting)

The different criteria it has been assigned the following value:

♦ 10 $\Rightarrow$ neighbourhood

- ♦ 15 ⇒ nearness to the street
- ♦ 15 ⇒ population dynamics
- ♦ 10 ⇒ square meters for “C” area
- ♦ 25 ⇒ land price from “E” to “C”
- ♦ 5 ⇒ slope
- ♦ 20 ⇒ quality of life

5) Sensitivity analysis.

The chart “Multicriteria Analysis Result” represents the overall scores for each of the alternatives. The bottom chart is the profile of criteria weights. The best alternative is 4A. But if the weight of the criterion cost will be a few points more, the alternatives classification changes. Life-quality and cost determine the modification of the dominance. The top part of the chart is a bar representing the score at the selected level of hierarchy for each of the alternative in the selected criteria. To conclude the analysis provides an ordering of the alternatives.

3 Conclusion

To cope with the problematic situation of landscape planning, the planners have to impose some order, taking into account the multiple aspects of environment and of politics, and to achieve a right decision. In order to pursue this goal all kinds of distinctions, classifications and other judgement might be considered. These methods and techniques and further the integration assist the planner to inventory, classify and feasibly arrange the information needed for a choice, giving a tool that enables to take a decision as responsibly as possible.

The integration of GIS data and multicriteria analysis it is now possible, thanks to new available softwares. The chosen software is Arcview3. The interoperability provided by ArcView, for communicating with executable DOS files, have allowed to run a multicriteria program and to look at the results inside an ArcView project.

The future development will be the complete integration of two different routines; the consequences of this integration will allow to control and check the results of multicriteria directly in the view, in order to appreciate the different solutions in the map.

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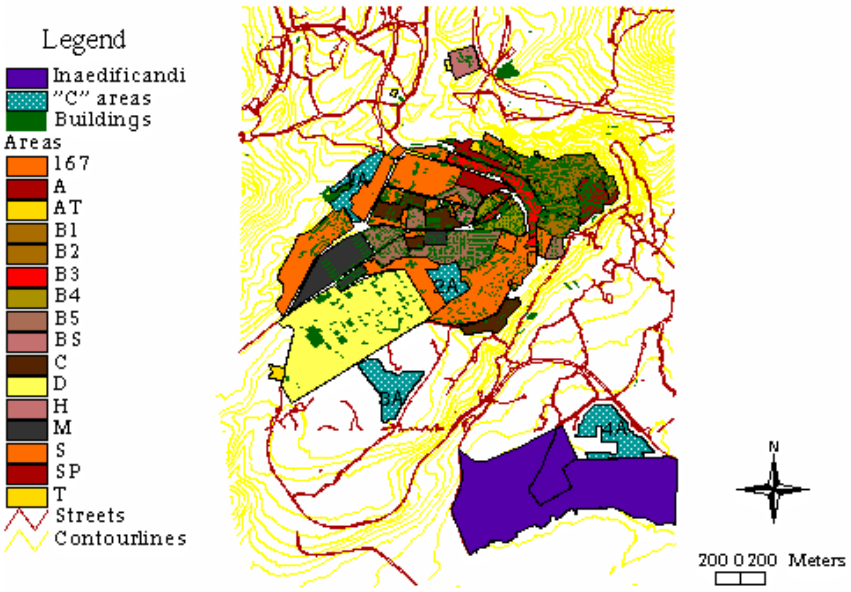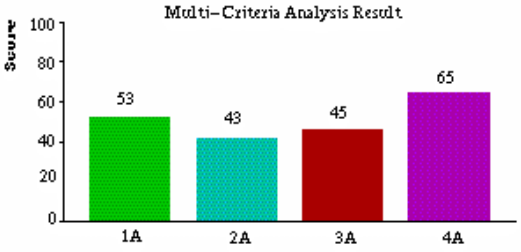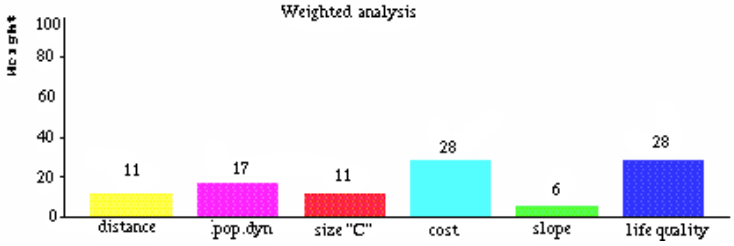
Multi-Criteria-Analysis Results