ICZM technologies for integrating data and support decision making

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Introduction

This paper aims to identify strategies for Integrated Coastal Zone Management (ICZM), coastal planning and sustainable development in north Adriatic using spatial modelling based on Geographic Information System (GIS). Geographic Information System (GIS) are valuable instruments to coastal managers in data integration and in identifying coastal impacts and conflicts, conservation "hot spots". GIS allows experimentation with various management approaches to working with coastal space planning and resources management (Vallega, 2005). Decision support systems (DSS), ecosystem modelling, and resource assessment allow users to put GIS data bases to their full use for individualized applications or research studies. GIS and GIS Based DSS are recognized widely as a valuable tool for managing, analyzing, and displaying large volumes of diverse data pertinent to coastal planning activities (at both local and regional scales). Its use in coastal management and planning is rapidly increasing. In European coasts, Industrial development, urban and infrastructure sprawl, fishing, gas extraction and tourism are activity conflicting and with high impact on environmental system. Hence, the strength of sustainable planning can be enhanced by GIS applications.

Materials and methods

The study analyzed 3 study areas in North Adriatic Italian coast: Venice, Rimini and Conero. Lagoon of Venice is characterized by an extraordinary mixing of activities: tourism, fishing, industrial areas (petrochemical plants). Rimini area is one of the most important beach tourist areas in Mediterranean Sea. Conero Area is in the Ancona Province, with an important industrial port and a petrochemical plant (API, Falconara). In spite of this, Conero is a wild mountain with a cliff coast; it is a park and Marine Protected Area with important ecosystems and geosystems.

The process of ICZM can be described by an integrated set of indices, at a geo-ecological level, modelling earth processes, human society and economy, and coastal uses at multiple scales (Vallega, 1999). The study describes a methodological approaches based on the integrated use of Geographic Information System (GIS) and Multi Criteria Decision Model (MCDM) to identify nature conservation and development priorities among the coastal areas. A geographic information system (GIS), and a geographic resources analysis support system (IDRISI™, Andes version) were used. IDRISI™ was used for the analysis of coastal changes and multi criteria analysis (MCA) (Eastman, 2006). A set of criteria were defined to evaluate coastal ecological status. Those criteria are space based following the landscape ecology methods and framework. Landscape ecology investigates the effect of the spatial arrangement of patches and corridors and related processes into a geographic area (Forman and Godron, 1986). Important applications to coastal management are the definition of Homogeneous Environmental Management Units (Brenner et al., 2006), the analysis of spatial and temporal structure, hierarchy and dynamics over multiple scales (Naveh and Liebermann, 1994; Marotta, 2006), the assessment of cumulative impacts and habitat loss in coastal ecotones (Thrush et al., 2008). GIS integrate and uses different data. For the landscape analysis and individuation, two Landsat satellite scenes were used for each study area.

The used indices and indicators for sustainability/health metrics were: Emergy, defined as all the available energy that was used in the work of making a product and expressed in units of energy (Odum, 1996); Exergy of a system, as the maximum work possible during a process that brings the system into equilibrium with a heat reservoir. When the surroundings are the reservoir, exergy is the potential of a system to cause a change as it achieves equilibrium with its environment. Exergy is then the energy that is available to be used. After the system and surroundings reach equilibrium, the exergy is zero (Jørgensen, 2006). Using land-use data and development-intensity measures derived from energy use per unit area, an index of landscape development intensity (LDI) can be calculated for the coastal zones to estimate the potential impacts from human-dominated activities. The intended use of the LDI is as an index of the human disturbance gradient (Brown and Vivas, 2005). The ecosystem function is measured using the biological capacity potential (BTC, Ingegnoli and Pignatti, 2007), based on resistance stability, vegetation type, and metabolic data of vegetation. Ecosystem services are based on the values calculated by Costanza et al. (1997).

Results

The value of indices and indicators are linked to the land/sea use. The resulting values of indices are calculated in the coastal fringe. The Sustainability weak and strong and the minimization are the used criteria. Having defined the criteria, the next step was selecting suitable indicators to measure the selected criteria. Subsequently the criteria were evaluated from industrial development, conservation and tourism development point of view. These criteria were then ranked

MCA and the results integrated into GIS. Several conservation scenarios are generated so as to simulate different evaluation perspectives. The scenarios are then compared to highlight the most feasible and to propose a conservation and development strategy for the coastal area. The generation and comparison of conservation and development scenarios highlighted the critical issues of the decision problem, i.e. the dunal and wetland ecosystems whose conservation and development relevance is most sensitive to changes in the evaluation perspective. Results shows the increasing during time of impacts and the need of governance of conflicts, unsustainability in resources use, urban and infrastructures sprawl, and pollution phenomena. Planning and management based on indices benefit from landscape ecology principles. For ICZM to advance and to make legitimate contributions to coastal sustainability, it must be practiced in a transdisciplinary manner – for it must meet the system knowledge, the needs of stakeholders, benefit from the support of decision makers, engage scientists and engineers and challenge planners and designers to innovate. The proof of its success depends on the extent to which real management follow-up programs, monitoring and systematic evaluations of long and short term results are made. This study represents an important contribution to effective decision-making because it allows practical results for both resource consumption and spatial planning.

A multi-time analysis of evolution of the landscape and a seascape was used as a baseline study. A balance of the coastal urban system was made in the study areas. As an example is presented in the Venice area (Figure 1, 2).

Decision support system is related to index and indicators. Indices and indicators for sustainability/health metrics are as follows. *Emergy* is defined as all the available energy that was used in the work of making a product and expressed in units of energy (Odum, 1996). The *exergy* of a system is the maximum work possible during a process that brings the system into equilibrium with a heat reservoir. When the surroundings are the reservoir, exergy is the potential of a system to cause a change as it achieves equilibrium with its environment. Exergy is then the energy that is available to be used. After the system and surroundings reach equilibrium, the exergy is zero (Jørgensen, 2006). Using land-use data and development-intensity measures derived from energy use per unit area, an index of landscape development intensity (LDI) can be calculated for the coastal zones to estimate the potential impacts from human-dominated activities. The intended use of the LDI is as an index of the human disturbance gradient (Brown and Vivas, 2005). The ecosystem function is measured using the biological capacity potential (BTC) (Ingegnoli and Pignatti, 2007), based on resistance stability, vegetation type, and metabolic data of vegetation. Ecosystem services are based on the values calculated by Costanza *et al.* (1997). Results are show in table 1.

Those scenarios are characterised by the parameters presented in the following Table 2. GAP and Coastal use conflicts are imposed as constraints for the scenarios.

Conclusion

A major problem in coastal management is the choice of the policy and the plan to be implemented. Multi-criteria analysis is a method of choosing between a set of alternative options on the basis of a set of defined evaluation criteria. Because non-monetary effects are becoming more important, a multicriteria method have to be used allowing a ranking of the alternatives on the basis of several criteria by only taking into account ordinal priorities, but also multicriteria analysis with multiple objectives is one of the most useful methods in order to integrate social preferences and economic and ecological values.

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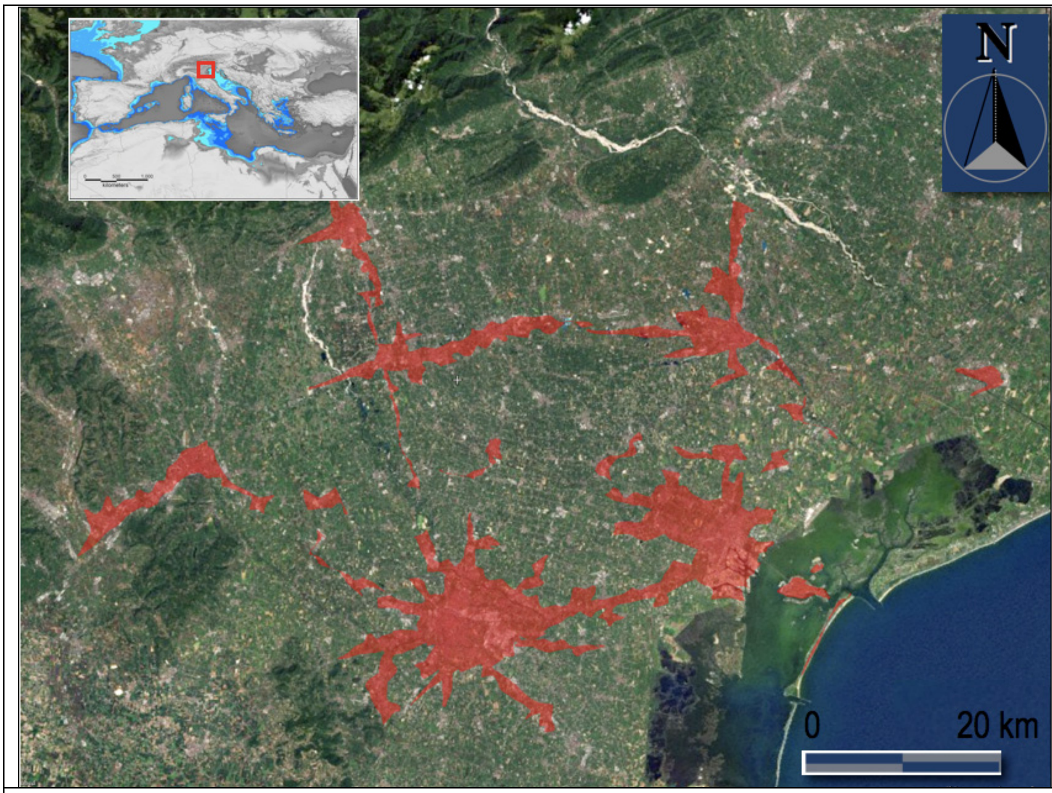

Figure 1. the coastal Metropolitan area of Venice, Padua and Treviso.

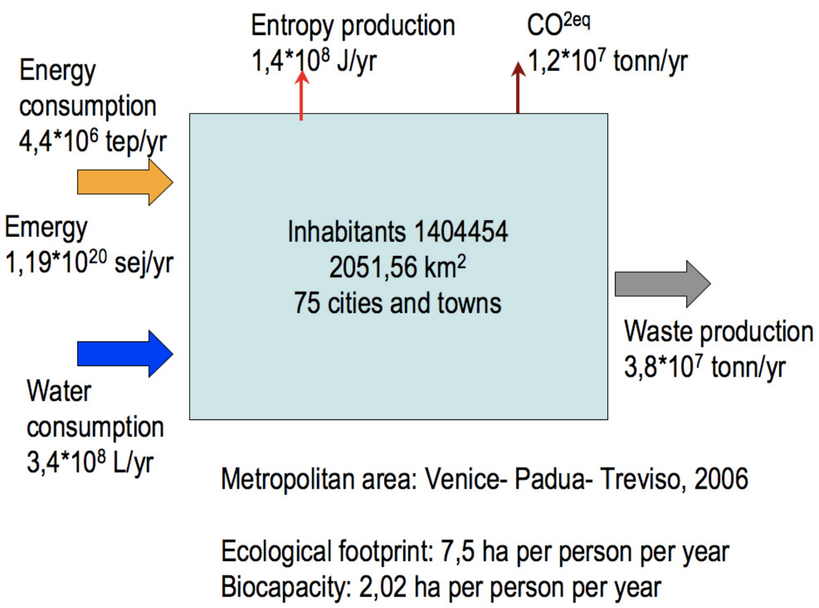

Figure 2. The system balance

	Lagoon of Venice	Rimini province	Conero area	Error
Non renewable Emergy (sej/yr) per ha	9.3E+16	5.5E+16	7.3E+16	20%
Renewable Emergy (sej/yr) per ha	2.6E+11	1.0E+10	1.0E+10	20%
LDI per ha	4.86	7,12	3.95	30%
Ecosystem value (euro) per ha	3.4E+03	9,2E+02	1.9E+03	10%
Human Value (euro) per ha	5.0E+05	7.9E+05	6.6E+05	30%
CO_2 absorption (tonn) per ha	3.8E+03	1.3E+03	3.6E+03	20%
BTC (J/yr) per ha	3.8E+10	0.9E+10	3.6E+10	15%
Exergy (J) per ha	5.8E+09	1.9E+09	6.0E+09	20%
Percolation in coastal area (5 km)	0.71	0.39	0.89	5%
Natural habitat Loss in total area (1970-2001*)	2.29E+3	4.11E+3	1.87E+4	5%
Total Area (ha)	255512	15988	89848	>0,1%
Sea Area (ha)	94520	71770	37890	>0,1%
Coastal Urban and Infrastructure in total area Sprawl Index (1970-2001*)	7.8	7.5	7.6	10%
Coastal use conflicts	0.85	0.41	0.53	5%
Ecological footprint (global hectares)	6.6	10.4	4.9	20%
Threshold: biocapacity (global ha)	1.6	0.44	2.1	20%
GDP (total per year, 2004), euro/ha	8.7E+4	1.8E+5	7.2E+5	10%

Table.1. Table of Coastal sustainability indices and constraints for the case studies. The value of indices and indicators are linked to the land/sea use. (*) First year of analysis for Venice is 1972, for Rimini is 1975, for the Conero area is 1976.

Scenario at 2015	Lagoon of Venice	Rimini province	Conero area	Error
Ecological footprint (global hectares) (at the actual level of consumption)	7.2	7.9	6.6	>20%
Threshold: biocapacity (global hectares)	1.8	0.91	2.1	>20%
Gap, unprotected areas	0	0	0	5%
Coastal Urban and Infrastructure Sprawl Index	3.2	3.1	3.1	>20%
LDI per ha	5.12	7.63	4.23	30%
Percolation in coastal area (5km)	0.68	0.32	0.85	5%
Coastal use conflicts	0.10	0.10	0.10	5%

Table 2. Table of results for final decision scenario. In light yellow are outlined the parameters used as constraints.