ENVIRONMENTAL PLANNING MODEL AT THE BASIN SCALE ACHIEVED USING SATELLITE REMOTE SENSING DATA AND GEOGRAPHICAL INFORMATION SYSTEMS

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ABSTRACT

The extreme complexity of the environmental problems require together with the recent establishment of the Environmental Information System of Italy (SINA) and the introduction of a soil protection law the development of methodologies of analysis and research that lead land planning to be a more efficient and dynamic tool of environmental management.

In the present paper it is reported the proposal of a new environmental planning model thought as a continuous process of territorial management, at basin scale, coherent with the hydrogeological reclamation and the lowering of the water pollution hazard.

KEYWORDS

Environment, water management, land planning, GIS, remote sensing, basin scale, methodology, Italy.

ENVIRONMENTAL PLANNING IN ITALY

In Italy there is a huge production of environmental data that are not linked yet to a national environmental network as it is supposed in the European Economic Community (EEC) requirements (Nespoli, 1992). Moreover, those data are not related to an environmental national project of natural resources uses control, consequent transformations and emergencies resolution (Ziparo, 1988; Cardarelli et Al., 1991b).

A little step toward the resolution of the first of these two problems has been the establishment of the Environmental Information System of Italy (SINA), not working yet and already blamed because, according to Nespoli (1992), it will not able to act as the E.P.A. in dealing with the complexity of the environmental problems. The second problems has been resolved, on the institutional point of view, with the introduction of a law (n.183/89) in matter of soil protection (Gisotti & Poliandri, 1992), operating at the basin scale.

Nevertheless, a great importance should be given to the environmental methodological approach in the context of land planning models. The present land planning method, based mainly on the economical input, is responsible for the lowering of the environmental quality of urban life.

It is needed to develop a methodology of analysis and research that leads "land planning to be thought as a continuous external input process direct to a dynamic system controlled by itself" (C.N.R., 1987) overcoming the traditional town-planning limits, based only on the zoning approach and compelling the acceleration of the economic system to respect the natural assimilation time of transformations (Cardarelli et Al., 1991b).

This can be achieved dealing with environmental and territorial problems in a systemic way, through a multi-disciplinary work (Cardarelli et Al., 1991c) and making use of techniques and instruments (i.e. Remote Sensing and GIS), that allows a real time representation of territorial development processes in order to optimize the decision choices considering all the involved features and reducing the complexity (Jemma et Al., 1992).

The combined action of the use of the Environmental Information System, of the application of the soil protection law at the basin scale and of the new environmental planning model, here proposed, can lead the static land planning model to be substitute by a dynamic one.

According to this, the aim of the research of the National Research Council (C.N.R.) Strategic Project "Clime, Environment and Territory in Southern Italy" undertaken in the Institute of Land Planning of Naples is to focus and to check methods, techniques and instrument routines that fit the characteristics of a typical southern italian basin area: the Sarno valley, Campania (Cardarelli et Al.1991a).

The aim of the research (Cardarelli & Jemma, 1989) is definition and its experimentation of a new methodological iter of environmental planning thought as a continuous process of territorial management coherent with the hydrogeological reclamation of the study area and the reduction to the minimum level of the water pollution hazard.

THE SARNO VALLEY PILOT EXPERIMENT

The Sarno valley (fig.1), southern Italy, is a coastal area approximately 27 x 33 Km. It lies to the south and south-east of the Vesuvius volcano and borders the

Tirrenian sea. It embraces 36 Communes (fig.2), including some well-known tourist sites such Pompei, that belong to three different districts (Cardarelli et Al., 1990).

It is an area with a considerable number of environmental problems typical of the Mediterranean. Planning and environmental regulations are poorly respected. The valley is heavily built-up and contains a wide range of industry and horticulture. Does not exist a sharp distinction between urban and agriculture areas and within the urban class, residential, commercial and industrial are closely interlaced (Cardarelli et Al., 1990). The agricultural assets of the area is very scattered generally with fields less wide than 1/3 of hectare. The field cultivation is of intensive type with two crops for year. The most important cultivations are wheat, rye, barley, oats, orchards, vineyards, tomatoes and flowers (mainly in greenhouses).

On the geological point of view the Sarno valley represents the extreme southern end of the Campania graben. The hydrogeological unit of the Sarno Valley comprises mainly loose piroclastic sediments and tuffs with less sea and marshy sediments (Celico., 1978). The permeability characteristics are of medium level for porosity and leaking.

Overall the region has a serious water management problem and the river system which runs down the valley is badly polluted. The very rich groundtables (more than 100 millions of cubic meters per year coming from the surrounding calcareous rocks, without considering the direct water infiltration) (Cassa per il Mezzogiorno, 1983) met the water demand for the growing residential and industrial development of the area and for the extensive horticulture.

Although discharges from industries are supposedly limited, restrictions imposed on companies are not always obeyed. The industrial pollution and the lack of adequate sewage facilities (the sewage network has been built only for the 5% of the total projected length) is putting the underground water system and the costal sea area under serious threat. Measurements of the biological pollution levels, in the main rivers of the valley and in their outlets, range from 2 to 44 times the EC limits (Ortolani & Pagliuca, 1988).

THE ENVIRONMENTAL PLANNING MODEL

The environmental planning method of the water resources, here proposed has been achieved making use of the classical relational data-base (RDB) architecture (Atzeni et Al., 1985; Cardarelli et Al., 1991c) throughout:

a) analysis of the research problems;
b) data identification in term of attributes, relative domains, availability, costs, and system implementation;
c) definition of the GIS relations necessary to the research methodological iter;
d) normalization of the RBB architecture in order to eliminate the management anomaly and to simplify the GIS use.

Moreover it has been necessary to consider the multi-disciplinary characteristic of the research subject in term of GIS relations scheme.

On the water resources point of view the environmental planning study, comprehensive of anti-polluting, guardianship and water management project, includes (Cardarelli et Al., 1991b):

- the hydrodynamic knowledge of the subsoil;
- the knowledge of the evolution of the water polluting index through the ground percolation;
- a census of all water wells (with watertables depth) and springs and water use destination;
- a surface and subsoil water quality monitoring (for one year);
- a census of all activities that allow water polluting hazard;
- a sewer and aqueduct status.

The data set (fig.4) has been structured in three main groups (Besio, 1991; Janssens, 1991; Jemma et Al., 1992):

1) the "Resources", or the natural system that represents the environmental picture in terms of potentiality and vulnerability;
2) the "Uses", or the anthropic system that describes the kind of use for each element of the natural system;
3) the "Management", or social, economic and political system that governs the previous.

Within each single group of the data scheme (fig.5) only the relevant features (subject) has been chosen, selecting the data classes (description) and their fonts (static or dynamic), forms (spatial or descriptive) and attributes (Cardarelli et Al., 1991a). At this step it is possible to assign a weighted index to each data in order to allowed, in the next processing steps, a subjective analysis.

The data processing structure (fig.7), planned through five successive steps, is characterized by a complexity increase contemporary with a synthesis level increment and by the possibility to process dynamic information. (Cardarelli et Al., 1991a). In this way it is possible to distinguish between a first processing level, where data integration is absent and there is only a data modification in function of assigned variables, and upper processing levels, where the data overlay is achieved in relation with the topics to develop.(Fig. 6)

For the experimentation in the Sarno Valley 36 graphic maps (regarding the DTM and the land use of the area, the hydrogeological characteristics, the urban growing and the water supply and sewage networks, etc.) and 38 tables (regarding the social and economic statistics) has been automated.

The data sets, organized in 27 coverages (Jemma, 1992) and processed by an Arc/Info system, give a synthetic picture of the real status (fig.7) of the Sarno valley in terms of the water needs and water polluting activity in the context of the environmental planning.

This final map has been achieved overlaying the potential vulnerability water pollution map, the water quality supply map, the water polluting letting in map and the water pollution abuses map. Ascribing some variable (i.e. time) or making some data modification to the data set of the first processing level the final representation (fig.7) begins a trend line or a projectual option respectively.

SATELLITE REMOTE SENSING APPLICATION

Due to the lack of up-to-date land-use information (the available cartography includes only a 1957 and 1984 topographic maps and a 1960 land-use map) the land-use development of the Sarno valley in the following 9 years after the Irpinia earthquake event (23/11/80) has been detected with three LANDSAT TM scenes (1988/89 - late summer, winter and spring time) and a SPOT PAN 1989 scene.

The SPOT PAN frame of 27 x 33 km has been UTM map projection system rectified (with 31 ground control points sampled, the Cubic Convolution re-sampling method with the 2nd order of transformation applied and an Erdas Disk Convolution enhance used). This image has been utilized to record the network of roads and the urban rise from 1984 to 1989, and to map the bigger industrial areas and quarries with a potential polluting activity.

The combined use of the existing cartography and the SPOT image has led (Cardarelli et Al., 1991b) to the reconstruction, through four main steps, of the urban rise model in the Sarno valley: 1) a progressive urban increase around the historical urban nucleus; 2) a following urban increase along the most important roads; 3) a linear urban melting among towns; 4) an urban spreading (today still alive) in the remaining country sides and its progressive urban density increase.

The LANDSAT TM frames of about 27 x 33 Km have been UTM map projection system rectified (with 30 ground control points sampled for each frame and the Nearest Neighbor re-sampling method with the 2nd order of transformation applied). Image classification of a very scattered built areas of heterogeneous nature has been attempted.

According to the very scattered land-use characteristic of this typical southern italian area, the combined use of LANDSAT TM and SPOT PAN imagery (Jemma, 1992) has been found quite reliable to produce a land-use supervised classification with level-I, some level-II and very few level-III classes (fig.3) of the USGS land-use and land-cover multilevel classification system (Anderson, 1976).

Multi-temporal analysis has been used to detect the seasonal changes of the fields under cultivation. A very careful training samples evaluation on site and a SPOT/LANDSAT merge has been used to distinguish the residential vs. industrial classes, industrial vs. greenhouses-horticultural classes and crops vs. orchards classes (Jemma et Al., 1992).

The Euclidean distance classifier has been found more reliable than others classifier techniques to distinguish among the level-I classes (Thomas et Al., 1987). Without considering any within class variability (in this area it is very high) we selected one class at a time from the most suitable scene and thresholded for each class all unclassified pixels become classified. In order to take the most variable into consideration the Maximum Likelihood classifier has been used (Mather, 1987) to distinguish within the level-II land-use classes and then thresholded. Next step would include knowledge base systems application (Wilkinson et Al., 1991) in order to reduce the misclassification degree.

CONCLUSION

The use of satellite remote sensing and geographic information systems (GIS) can lead to a better environmental management of the Sarno valley area and to more effective regional planning.

Satellite data (LANDSAT TM and SPOT PAN) have been used to derive the land-use map of the area and land-use statistics which can then be input to the environmental planning model of the basin, here presented, using also GIS datasets.

The GIS data processing structure is characterized by a complexity increase contemporary with a synthesis level increment of the information. An Arc/Info PC system has been used to processing 27 coverages (regarding environmental, urban, social, economic and administrative features).

The final map, achieved overlying of the potential vulnerability water pollution map, the water quality supply map, the water polluting letting in map and the water pollution abuses map, shows the real picture of the water needs and water polluting activity in the context of the environmental planning.

The further possibility of this dynamic environmental planning model is the continuous testing in relation with different land planning projects and the up-to-date of the system throughout the monitoring of the environmental evolution processes.

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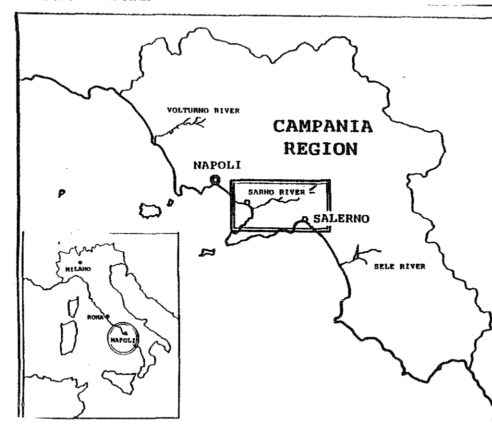

Fig.1 The area of study.

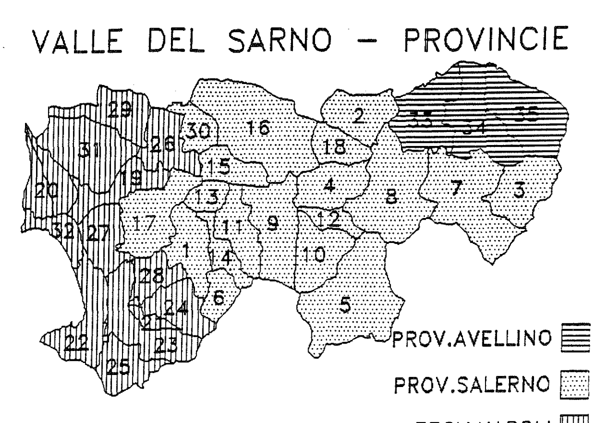

Fig.2

	SALERNO		NAPOLI		AVELLINO
1	ANGRI	19	BOSCOREALE	33	MONTORO INF.
2	BRACIGLIANO	20	BOSCOTRECASE	34	MONTORO SUP.
3	CALVANICO	21	CASOLA DI NAPOLI	35	SOLOFRA
4	CASTEL S.GIORGIO	22	CASTELLAMM.DI STABIA		
5	CAVA DEI TIRRENI	23	GRAGNANO		
6	CORBARA	24	LETTERE		
7	FISCIANO	25	PIMONTE		
8	MERCATO S.SEVERINO	26	POGGIOMARINO		
9	NOCERA INF.	27	POMPEI		
10	NOCERA SUP.	28	S.ANTONIO ABATE		
11	PAGANI	29	S.GIUSEPPE VESUVIANO		
12	ROCCAPIEMONTE	30	STRIANO		
13	S.MARZANO SUL SARNO	31	TORRE ANNUNZIATA		
14	S.EGIDIO MONTEALBINO	32	TERZIGNO		
15	S.VALENTINO TORIO	20a	TRECASE		
16	SARNO				
17	SCAFATI				
18	SIANO				

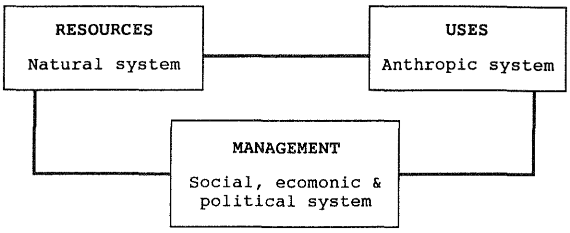

Fig.4 The data set scheme.

RESOURCES	SOIL	MORFOLOGY GEOLOGY PEDOLOGY ETC	
	VEGETATION	FOREST GRASSLAND ETC	
	WATER	RAINLESS HYDROLOGY HYDROGEOLOGY	
	AIR		
USE	LAND	URBAN	SETTLING MOBILITY ORGANIZATION ETC
		AGRICULTURAL-PASTURE	CROPLAND OCHARDS PASTURTE INACTIVE ETC
		NATURAL	FOREST SHRUB-BRUSH ROCKS WATER
	WATER	WATER SUPPLY SEWAGE ETC	
	AIR		
MANAGEMENT	ISTITUTIONAL	BORDERS PLANS LAWS	
	ECONOMIC	PRIMARY SECONDARY TERTIARY	
	POPULATION	DISTRIBUTION GROWING ATTIVITY SOCIAL LEVEL AGE-SEX	
	SERVICES	PUBLIC PRIVATE	

LEVEL - I	LEVEL - II	LEVEL - III
URBAN or BUILT-UP	RESIDENTIAL	Heavily built-up (dense) Lightly built-up (diffuse)
	INDUSTRIAL	Large industrial areas Extractive
	TRANSPORTATION	Major roads and Highways Railroads Port areas Auto parking areas
	RECREATIONAL	Parks Stadiums
	OPEN LAND and OTHER	Undeveloped land
	MIXED	
AGRICULTURE	CROPLAND	
	PRODUCTIVE ARBOREOUS	Citrus orchards Nut orchards Vineyards
	OTHER AGRICULTURE	Flowers in greenhouses
RANGELAND	GRASSLAND	
	SHRUB and BRUSHLAND	
FOREST LAND	EVERGREEN FOREST	Pine
	DECIDUOUS FOREST	Oak, holm, acacia
	BURNED AREAS	
BARREN LAND	EXPOSED ROCK	
WATER	STREAMS and CANALS	
	LAKES and PONDS	

Fig 3. The land-use classification system for this area.

			DATA	STRUCTURE			
SISTEM	SUBJECT	DESCRIPTION	SOURCE		TYPE		
					Geographic		Description
			STATIC	DYNAMIC	VECTORIAL	RASTER	ALFANUMERIC
RESOURCES	Morphology	Contour lines	IGMI		Lines		Elevation
	Geology	Lithology	SGN, Univ.		Polygons		Borders, type
	Hydrology	Hydrogr. netw.	IGMI		Lines		Class, lenght
	Hydrogeology	Hydrogeol. compl.	Gov., Univ.		Polygons		Type, area
		Groundtables	Gov., Univ.		Lines		depth,
		Hydro-structure	Gov., Univ.		Lines, points		Texture, etc.
	Hydrochemical	Water monitoring	Univ., Priv.	Monitoring	Lines, points		Concentr., etc.
	Meteorology	Raininess	Statistics	Monitoring	Polygons		Area, mm
USES	Land uses	Agricultural	Reg. Gov.	Landsat, Spot	Polygons	OK	Type, area
		Industrial	IGMI	Landsat, Spot	Polygons	OK	Type, area
		Residential	IGMI	Landsat, Spot	Polygons	OK	Type, area
		Extractive		Landsat, Spot	Polygons	OK	Type, area
		Forests	Reg. Gov.	Landsat, Spot	Polygons	OK	Type, area
		Farms	Reg. Gov.	Landsat, Spot	Polygons	OK	Type, area
	Mobility	Network	IGMI	Landsat, Spot	Lines	OK	Type, area
	Water system	Aqueduct netw.	Reg., Priv.		Point		Type
		Sewers netw.	Reg., Priv.		Point, polygons		Type
	Solid waste	Gathering	Reg., Priv.		Point		Type
MANAGEMENT	Istitutional	Borders	IGMI		Polygons		Area
		Plans	Loc. Gov.		Polygons		
		Laws	Gov.		Polygons		
	Social	Population	Statistics		Polygons		Many
	Economic	Productivity	Statistics		Polygons		Many

Fig.5 Data structure within each single group of the data set scheme.

			FIRST PROCESSING LEVEL		
	THEMATISM	VARIABLE	REPRESENTATION		
			Cartography	Tables	Charts
R 1	Slope	Class	Polygons	% value	% class
R 2	Stratigraphy	Class	Polygons	Depth	% type
R 3	Order	Class	Lines	Class lenght	% class
R 4	Permeability	Class	Polygons	Type, charact.	% class
R 5	Water flow direct.	Time	Lines	Charact.	% type
R 6					
R 7	Water quality	Class	Points, polygons	Charact.	% class
R 8	Infiltration	Time	Polygons		% time
U 1	Area decrease	Time	Polygons	Agric. pollut.	% class
U 2	Number increase	Time	Polygons	Ind. pollut.	% type
U 3	Area increase	Time	Polygons	typology	% class
U 4	Number increase	Time	Points, polygons		% type
U 5	Area variation	Time	Polygons		% class
U 6	Number increase	Time	Polygons	carat.	% type
U 7	Lengh increase	Time	Lines	carat.	% type
U 8	Water qual. needs	Class	Points, polygons	carat. type	% class
U 9	Lengh increase	Type	Points, polygons	flow	% type
U 10	Number increase	Type	Points	carat.	% type
G 1	Modification	Area	Polygons		
G 2	Modification	Kind	Polygons	Regul. changes	
G 3	Modification	KInd	Polygons	Environ. change	
G 4	Number variation	Time	Polygons	Age	% class
G 5	Variation	Time	Polygons	Charact.	% class

Fig.6 First elaboration level.

Fig.7

WATER AND ENVIROMENTAL PLANNING

Methodological path - data processing leves