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D5.2 Material for the on-line training courses
D5.3 Report on meetings in each site
D5.4 Internet knowledge base structuring
D5.5 Internet knowledge base development – experimental phase
D5.6 Internet knowledge base

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Spatial Decision Support Systems, GIS, Multi-Criteria Analysis, knowledge base, training.

ABSTRACT

This report aggregates the deliverables of WP5 concerning the application of Decision Support Systems for training purposes

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D5.1 Definition of lines for training courses for scenario simulation using the SDSS (Proposal to stakeholders)

Preface

The aim of this deliverable was to define a set of topics and tools useful for involving the stakeholders in participating to scenario simulation in coastal zone management using the information technology of Spatial Decision Support Systems.

The problem of integrated coastal zone management participation was discussed by the Trieste team in BRAZIL (Feoli) and Chile (Feoli and Ianni). This report discuss the methodologies that the coastal zone managers should know and/or acquire in order to be part of the integrated network discussed in the deliverable 4.17.

1. Introduction

Integrated Coastal Zone Management (ICZM) is an holistic approach that considers both water and land management. Under this perspective the ICZM requires an integrated knowledge about the several aspects of the coastal landscape: chemical – physical, geo-morphological, biological, sociological, economical and institutional as suggested by Spangenberg (2002) and Ahern (2005). The integration between human and environmental disciplines is a complex matter that is out of a real control and planning of the scientific community. We have to admit that scientific integration is a result of a "self organisation" of the scientific system which is evolving following the evolution of "human needs". New disciplines are emerging by the spontaneous integration of scientific disciplines. Landscape ecology (Farina 2000) is a typical example that was born to face and solve complex problems related to sustainable landscape planning.
Landscape ecology and ICZM are strongly interconnected since spatial planning of the socio-economic development cannot ignore the spatial pattern of the land and water resources. This interconnection requires the multidisciplinary analysis of the landscape and a transdisciplinary action in which members of professionals, non-academic and academic bodies participate in a process in which knowledge is shared across disciplines and all participants are engaged in decision making (Cundill et Al. 2005). According to Ahern (2005) "Under the transdisciplinary model, planning may become more integrated with research, enabling the multidimensional challenge of sustainability to be understood more rigorously with many disciplines involved, and the public (i.e. stakeholders, elected officials) are similarly involved in planning and decision making. The level of transdisciplinarity has become a key indicator of rigorous sustainability". It follows that sustainable ICZM needs a Spatial Decision Support System (Malczewski 1999) that should keep into consideration the principles of landscape ecology.

2. Landscape ecology: a "multidisciplinary"discipline for ICZM

Landscape ecology is dealing with the integrated socio-economic-institutional-ecological system of "pieces of land" with the ambitious aim of "unifying" the views and actions of environmental and human sciences to understand the system and to plan a sustainable development of the real world. It is the ecological discipline dealing with "spatial ecology" at "landscape level". However the "landscape level" is a vague concept owing to the possibility to define landscapes at different scales. Several landscape ecologists indicated the proper scale as corresponding to "human perception scale", but this is strongly questionable. The basis for a sound discussion about the matter are settled by Forman (1995), who considers the hierarchical aspect of landscape

- Landscape

Within the many definitions of the term landscape the one proposed by Farina (2000) is one of the most simple and general. He suggests that: “we could define landscape as “a piece of real world” in which we are interested in describing and interpreting processes and patterns”.

When such “a piece of real world” is selected for a study, it automatically represents a complex system (landscape system) with geographically located states determined by all the spatial interactions between man, plants, other living organisms and the chemical-physical environmental factors.
A landscape may contain one or several ecosystems that are interacting. The interactions between them are given by material, energy and information flows. Ecosystems can be defined in different ways and at different scale depending on the aim of the study for this reason O’Neill (2001) started to question about its use for environmental management. Without entering in a “vague” debate we prefer to consider landscape and ecosystems as operational concepts (Biondi et Al 2004) that can help to understand the noosphere (Vladimir Ivanovich Vernadsky, Владимир Иванович Вернадский, 1863 -1945), namely the system given by man, biosphere and geosphere at different hierarchical levels. Superficial water (rivers, torrents, lakes etc.) and underground water bodies, are essential components of the landscape both at small scale and at large scale.

***- Landscape units and data integration for* ICZM**

The PATCH is the fundamental unit in landscape ecology, it is considered a piece of land that is “homogeneous” and distinct from its surroundings. The patches are the result of the interaction between land use and geomorphological and environmental features of the landscape. The patch may have different shape and size and may be easily detected by visual inspection. Patches can be detected also on maps and in remote sensing images. Rivers and lakes are patches that condition the distribution of the other patches corresponding to states of natural and/or artificial ecosystems defined by land use.
Also underground water bodies are patches and even if they are not visible, they are conditioning the natural and/or artificial “above ground” ecosystems. The first ones are conditioned directly the deepness of the water table, the last ones by the possibility to extract and use ground water by means of wells. Patches may be connected giving rise to networks or may be isolated. When a patch is showing high connection with other patches of the same type and it corresponds to the dominant land cover of a given landscape, it is called the matrix of the landscape (Farina 2000), however such term should be avoided because matrix is a mathematical term for a tool that is routinely used in science including landscape ecology. Landscape ecology is not studying the single patches, but mosaics of patches that constitute the landscape system. Landscape ecology analyses the quality of the patches, their spatial characteristics (shape, area, numbers, fragmentation, networking etc.) and the relationships between them both in spatial terms (proximity, contacts etc) and in terms of transfer of material, energy and information. Water irrigation is a clear example of transfer of material, “water”, from one patch (the water body) to other patches (croplands). Water transfer from water bodies to urban areas or industrial areas is another example of transfer of material between patches. The transfer of agricultural products from the agricultural lands to urban areas and the transfer from industrial products between different areas are other examples of transfer of material between patches. The transfer of energy from an hydroelectric power station, close to an artificial lake, to a city is an example of energy transfer from the patch “lake” to a patch “city”. The networks of roads and railways represent systems of patches that have the role of transferring material, energy and information between other type of patches. The transfer of information between the patches is a very complex matter being the information transfer done in many ways by several organizations, companies, institutions, with different technologies and tools (books, journals, television, radio, conferences, meetings, satellites, internet etc.).

The patches may be described by different variables depending on the aim of a study, however if we are interested in ICZM, patches have to be described also in terms of water demand and water use beside other variables from socio-economic and from environmental points of view. A set of patches can be described by a matrix in which the patches are in rows (or columns) and the variables describing them are in columns (or rows). The variables describing the patches have to be chosen in function of the problem to be solved.

- Operational Geographic Units (OGUs)

The integrated description of landscape can be achieved by different ways, however the description of the patches is the basis for the description of the entire landscape. Patches may be considered isolated or associated in mosaics included in heterogeneous or "composite" landscape units of higher hierarchical level. The units to be used in landscape studies are defined on the basis of the aim of the study. They are sampling units, which are supposed to represent in a satisfactory way a landscape at a given time in a given geographical area. These sampling units are parts of the landscape and may have different shapes (cells of grids, polygons of different shape, e.g. Thiessen polygons, circles etc.) that can be defined arbitrarily or on the basis of geomorphological criteria (watershed, geomorphological landscape types etc.) and/or administrative criteria (administrative units). It must be clear that the units have an operational meaning, for this reason they are called Operational Geographic Units (OGU). The concept of Operational Geographic Unit (OGU) was defined as the basic cartographic element for understanding biogeographical patterns by classification and ordination techniques. It is analogous to the concept of Operational Taxonomic Unit in numerical taxonomy (Sneath and Sokal 1973) with the only difference that OGU is a georeferenced unit. The concept of OGU has been already introduced in GIS context by Feoli and Zuccarello (1996) to describe ecological processes in space and time. OGUs may be used to store information in data bases or to develop models of landscape dynamics. With the help of GIS technology (Aronoff 1989, Malczewski 1999) it is easy to describe the OGUs in terms of spatial variables and other variables stored in data bases (Feoli and Zuccarello 1996).

- Landscape from a mathematical point of view

Landscape is a complex system with states determined by all the interactions between man, plants, other living organisms and the chemical-physical environmental factors (Dragan et Al 2008). The following are points that have to be taken into consideration for ICZM in the landscape perspective:

1) In analogy with ecology, landscape ecology is dealing with a multidimensional space (ecological space), that may be called landscape ecological multidimensional space (LEMS). This is a dynamical space that according to the general system theory (including the chaos theory, complex system theory, self organisation system theory etc.) is the phase space (von Bertalanffy 1968; Ulanowicz 1997). If we consider the DPSIR (Driving forces, Pressures, States, Impact, Responses) model of SEA (Strategic Environmental Assessment) supported by the majority of national environmental agencies (Therivel 2004, Dalal-Clayton and Sadler 2005), the land use may be considered the result of the driving forces behind the economy of the area where the landscape is located. As consequence of different land uses different land cover types and land cover patterns are emerging. They correspond to the man-made ecosytems (or artificial ecosystems) that may have different degrees of naturalness (Maarel 1975, 1980, 1993). The same land use may produce different land cover types depending on several factors such as the type of ecosystems involved and their reaction to the impact, the way in which a land use is implemented, the intensity of land use etc. The land use of a given landscape is the result of choices made between different alternatives considered appropriate (or good enough) in that area to reach some economical goals (generally income growth). Today the choices of land uses are almost always and

everywhere mediated and/or supported by local, national and international policies (Nijkamp and Vindigni 2003) notwithstanding a certain degree of freedom is still in the hand of the land owners.

2) In this space the land use types have trajectories towards stable positions (attractors) as the species and communities have in the ecological space (the ecological niches). A land use type can be considered as the phenetic-functional expression of socio-economic driving forces and their interactions with the ecosystems. As species and communities have their niches in the ecological multidimensional spaces (Feoli, Ganis, Zerihun 1988), land use types have their "niches" in LEMS. This space is defined by all the variables (landscape variables) that are influential (factors or driving forces natural and "artificial"), and the variables that are influenced and that at the same time may have feed- backs to the system such as the shape and spatial pattern of the patches.
3) Land use type niches may be partially or completely represented by a matrix **X** where rows (or columns) are the chosen variables and the columns (or rows) represent the land uses types. In this case the columns are patches of land use type that represent the OGUs of the landscape. In the multidimensional space generated by matrix **X**, each variable has a number of co-ordinates equal to the number of OGUs and each OGU has a number of co-ordinates equal to the variables that are describing it, however the dimensionality of the space represented by **X** is equal to the number of positive eigenvalues of **X**. Variables and OGUs may be seen as vectors with a common origin, namely the origin of LEMS. Furthermore, it should be always kept in mind that **X** is a data matrix that may represent only partially the complex system of the chosen landscape because only the variables of interest are taken into consideration.
4) The dimensionality (rank of the matrix) of LEMS is the minimum number of orthogonal axes that are able to get the projections of all the OGUs and all the variables. Only the variable or OGU with all the co-ordinates equal to the co-ordinates of the origin of the space do not have axes where to be projected. The orthogonal axes are the reference system for variables and OGUs. They give the minimum number of co-ordinates necessary to correctly positioning variable and OGUs in the multidimensional space. These axes are also used to represent the space by a reduced number of dimensions. Their efficiency in doing this is measurable. **X** may be divided into sub-matrices on the basis of the kind of variables used to describe the OGUs: e.g. **X**(1) matrix of biological variables, **X**(2) matrix of environmental variables, **X**(3) matrix of socio-economic variables, **X**(4) matrix of human impacts, etc. However the integrated way to analyse the landscape has to take into consideration all these multidisciplinary matrices.

5) Each matrix **X**(i) is the matrix representing the states of landscape system according to some set of variables. The study of the correlation between different matrices and thus between sets of different variables is possible by many mathematical methods. Mantel's test is one of them based on permutation techniques (Mantel 1967, Mantel and Valand 1970, Manly 1997).

6) The spectral and singular value decomposition theorems of matrix algebra are fundamental to deal with matrices describing the landscape in analogy with what happen for community analysis (Feoli 1998) for ICZM. The theorem of spectral decomposition says that a symmetric matrix **S** of rank p can be decomposed by the following three matrices:

   S = **T** □ **T**' (1)

   where **T** is an orthogonal matrix (mxp), i.e. $\square_i{}'\square_h = \tilde{}$, □ is a diagonal matrix (pxp) and **T**' is the transposed of **T**. □ is the matrix of the p positive eigenvalues of **S** that are disposed in decreasing order. **T** is the matrix of standardized eigenvectors of **S**.

- □ may be calculated by the characteristic equation of eigenvalues:

det (**S**- □**I**) = 0

where *det* means the determinant of the matrix ($\mathbf{S}-\square\mathbf{I}$), $\square$ is a scalar and **I** is the identity matrix (i.e. a matrix with ones along the diagonal and zeros outside). Out of this equation only the positive p solutions are considered in the diagonal matrix $\square$. Once calculated the p positive eigenvalues ($\square i$, $i=1,...,p$), **T** may be obtained by solving p times the system of equations:

$$(\mathbf{S}-\square i\mathbf{I}p)\square_i = \mathbf{0} \qquad (2)$$

The singular value decomposition theorem says that given a rectangular matrix **X** of m rows and n columns (mxn) of rank p it can be decomposed in the following product of three matrices:

$$\mathbf{X} = \mathbf{U}\square\mathbf{V}' \qquad (3)$$

where **U** is an orthonormal matrix (mxp) ($\mathbf{U}'\mathbf{U} = \mathbf{I}p$, identity matrix), **V** is an orthonormal matrix (nxp) ($\mathbf{V}'\mathbf{V}=\mathbf{V}\mathbf{V}'= \mathbf{I}p$) and $\square$ is a diagonal matrix (pxp) with positive elements.

If we consider that:

$$\mathbf{X}'\mathbf{X} = (\mathbf{U}\square\mathbf{V}')'\ \mathbf{U}\square\mathbf{V}'$$

it follows that

$$\mathbf{X}'\mathbf{X} = \mathbf{V}\square'\ (\mathbf{U}'\mathbf{U})\ \square\mathbf{V}'$$

and since $\mathbf{U}'\mathbf{U} = \mathbf{I}p$ it follows that

$$\mathbf{X}'\mathbf{X} = \mathbf{V}\square^2\mathbf{V}'$$

on the other hand

$$\mathbf{X}\mathbf{X}' = \mathbf{U}\square^2\mathbf{U}'$$

and since both **X'X** and **XX'** are symmetric matrices (**S**) the theorem of spectral decomposition holds true. From this it follows that the eigenvalues of the two symmetric matrices are the same.

The relevant implications of these two theorems for exploring multidimensional (multidisciplinary) spaces of **X** (or **X**(1), **X**(2), **X**(3), etc.) are the following:

a) each numeric matrix **X**, i.e. a matrix for which it is possible to apply the product matrix (**X'X**) or (**XX'**), may be represented by two sets of orthogonal axes that may be used to order column vectors (objects) and the row vectors (variables) simultaneosly by biplot graphs (Gabriel 1971; ter Braak 1995). The efficiency of the representation is given by the ratio between the sum of the eigenvalues corresponding to the eigenvectors used for ordination and the total sum of eigenvalues;

b) for any numeric symmetric matrix **S** obtained in some way from **X** it is possible to compute its eigenvalues and eigenvectors by equation 2). $\square_i$ may be adjusted in several ways, e.g. $\square_i'\square_i= 1$ or $\square_i'\square_i= \square i$ or $\square_i'\square_i= \square i^{1/2}$;

c) if **S** is the symmetric matrix for the rows, $\square_i$ is an axis of ordination for the elements in rows. If **S** is a symmetric matrix for the columns, $\square_i$ is an axis of ordination for the elements in columns. For better clarity we can indicate with **R** the symmetric matrix for rows and with **Q** the symmetric matrix for columns (in analogy with the well known terminology R-mode and Q-mode algorithms, ter Braak 1995), and respectively we can indicate by $\square_i$ the eigenvectors of **R** and by $\square_i$ the eigenvectors of **Q**. Only in some circumstances the matrix of $\square_i$ can be computed by multiplying the matrix of the $\square_i$ by **X**. This happens when **R** is obtained by **XX**'. When **Q** is obtained by **X'X**, $\square_i$ can be obtained by multiplying **X** by $\square_i$ (Orloci 1978). Not always the **R** and **Q** matrices can be obtained by scalar products between row or column vectors. If the matrix **X** is ordinal or alphanumeric, other measures of similarity or correlation (association) rather scalar products should be applied, e.g. Gower's and/or Goodall's and Burnaby's indices (Goodall 1964; Dale 1991; Carranza et Al. 1998). In this case only the SVD of the symmetric matrix makes sense.
If the matrix **X** is a dynamic matrix, i.e. if the OGUs are described in different times, the axes **T** are used to represent the trajectories of the OGUs.

3. Data integration with MATEDIT for ICZM

Rotmans (1999) defines IA as “an **interdisciplinary** process of structuring knowledge elements from various scientific disciplines in such a manner that all relevant aspects of a complex societal problem are considered in their mutual coherence for the benefit of decision-making”. “Thus, integrated assessments usually require involvement of scientific experts, stakeholders and decision-makers and should result in added value compared to insights derived from disciplinary research” (Rotmans & van Asselt, 2001). Tools are necessary to deal with data and information. Within the activities foreseen in ECOMANAGE a flexible software tool addressed to data analysis and data integration, MATEDIT (Burba et Al. 2008, deliverable D 4-15) was developed to complement other software widely used in community and landscape ecology (Jongman and Al. 1995). MATEDIT is an expanded WINDOW version of an old one that was written for DOS environment and specifically addressed to create biodiversity data bases (Burba et Al 1992). MATEDIT is based on the idea of using the classificatory approach to analyse community data and it facilitate to apply the emerging similarity theory in ecological and environmental assessment and decision making. It is based on matrix algebra and produces fuzzy sets once a set of data elements (objects or variables) is classified. The degrees of belonging of the elements are calculated on the basis of similarity they have with sets of elements defined in a classification process. Different classifications of the same sets of elements based on different sets of characters (if objects) and/or different similarity functions and clustering methods can be compared and tested with permutation techniques. An original method is proposed that uses the evenness of the eigenvalues of within-between clusters similarity matrix. MATEDIT implements few similarity functions among those most commonly used, but includes some similarity functions that are rarely found in other software tools, such as the probabilistic index of Goodall, the index of Gower and the index of Yager. All the functions are adapted to consider missing values and they can be used to obtain suitability maps according to the idea implicit in formula 4) but by implementing also non linear functions. MATEDIT can import matrices from OpenOffice Calc and Microsoft Excel and can export data directly to EXCEL or in free format that can represent raster grid maps. MATEDIT performs hierarchical cluster analysis with the three fundamental criteria: single, average and complete linkage and extracts eigenvalues and eigenvectors from squared matrices. It performs other simple matrix operations such as matrix sum and multiplication, and also it performs product of the elements of rows and columns of a matrix by elements in rows or columns of other matrices of the same size. This is useful for weighting variables and criteria originated from “multidisciplnary” sources. MATEDIT produces dendrograms and scattergrams and allows to produces subsets of data matrices by clicking on the dendrogram branches and by delimiting clusters drawing closed lines around points with the cursor in the scattergrams. It rearranges rows and columns of a data matrix according to dendrogram sequences or other given sequences, so it is very useful for structuring data tables. It standardises and transforms variables by many ways and normalises rows and column vectors. It also gives ranks to variables by the sum of squares criterion. It reduces the data matrix by grouping column and row vectors according to a specified dendrogram classification or clusters isolated from the scattergrams or by other external grouping criteria. The scoring in the groups can be done in several ways (sum, average, minimal value, maximal value) to produce degrees of belonging of objects or variables to sets. Thus MATEDIT can originates fuzzy sets in different way including the single, average and complete linkage criteria. MATEDIT can be used to measure the correlation between sets of variables by comparing classifications with contingency tables or by measuring the sharpness of classifications. In both cases MATEDIT uses the permutation techniques. MATEDIT can be used for identification purposes (supervised classification) by assigning new objects or variables to clusters already established using the available similarity functions and all the three criteria implemented in the program namely single, average and complete linkage). Furthermore MATEDIT can be used to prepare the input for the public domain software tool SNNS (Stuttgart Neural Network Simulator). Finally MATEDIT can be used as a decision support tool (Janssen and Herwijnen 1994) since it is capable to rank alternatives by comparing their effects with the vectors representing respectively the best and the worst alternatives. MATEDIT has also the possibility to use a script language in format XML that allows to make in one run different procedures of data analysis.

- An example of integrated assessment of water ecosystem pollution in Santos Bay

MATEDIT is applied to assess the pollution level in the water ecosystems of the Santos Bay using the data collected in 62 points in three components of the ecosystems, namely: water, sediments and organisms by Governo do Estado de Sao Paulo et al. (2001). Almost 120 parameters were determined including heavy metals and arsenic, organic-clorated pesticides, aromatic organic-clorated, organic-phosforated, herbicides and other pesticides, also fenolic compounds, poli-aromatic hydrocarbons (PAHs), aromatic solvents and halogens, policlorated bifenils (PCBs), dioxins and furans. The analysis of pollutants have been done according to methods of the United States Environmental Protection Agency-USEPA (APHA 1995, Bonn 1997).
The report of Governo do Estado de Sao Paulo et al. (2001) offers several tables and maps showing the pollution level of the points, however it is missing to show the situation with a synthetic index that can be used to map the “integrated assessment” of the pollution of the water ecosystems of the bay. MATEDIT was applied considering the full matrix of data. The quality of the water and sediments has been estimated by transforming the data between 0 and 1 with the formula $(x_i-x_{min})/(x_{max}-x_{min})$ (1). To the transformed matrix it has been added the vector of all ones expressing the worst situation (i.e. the situation with the maximum concentration of all the pollutants, worst siuation) and the vector of all zeros (i.e. the situation of the minimum concentration of the pollutants, ideal situation). The index suggested by Malcewsky (1999): C= Dw/ (Dw+Di), where Dw is the distance to the worst situation and Di is the distance to the ideal situation, has been applied for each sampling point by calculating D as the complement to the Gower’s similarity coefficient.
Figure 1 shows the quality of water ecosystems corresponding to the 62 sampling points according to three classes of index C (less than 0.50, from 0.50 to 0.60, and more than 0.60). It is clear from Figure 1 that the majority of the points fall below the value of 0.60, meaning that the majority of the water ecosystem components of the Bay are far from the ideal situation. MATEDIT was also applied to the matrix 391 variables x 62 points in order to find clusters on the basis of similarity between the points. Seven clusters of points have been defined with the seven corresponding fuzzy sets and the similarity between them and the fuzzy sets. In this way it was possible to show what is the contribution of water, sediments and organism pollution to the total quality index (Figure2 and Table 2). From Table 2 it is clear that the pollution of water is contributing in the highest way to the overall quality of the water ecosystems.

Figure 1 Distribution of quality values for the water ecosystems of Santos Bay by integrating the analysis of water, sediments and organisms

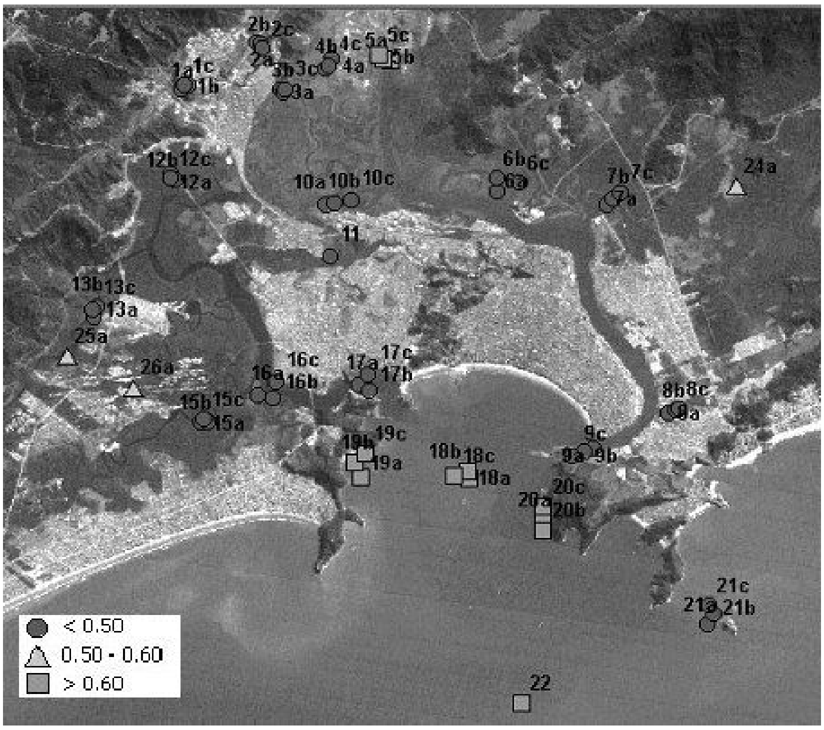

Figure.2 Distribution of the sampling points in 7 clusters, for each cluster it is indicated the average quality index C.

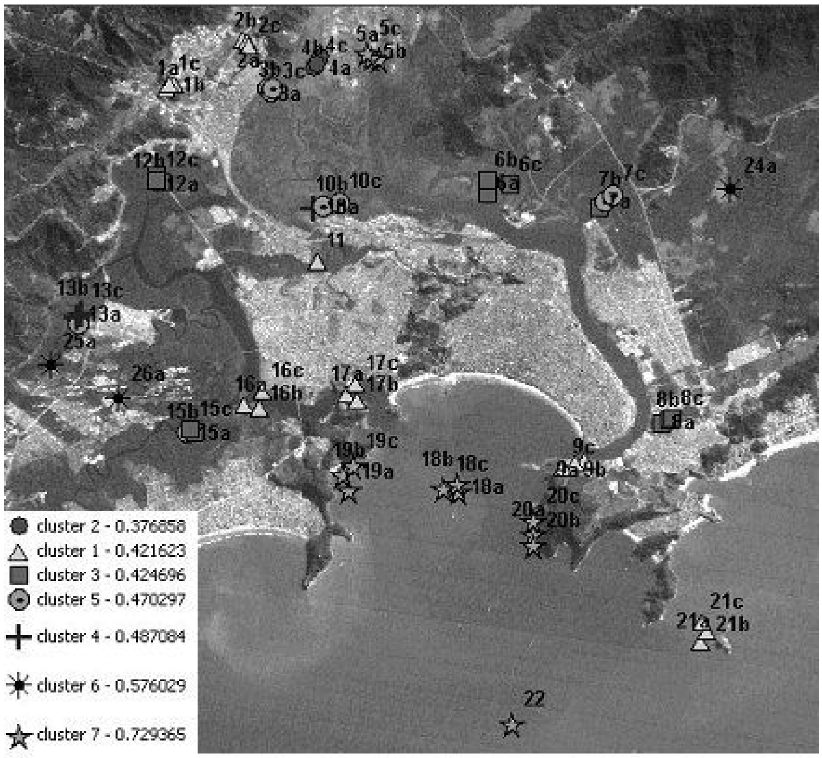

Table 1. Sampling points for water ecosystem quality analysis in the Santos Bay

Name	Clusters	Location
1a	1	Rio Cubatao
1b	1	Rio Cubatao
1c	1	Rio Cubatao
2a	1	Rio Pereque
2b	1	Rio Pereque
2c	1	Rio Pereque
3a	5	Rio Cubatao
3b	5	Rio Cubatao
3c	5	Rio Cubatao
4a	2	Rio Piacaguera a jusante do Rio Mogi
4b	2	Rio Piacaguera a jusante do Rio Mogi
4c	2	Rio Piacaguera a jusante do Rio Mogi
5a	7	Bacia de evolucao da Cosipa
5b	7	Bacia de evolucao da Cosipa
5c	7	Bacia de evolucao da Cosipa
6a	3	Largo do Caneu-Ilha dos Bagres
6b	3	Largo do Caneu-Ilha dos Bagres
6c	3	Largo do Caneu-Ilha dos Bagres
7a	3	Canal do estuario de Santos. proximo ao Canal de Bertioga
7b	5	Canal do estuario de Santos. proximo ao Canal de Bertioga
7c	5	Canal do estuario de Santos. proximo ao Canal de Bertioga
8a	3	Rio Santo Amaro
8b	3	Rio Santo Amaro
8c	3	Rio Santo Amaro
9a	1	Saida do canal de Santos
9b	1	Saida do canal de Santos
9c	5	Saida do canal de Santos
10a	4	Rio Casqueiro
10b	5	Rio Casqueiro
10c	5	Rio Casqueiro
11	1	Largo da Pompeba
12a	3	Rio Santana proximo ao Rio Queiroz
12b	3	Rio Santana proximo ao Rio Queiroz
12c	3	Rio Santana proximo ao Rio Queiroz
13a	4	Rio Branco (jusante)
13b	4	Rio Branco (jusante)
13c	4	Rio Branco (jusante)
15a	5	Rio Mariana (jusante)
15b	3	Rio Mariana (jusante)
15c	3	Rio Mariana (jusante)
16a	1	Canal dos Barreiros
16b	1	Canal dos Barreiros
16c	1	Canal dos Barreiros
17a	1	Entre a Ilha Porchat e Praia Paranapua
17b	1	Entre a Ilha Porchat e Praia Paranapua
17c	1	Entre a Ilha Porchat e Praia Paranapua
18a	7	Saida do emissario de Santos
18b	7	Saida do emissario de Santos
18c	7	Saida do emissario de Santos
19a	7	Morro do Itaip¨
19b	7	Morro do Itaip¨
19c	7	Morro do Itaip¨

20a	7	Ponta Grossa da Barra
20b	7	Ponta Grossa da Barra
20c	7	Ponta Grossa da Barra
21a	1	Ilha da Moela
21b	1	Ilha da Moela
21c	1	Ilha da Moela
22	7	Laje de Santos
24a	6	Canal de Bertioga (l. do Candinho)
25a	6	Rio Branco (montante)
26a	6	Rio Mariana (montante)

Table 2. Correlation coefficient between fuzzy set defined by clustering the 62 sampling points and fuzzy sets obtained considering the most polluted points for water, sediments and organism according to Governo do Estado de Sao Paulo et Al. (2001). In bold are indicated the maximum values of correlation per column

Fuzzy sets	1	2	3	4	5	6	7	Water	sediments	organisms
water	0.94	**0.98**	0.92	0.54	**0.9**	0.63	-0.96	1	**0.97**	0.91
sediment	**0.97**	0.95	**0.98**	0.62	**0.85**	**0.67**	-0.94	1	1	**0.92**
organisms	0.85	0.95	0.9	**0.64**	0.73	0.43	**-0.8**	0.9	0.92	1

4. Suitability maps and scenario simulation

- *Suitability maps*

Suitability maps are obtained by applying Spatial Decision Support Systems (SDSS) with the GIS technology (Eastman 1999, Malczewski 1999) (see Deliverable 4.14). In the context of SDSS each OGU is a possible alternative for a given land use type and its suitability can be calculated with formula:

$$S_{jl} = \sum_i w_i x_i \prod_h C_h \qquad (4)$$

where S_{jl} is the suitability of OGU j-th to land use type l-th, x_i is the score of variable (criterion) i-th, w_i is is weight and C_h represents the constraint h-th which prevents the allocation of land use l in the j-th OGU. If the criteria are formulated in terms of sustainable development the maps show where a certain land use could be optimally allocated and where its location would be unsustainable.

Considering formula (4), that is the basic formula of Multi-Critera Evaluation (Saaty 1977, 1999), under the perspective of LEMS (matrix algebra perspective)**,** we can say that S_{jl} is the scalar product between the vector **W** and the vector **X**j of matrix **X**. If **W** and **X**j are normalized, S_{jl} is the cosine between the two vectors. It ranges between 0 and 1. It is 1 when the scores of $\mathbf{X}_j$ have the same behaviour of the scores (weights) in **W**: low scores in $\mathbf{X}_j$ low scores in **W** and high scores in $\mathbf{X}_j$ high scores in **W**. It follows that S_{jl} is just a measure of similarity of the OGUj with the vector **W** describing the importance (weights) given to the variables in **X**. Under this perspective, the vector of the weights (**W**) may be interpreted as the reference vector representing the "ideal" most suitable situation to host a given land use type, in other word the "core" of its niche. The suitability maps obtained for each land use types, are similarity maps of the OGUs with the vectors representing the most suitable sites for each land use.

The selection of the criteria on which the suitability maps are based is depending on many factors related to the knowledge and perception of the stakeholders about their landscape and

to their economic interests. The criteria may be considered arbitrary: different sets of criteria may be used and their weights can be changed. Of course changing criteria and weights may have effects on suitability maps. It is for this reason that Malczewski (1999) describes the problems solved with Spatial Decision Support Systems (SDSS) as semi-structured problems. They are based on a first step that is completely in the hands of the involved stakeholders (including the scientists), namely the choice of the criteria (variables in **X**) and their weight (scores in **W**), and a second step that is completely and univocally solved by the computer, namely ranking the alternatives. It follows that suitability maps are more than a methodological issues since they drive the planners to shift from multidisciplinary model to interdisciplinary and transdisciplinary models requiring the participation of all the interested stakeholders in defining the criteria (variables) and their weights. The suitability is a concept that is not absolute, but relative to the context. For example a piece of land may be suitable for rice cultivation even if it is in a dry area provided there is a system for irrigation that can supply the necessary water quantity for a "convenient" cost. The same OGU may be suitable for different land use types, conflicts of this type occurring when producing suitability maps can be solved with cost benefit analysis or other techniques of participation of the stakeholders (Rotmans and van Asselt 2001, Asselt and Rijkens-Klomp 2002).
If the criteria are chosen in function of a sustainable development the suitability maps will present the optimal allocation of the selected land use according the criteria chosen. It follows that suitability maps can be very useful for a cartographic presentation of different scenarios of sustainable development (e.g. Altobelli et A. 2001).

- Scenario simulation

The scenario simulation can be based on different methods. Scenarios can be defined both according to possible different socio-economic alternatives and considering the "business as usual". In the first case the SDSS will create maps according to suitability of land to suggested uses obtained by MCE and MOE (Altobelli et Al. 2001). Commercial programs such as DEFINITE or public domain software as MATEDIT may be used to evaluate alternatives, in the latter case two methods can be used both based on cellular automata (Ilachinski, 2001): one in which land cover maps of different time (1975- 1987- 2002) will be compared to obtain transition matrices on which to apply of Markov chain and MCE and MOE (Eastaman 1997, Feoli and Giacomic 2003); the second one in which the changes are "learned" by neural network and the scenario maps are originated on the basis of such a learning process (Li and Gar-On Yeh 2002).

- *Cellular automata and simulation models*

From a theoretical point of view the cellular automata (CA) have been introduced in the late '40 of the twentieth century by John von Neumann (Neumann von, 1966). Successively, it was the Horton Conway's "Game of Life" to bring them to the attention of the scientific community (Gardner, 1970) in the '60.
Cellular automata are discrete dynamical systems which have the capability to describe continuous dynamic systems. By saying discrete we mean that both time and space have a finite number of states. Their basic purpose is the attempt to describe a complex system not by complex equations but through the interaction of simple entities that follow simple rules, the so called bottom-up approach.
The basic properties of the cellular automata are:

- n-dimensional matrix in which every cell has a discrete state
- dynamic behaviour given by rules. These rules establish the state of the given cell in the next time interval in function of the surrounding cells states.

The basic element of the CA is the cell. We can consider a cell as a unit memory of states. In the elementary case only two states should be considered. On the contrary, in a more sophisticated example a cell may assume many states during its life and even have more than one property (attribute) each with many states. This is the approach adopted for urban cellular automata utilized in land use and land cover change simulation models for economically fast growing areas, as in our case. In such automata, cells represent portions of land of a given extension and their states are characterized by variables related to the considered context (e.g. land use, land value, altitude, etc.).
Rules are used to introduce dynamics in the system. Their function is to determine the state of a cell at a time (t+1) by considering the surrounding cells states at a precedent time (t). The Moore (3x3) neighbourhood is commonly used to determine which cells have to be considered in the evaluation (Figure 3).

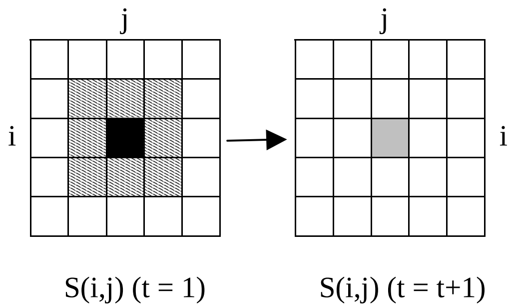

Figure 3. Cell state change and Moore neighbourhood

The quoted Game of Life (Gardner, 1970) was one of the first applications to demonstrate the capability of the cellular automata to produce dynamic structures and patterns. The Game is carried out in a bi-dimensional matrix, with binary cell states and using Moore neighbourhood. In practice value 1 represents a cell that is "alive" and value 0 represents a "dead" cell. It was John Conwy to introduce the following set of rules:

- A cell that is dead at time t becomes alive at a time t+1 if exactly three of the eight cells in his neighbourhood were alive at time t.
- A cell alive at time t dies in a time t+1 if his neighbourhood at time t consist of less than two or more than three alive cells.

In simulation models based on urban cellular automata (e.g. Sanders, 1996), the urban settlements and the surrounding territories are considered as a self-organizing system in which the base elements, cells representing portions of land, experience changes of state i.e. land use and land cover changes (Sui and Zeng, 2001). Land use conversions are governed by transition rules that define the behaviour of the single cells. In this way a global pattern can evolve from the definition of local behaviour according to the interactions between a cell and its neighbourhood (local interactions leads to global dynamics).
Many different approaches have been undertaken in recent years: from basically heuristic models (Besussi, 1998) to models based on logistic regression (Wu, 2002). Nevertheless it appears convenient to derive or calibrate land use development from the observation of occurred changes in land use. These land use change data can be effectively supplied by remote sensed imagery through GIS analysis.

We are thus facing the necessity to express the relationships between land use and the factors that influence the probability of land use conversions. The number of required variables and their parameters rise considerably taking into account the fact that the development of an area is not based solely on physical attributes (soil types, altitude, etc.) but also on the development sequence and on the neighbourhood effect. In this innovative approach (Li and Yeh, 2002), the parameters are calculated automatically during the learning process of a neural network and the land use change probabilities are represented by the network output values. Furthermore the site attributes are automatically updated at the end of each cycle making the network operate in an iterative way. In Deliverable 4.16 an example of scenario simulation based on suitability maps and cellular automata is given for Santos Bay. The simultaneous growth of the system complexity has brought to a new method based on the integration of cellular automata and neural networks that is capable to handle the increased data complexity. ECOMANAGE develop the tools for applying this method within the framework of MATEDIT even if it was not time to apply it.

- *Neural Networks*

Neural networks are composed of simple elements that operate in parallel and are inspired by biological nervous systems (Demuth and Beale, 2002). As in the biological case, the function of a network is largely determined by the connections between the elements. It is hence possible to train a neural network to perform the desired function by adjusting the values of those connections (weights) between the elements.

We can represent the various inputs to the network by the mathematical symbol, x(n). Each of these inputs is multiplied by a connection weight. These weights can be represented by w(n). In the simplest case, these products are simply summed, fed through a transfer function to generate a result, and then output. Considering that weights are adjustable parameters, we can train the network to show the desired behaviour by modifying them until the network functions properly. Typically, a training set containing numerous couples (input – desired value) is used to perform this kind of supervised training.

Sigmoid transfer functions are frequently adopted. These functions receive an argument between $\pm\infty$ and successively restrict their output in a [0,1] range making them suitable to be used in combination with the back-propagation algorithm (Rumelhart et al., 1986) in feed forward neural networks.

Using the quoted algorithm the learning phase begins by picking up the weights values randomly and then proceed to minimize the error function by adjusting the connection values (weights) backwardly, from the output layer to the inside layers.

A single neuron certainly can't do much. But a considerable power is distinctive of neural networks obtained combining many neurons in a layer or in many layers (Figure 4). The different layers play different roles and an input layer, an output layer and one or more hidden layers between them can be distinguished. It is notable that the output of a layer represents the input for the layer that follows.

There is no universal optimal structure for all applications. The principle is to use as few layers and neurons as possible and three layers networks have been commonly used because of their simplicity and effectiveness. Kolmogorov's theorem indicates that any continuous function Φ: Xn $\rightarrow$ Rc can be implemented by a three layer neural network which has n neurons in the input layer, (2n+1) neurons in the single hidden layer, and c nodes in the output layer. However, experiments indicate that 2n/3 hidden neurons can generate results of comparable accuracy requiring considerable less time to train (Wang, 1994, Li and Yeh, 2002).

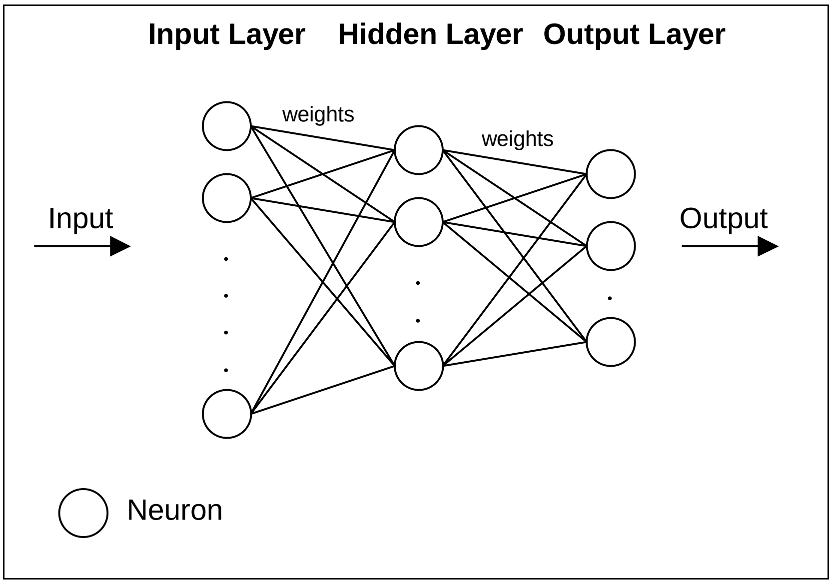

Figure 4. Artificial neural network scheme

Properly trained back-propagated neural networks provide reasonable outputs if supplied with input data that they never saw before. Such characteristic makes them appropriate for urban simulation models and represents the reason for choosing them as the tool for our application.

5. Suitability maps, scenarios and order and chaos in landscape

The emerging landscape structure (the set of relationship, spatial and functional, between the components of the landscape system) is the result of land use. The structure may fit or not with the one ensuring the sustainable development. The consequences of chaotic structure may be several and of different nature: erosion, slides, floods, extra energy consumption, emigration etc. Dragan et Al. (2008) suggest to use suitability maps to measure the order and chaos of a landscape with the aim to improve the landscape pattern under the perspective of sustainability. Such order may be calculated n the basis of acual situations or on the basis of situatios originated by scenario simulation. The chaos is measured as divergence between the real land use pattern and the pattern suggested by suitability maps: the higher the divergence the higher the chaos in the landscape.
Following Dragan et Al. (2008), the concept of order refers to the spatial and/or temporal assessment of sets of elements (and/or events): if the elements of one set are in the right spatial and/or temporal position then the set is ordered. Accordingly if the spatial pattern of land use fits the suitability maps the landscape is ordered.
Dragan et Al. (2008) suggest some functions to measure the order of landscape that should be useful to develop policies addressed to maximize such functions.

The functions are :

$$O(L) = (\Sigma_l P_l A_l)/\Sigma_l A_l \qquad (l= 1,\ldots N) \qquad (5)$$

where A_l is the area or number of OGUs of land use type l-th, N is the total number of land use types in the landscape, P_l is equal to $\Sigma_j S_{jl} a_{jl}/ A_l$(with j= 1,…, s), a_{jl} is the area or number of OGUs with S_{jl} suitability value to land use l-th (S_{jl} is ranging between 0 and 1), s is the number of suitability classes in which the suitability values calculated with formula (4) have been grouped. P_l is the weighted average suitability of each l-th land use in the landscape and it is a measure of order within the land use type. O(L) is the weighted average suitability of the l land use types, it ranges between 0 and 1, 0 representing the full chaos, 1 representing the full order. If the area of each land use has to be kept fixed, i.e. the economy of the area requires a certain proportion between the N land uses, then the order can be calculated by the following function:

$$O(L) = (\square_l P_l)/\square \square$$

because the value does not need to be weighted according to the area of each land use type. The values P_l are obtained by overlapping the maps of the actual distribution of N land use types with the corresponding suitability maps.

6. The necessary topics to be considered for on line training courses

To perform what was presented before courses should be organized on the components of the Spatial decision support systems, namely:

- Geographic Information System (GIS)

The Geographic Information System (GIS) is a computer tool to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information (e.g., ESRI 1994). A GIS typically links data from different sets, using geo-referencing, i.e., spatial co-ordinates, as a common key between the data set.

- Data Analysis and Image processing

The maps obtained by GIS may be seen not only as cartographic representations of a classification of the landscape at the end of an analytical process, but mainly as data sources for the landscape spatial pattern analysis through the many different indices of the landscape structure such as shape, fragmentation, fractal, diversity, etc. (Ebdon 1977, Turner 1989, Milne 1991, Gardner and O'Neill 1991, Fabbri 1991, Baker and Yunming 1992, Cullinam and Thomas 1992, Gustafson and Parker 1992, Olsen, Ramsey, and Winn, 1993). Many GIS have internal data analysis and image processing systems that can calculate different pattern indices. Some GIS such as IDRISI, ILWIS, GRASS (see Malczewski 1999 for a comparison between different GIS) have the possibility to treat remote sensing data (Image processing) coming from LANDSAT, SPOT, NOAA, etc. however there aren’t GIS including data analytical and statistical techniques that are able to classify specific Operational Geographic Units (OGU) according Crovello (1981). The classification may be obtained by applying the clustering algorithms (Orlóci 1978, Legendre and Legendre 1983, Goodall and Feoli1991) or other multivariate techniques. Feoli and Zuccarello (1996) treat this aspect. GIS can manage different OGUs to obtain maps. MATEDIT is available as ECOMANAGE result a s a system for data analysis and data integration and also usable for image processing.

- Modelling and expert systems

In GIS, the basic concept is one of location, of spatial distribution and relationship; basic elements are spatial objects. In environmental modelling, by contrast, the basic concept is one of state, expressed in terms of numbers, mass, or energy, of interaction and dynamics; the basic elements may be biological, chemical, and environmental media such as air, water or soil.

- Multi-Criteria Evaluation

In a Multi-Criteria Evaluation (MCE), an attempt is made to combine a set of criteria to achieve a single composite basis for a decision according to a specific objective (Eastman et al., 1995). Decisions about the allocation of land typically involve the evaluation of multiple criteria according to several, often conflicting-objectives (Eastman ET al., 1995). Making-decisions about the allocation of land is one of the most fundamental activities of resource development (FAO, 1976). With the development of GIS, we now have the opportunity, for a more explicitly reasoned process of land-use evaluation.
The advantage of MCE is that it provides a flexible way of dealing with qualitative multi-dimensional environmental effects of decisions (Munda, 1995).

Although a variety of techniques exist for the development of weights for the criteria, one of the most promising would appear to be that of PAIRWISE comparisons developed by Saaty (1977) in the context of a decision making process known as the Analytical Hierarchy Process (AHP). In the PAIRWISE comparison method the decision-maker is asked to give the relative importance to the criteria by comparing them two by two.

- Multi-Objective Evaluation (MOE)

While many decisions we make are prompted by a single objective, it also happens that we need to make decisions that satisfy several objectives. A Multi-Objective problem is encountered whenever we have two candidate sets (i.e., sets of entries) that share members. These objectives may be complementary or conflicting in nature (Carver, 1991:332).

In case of complementary objectives, multi-objective decisions can often be solved through a hierarchical extension of the multi-criteria evaluation process. For example, we might assign a weight to each of the objectives and use these along with the suitability maps developed for each to combine them into a single suitability map indicating the degree to which areas meet all of the objectives considered (see Voogd, 1983). However, with conflicting objectives the procedure is more involved.

With conflicting objectives, it is sometimes possible to rank order to objectives and reach a prioritised solution (Rosenthal, 1985). In these cases, the needs of higher ranked objectives are satisfied before those of lower ranked objectives are dealt with. However, this is often not possible, and the most common solution to conflicting objectives is the development of a compromise solution. Undoubtedly the most commonly employed techniques for resolving conflicting objectives are those involving optimisation of a choice function such as mathematical programming (Fiering, 1986) or goal programming (Ignizio, 1985). In both, the concern is to develop an allocation of the land that maximises or minimises an objective function subject to a series of constraints.

7. Conclusion

ICZM requires multidisciplinary data collection, interdisciplinary data analysis and transdisciplinary knowledge integration. ECOMANAGE offers MATEDIT as a mathematical software tool that can help in all the three phases. It can be used to manipulate the data stored in

matrices, by applying the matrix algebra useful for representing the multidimensional spaces as defined by matrices describing landscape states or alternatives in terms of the effects (Multicriteria analysis). These spaces may be represented both in terms of eigenvectors (Jongman et Al 1995) and/or fuzzy sets (Feoli and Zuccarello 1986, 1988). ICZM can be seen under the perspective of "deliberation matrices" O' Connor (2000, 2004), in this context MATEDIT can be used to compare the matrices produced in the deliberation procedure being capable to compare the Matrices of the "deliberation cube" in the three dimensions given respectively by the classes of stakeholders (one dimension of the cube) judging a set of scenarios (second dimension of the cube) described by a set of key governance or decision issues (third dimension of the cube).
MATEDIT is based on the application of several similarity functions developed primarily for vegetation ecology and taxonomy (Goodall 1964, Orloci 1978), however it can contribute to develop further the similarity theory that is emerging in different field of science and technology as an efficient tool to deal with complex system when the analytical solution is not applicable (Rushton & Nicholson,1988, Zilitinkevicha et Al. 1998, Janowicz, K. 2006).
MATEDIT is a tool that can help both to develop and to apply the concept of increasing policy integration in ICZM by integrated management of different water functions with spatial planning functions.   MATEDIT is focusing on a multi-dimensional evaluation of landscape for sustainable resource use using matrix algebra, however the tabular (matrix) rearrangement and the ordination scattergrams can be easily understood by stakeholders.

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Appendix 1.

This Appnedix describe simply the way to give priorities of different alternativeswith pairwise comparison, following the request of stakeholders that found the method very attractive from a participatory point of view.

Establishing priorities in Multicriteria Analysis

(notes from the book of T. Saaty 1999 Decision making for leaders: The analytic hierarchy process for decisions in a complex world. RWS Publications University of Pittsburg, 322 Mervis Hall)

Calculating the priorities using an approximation method

Let have a Saaty's matrix of pairwise comparison between three criteria:

	C	T	L
C	1	½	¼
T	2	1	½
L	4	2	1
Column total	7	3.5	1.75

A normalized matrix is computed by dividing each element in the matrix by the corresponding column total

	C	T	L
C	1/7	1/7	1/7
T	2/7	2/7	2/7
L	4/7	4/7	4/7

The priority of each criterion is calculated by averaging the row scores of the normalized matrix

In the present example it is:

Priority C = (1/7+ 1/7+1/7)/3= 1/7= 0.14
Priority T =(2/7+2/7+2/7)/3= 2/7= 0.29
Priority L = (4/7+ 4/7+4/7)/3= 4/7= 0.57

The concept of consistency:

In the example we can see that C=1/2 T and that C=1/4 L so that 1/2T =1/4 L which brings T=1/2 L that is what we have in the Saaty matrix. This proves that the matrix is consistent. Another proof: of consistency is given by the fact that L is 2 T, and C is ½ T so L should be 4 C, that is actually what happen in the Saaty matrix.

Calculating the priorities using the exact method

This is based on the idea of consistency. If the matrix is consistent all its powers (multiplication of the matrix by itself 1 time = power 2, 2 times = power 3, etc.) give the same priority or dominance pattern.

When the matrix is consistent, the normalized sum of each row tells us how much each element dominates the others in relative terms. The sum of the entries in each column tells us how much each element is dominated by other elements.

To derive the priorities from the matrix we add the numbers in each row and divide each of the results by their total sum to obtain the normalized scores. The operation is repeated till results are stabilized. (In the approximation method each value in the row is divided by the sum of the corresponding column!). The resulting vector is approximating the first eigenvector of the matrix, i.e. the eigenvector corresponding to the first eigenvalue of the matrix.

If the matrix is consistent the product of the vector of the sum of the elements in columns by the vector of the normalized scores is equal to n, where n is the number of elements (criteria). If the product is higher then n it means that the matrix is not consistent.

The inconsistency is assumed to be generated when the scores in the pairwise comparison matrix the values are generated by random.

The ratio CI= (eigenvalue - n)/ n-1 is the consistency index, the consistency ratio is given by the ratio between CI and CIR where CIR is the consistency index corresponding to a completely random judgement (there are tables for this!!!). If the consistency ratio CR= CI/CIR is less than 0.05 the matrix of Saaty can be considered good!

There are computer programs for calculating priorities, CI and CR. IDRISI is calculating them automatically within a GIS environment. EXPERT CHOICE is doing out of a GIS environment.

D5.2 Material for the on-line training courses

The aim of this deliverable was to present all the material collected in the three sites that could be used for establishing on line training courses. It was already presented to the e-meeting and video conference of 28/06/06.

ECOMANAGE / Updated Inventory GIS material, June 06 (document prepared by P. Almeida and R. Napolitano)

Brasil	Argentina	Chile
1. Landsat images (30/4/2000) 2. MODIS images (6-21/3/2006) 3. Study area delimitation* 4. Land cover/land use 1 5. Land cover/land use 2* 6. NDVI 7. LAI 8. Erosion (C-factor, P-factor) 9. Water bodies* 10. Industries* 11. Pollutants distribution in the Santos Bay* 12. DEM (slope, aspect) 13. Contour lines * 14. Types of soils * 15. Road network* 16. Sampling points 17. Sub-watersheds* 18. Geology* 19. Urban areas* 20. Census 2000* 21. LAI sampling points *maps given by partners	1. Landsat images (18/4/2004)* 2. Study area delimitation* 3. Land cover/land use 1 4. Land cover/land use 2* 5. NDVI 6. LAI 7. Water bodies* 8. Bathymetry (Estuary)* 9. Erosion (c-factor, p-factor) 10. DEM (slope, aspect) 11. Sampling points 12. Types of soils* 13. Road network* 14. Industries*	1. Landsat images (11/3/2001) 2. Landsat images (3/2/2005 ongoing) 3. MODIS images (6-21/3/2006) 4. Land cover 1** 5. Land cover/land use 2* 6. NDVI** 7. EVI 8. LAI** 9. Erosion (p-factor) 10. Erosion (c-factor 1) 11. Erosion (c-factor 2) 12. Erosion (c-factor 3) 13. Erosion (k-factor)* 14. Erosion (r- factor)* 15. Erosion maps (RUSLE)** 16. DEM (slope, aspect) 17. Road network* 18. Urban areas* 19. Sampling points 20. LAI sampling points **MODIS images, to be updated after the acquisition of LANDSAT images (ongoing)

The above mentioned maps and spatial databases are actually available and will be installed on the web-GIS according to the discussion and the indications of partners.

The ***web-GIS structure*** is ready and will be shown as example in the video-conference. It will be improved based on the indications of partners and will be progressively updated with the selected maps / databases.

BRAZIL

1. Landsat images (30/04/2000): free images Landsat 7 ETM+ downloaded from Global Land Cover Facility web site (http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp. Spatial resolution: 30 m, spectral resolution: 7 bands. Format: tiff Source: University of Trieste, Italy.

2. Modis images (6-21/3/2006): free images of MOD13 product downloaded from Earth Observing System Data Gateway (http://edcimswww.cr.usgs.gov/pub/imswelcome/). Spatial resolution: 250 m, spectral resolution: 4 bands plus NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index). Format: tiff. Source: University of Trieste, Italy.

3. Study area delimitation: Map of the study area, delimited by partners according to the main interests of the Ecomanage project and including main sub-basins: Pereque, Cubatão, Quilombo, Piaçabucu, Mogi, Jurubatuba, Boturoca and Ilha de São Vicente. Satellite image Landsat ETM (30/04/2000) used for the elaboration of landcover and landuse maps does not cover the entire study area. Format: GRID and shapefile feature data.

4. Land cover/land use 1: obtained from supervised classification applied on Landsat 7 ETM+ (30/4/2000) using training sites collected in situ on March 2005 and 2006 and information provided by partners. Specific classes were selected according to the most representative characteristics of the study area (forest, mangrove, urban areas, industrial areas, etc) then for these classes the appropriate training areas were located. Supervised classification based on the selected training areas, which contains specific spectral signatures of the represented classes, and by the application of the *Maximum Likelihood* algorithm compares these training areas with the rest of the image. Then based on all spectral similarities the image is completely classified. Format: GRID and shapefile feature class. Source: University of Trieste, Italy.

5. Land cover/land use 2*: Data contained on CD: types of vegetation, urban and industrial areas, etc. Original maps and data in dwg were then transformed to shapefile format. In this way data could be elaborated and processed using ArcMap 9.0 in order to be included on a GIS. Format: GRID and shapefile feature class. Original source: EMBRAPORT (Empresa Brasileira de Terminais Portuarios S.A) Environmental Impact Assessment and Companhia Siderurgica Paulista-COSIPA Dragging Assessment. Provided by: Cristina Simonetti, Brazil.

6. NDVI: obtained from the satellite image (30/04/2000) applying formula (TM4-TM3/TM4+TM3) on ENVI software. Format: GRID. Source: University of Trieste, Italy.

7. LAI (Leaf Area Index): obtained from the inversion of the empirical relationship between LAI field data measured with LAI-2000 Plant Canopy Analyzer instrument and NDVI map of 30/04/2000. Format: GRID. Source: University of Trieste, Italy.

8. Erosion (C-factor, P-factor): Maps elaborated using bibliographical sources according to the typical C and P factors assigned to the classes selected on the supervised classification. Format: GRID and shapefile feature class. Source: Source: University of Trieste, Italy. Bibliography used for the elaboration of the C and P factors:

    - Hartcher M.G. *Reducing Uncertainty in sediment Yield Through Improved Representation of Land Cover: Application to two Sub-catchments of the Mae Chaem, Thailand.* In: http://www.mssanz.org.au/modsim05/papers/hartcher.pdf
    - Malla K.M. *Bio-physical condition of Andhi Khola watershed to estimate the life span of proposed dam.* In: http://www.gisdevelopment.net/aars/acrs/2002/wrs/215.pdf
    - Rinos Mahoamed M.H., Aggarwal S.P., Ranjith Premalal De Silva. *Application of Remote sensing and GIS on soil erosion assessment at Bata River Basin, India.* In: http://www.gisdevelopment.net/application/geology/geomorphology/geogmf001a.htm
    - Gadem A.E., Narunalani S., Waltman W.J., Reichenbach S.E., Dappen P. *A decision support system for soil productivity and erosion in Polk County, Nebraska.* In: http://cse.unl.edu/~reich/publications/asprs2001-036.pdf
    - Zihni E., 2000. *C-Factor Mapping Using remote Sensing and GIS: A case study of Lom Sak/ Lom Kao, Thailand.* In: http://cse.unl.edu/~reich/publications/asprs2001-036.pdf

9. Water bodies*: Contains information about main rivers, permanent rivers and water bodies like dams present in the study area and surroundings. Transformed to shapefile (ArcMap 9.0) to be introduced on the GIS. Format: shapefile feature class. Original source EMBRAPORT Environmental Impact Assessment. Provided by: Cristina Simonetti, Brazil.

10. Industries*: The GIS database of the industries contains information about the name, location and production of the main industries located on the study area. Also contains information about the heavy metals produced by these industries. Format: shapefile feature class. Original source: CETESB, Provided by: UNISANTA, Brazil.

11. Pollutants distribution in the Santos Bay*: This GIS database contains information about the location of specific sampling points where pollution is present, their source of pollution, also if this pollutants are present as raw materials or as dumping materials and if these substances and pollutants exceed the permitted levels of the law. The sample points database gives information about the type and concentration of substances found on the water, sediments and organisms. Format: shapefile feature class.Original source: CETESB, Provided by: UNISANTA, Brazil.

12. DEM: downloaded from free site ftp://e0srp01u.ecs.nasa.gov/srtm/version2. Spatial resolution of 90 m. From this DEM maps of slope and aspects were obtained. Format: tiff and GRID. Source: University of Trieste, Italy.

13. Contour lines*: Contains information about main and secondary level curves of the study area and surroundings. Transformed to shapefile (ArcMap 9.0) to be introduced on the GIS. Format: shapefile feature class. Original source EMBRAPORT Environmental Impact Assessment, Provided by: Cristina Simonetti, Brasil.

14. Types of soils*: Pedologic maps indicating the types of soils present in the study area. Original source 1: Soil Map of São Paulo State (Ministery of Agriculture, 1960 - scale 1:500000 000 - in CETEC 1999, Brasil. Provided by: Laboratorio Nacional de Engenharia Civil (LNEC-Portugal), Relatorio 413/05-NAS. Original source 2: Instituto de Pesquisas Tecnológicas – IPT, Brazil.

15. Road network*: Contains information about main and secondary roads and train ways of the study area and surroundings. Transformed to shapefile (ArcMap 9.0) to be introduced on the GIS. Format: shapefile feature class. Original source EMBRAPORT Environmental Impact Assessment, Provided by: Cristina Simonetti, Brasil.

16. Sampling points: Location of the sampling points collected on the study area on March 2006 by a GPS. These sampling points were used for the location of the training areas in the satellite image 30/04/2000 for performing the supervised classification. Format: shapefile feature class. Source: University of Trieste, Italy.

17. Sub-watersheds*: Map containing the location of the main watersheds of the study area: Pereque, Cubatão, Quilombo, Piaçabucu, Mogi, Jurubatuba, Boturoca and Ilha de São Vicente. Format: shapefile feature class. Provided by Instituto Superior Tecnico (IST), Portugal.

18. Geology*: Map containing the main geologic information of the study area. Format: shapefile feature class. Source and Provided by: Instituto de Pesquisas Tecnológicas – IPT, Brazil.

19. Urban Areas and Main cities*: Location of urban areas in the study area. Original source: EMBRAPORT Environmental Impact Assessment, Provided by: Cristina Simonetti. Location of the main cities Cubatão, San Vicente, Santos, Guarujá, Praia Grande. Format: shapefile feature class. Provided by: UNISANTA, Brazil.

20. CENSUS 2000*: GIS database of the population census of 2000 for Cubatão, San Vicente, Santos, Guaruja, Praia Grande. Format: shapefile feature class. Provided by: UNISANTA, Brazil.

ARGENTINA

1. Landsat image (18/04/2004)*: Landsat image ETM-7. Spatial resolution: 30 m, spectral resolution: 7 bands. Format: tiff. Provided by: Instituto Argentino de Oceanografia (IADO), Argentina.

2. Study area delimitation: Map of the study area, delimited by partners according to the main interests of the Ecomanage project and including main sub-basins: Naposta Grande, Sauce Chico and Saladillo. Satellite image Landsat ETM (18/04/2004) used for the elaboration of landcover and landuse maps does not cover the entire study area. Format: GRID and shapefile feature data.

3. Land cover/ Land use 1: obtained from supervised classification (Maximum Likelihood Algorithm) applied on Landsat 7 ETM+ (18/04/2004) using training sites collected in situ on March 2006 and information provided by partners. Specific classes were selected according to the most representative characteristics of the study area (crops, pastures, saltmarshes, etc) then for these classes the appropriate training areas were located. Format: GRID and shapefile feature class. Source: University of Trieste, Trieste.

4. Land cover/land use 2*: Map elaborated from data provided by IADO containing location of urban areas, crops, tidal flats, saltmarshes, farms-yards, industrial areas, sand banks and beaches, transitional vegetation, military areas, etc. Format: GRID and shapefile feature class. Source: IADO, Argentina.

5. NDVI (Normalized Difference Vegetation Index): obtained from the satellite image (18/04/2004) applying formula (TM4-TM3/TM4+TM3) on ENVI software. Format: GRID. Source: University of Trieste, Italy.

6. LAI (Leaf Area Index): LAI map elaborated from bibliographical information collected. Format: GRID. Source: University of Trieste, Italy. Bibliography used:

- http://c100.bsyse.wsu.edu/cropsyst/manual/parameters/crop/morphology.htm
- http://topsoil.nserl.purdue.edu/nserlweb/weppdoc/PlantSpecificParameters.html
- Bertness, M., and Ellison, A., 1987. Determinants of pattern in a New England salt marsh plant community. STOR. Ecological Monographs, Vol. 57, No. 2:129-147.

7. Water Bodies*: Contains information about main rivers of the study area. Format: shapefile feature class. Original source: CD Atlas Digital de los Recursos Hidricos de la Republica de Argentina, Presidencia de la Nación. Provided by: Fabiana Limbozzi, Argentina.

8. Bathymetry (Estuary)*: Bathymetry map of the estuary of Bahia Blanca. Map provided by IST, Portugal. Format: shapefile feature class.

9. Erosion (C-factor, P-factor): Maps elaborated using bibliographical sources according to the typical C and P factors assigned to the classes selected on the supervised classification. Format: GRID and shapefile feature class. Source: University of Trieste, Italy. Same bibliography used for Brazil.

10. DEM (slope, aspect): downloaded from free site ftp://e0srp01u.ecs.nasa.gov/srtm/version2. Spatial resolution of 90 m. From this DEM maps of slope and aspects were obtained. Format: tiff and GRID. Source: University of Trieste, Italy.

11. Sampling points: Location of the sampling points collected on the study area on March 2006 by a GPS. These sampling points were used for the location of the training areas in the satellite image 18/04/2004 for performing the supervised classification. Format: shapefile feature class. Source: University of Trieste.

12. Type of soils*: Map of main soil types of the study area and surroundings containing information about depth of soil horizons, analytical and grain characteristics, etc. Format: shapefile feature class. Original source: Atlas digital de Suelos de la Republica Argentina. Provided by: Fabiana Limbozzi, Argentina.

13. Road Network*: Contains information about main roads and train ways of the study area and surroundings. Format: shapefile feature class. Provided by: IADO, Argentina.

14. Industries*: The GIS database of the industries contains information about the name, location and production of the main industries located on the study area. Format: shapefile feature class. Source: IADO, Argentina.

CHILE

1. Landsat images (11/3/2001): free images of Landsat 7 ETM+ downloaded from Global Land Cover Facility web site (http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp). This images cover only a part of study area. Spatial resolution: 30 m, spectral resolution: 7 bands. Format: tiff. Source: University of Trieste, Italy.

2. Landsat images (3/2/2005): four images of Landsat 5 TM order to Comision Nacional de Actividades Especiales CONAE (http://www.conae.gov.ar/eng/principal.html) that cover entire study area. Spatial resolution: 30 m, spectral resolution: 7 bands. Format: tiff Source: University of Trieste, Italy. Ongoing.

3. MODIS images (12-28/7/2005; 1-16/11/2005; 6-21/3/2006): free images of MOD13 product downloaded from Earth Observing System Data Gateway (http://edcimswww.cr.usgs.gov/pub/imswelcome/). Spatial resolution: 250 m, spectral resolution: 4 bands plus NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index). Format: tiff. Source: University of Trieste, Italy.

4. Land cover/land use 1: obtained from supervised classification applied on Landsat 7 ETM+ (11/3/2001) and on MODIS (6-21/3/2006) using training sites collected in situ on March 2006 and information provided by partners. Specific classes were selected according to the most representative characteristics of the study area (broadleaves forest, coniferous forest, pasture, urban areas, snow and glaciers, lakes and rivers etc) then for these classes the appropriate training areas were located. Supervised classification based on the selected training areas, which contains specific spectral signatures of the represented classes, and by the application of the *Maximum Likelihood* algorithm compares these training areas with the rest of the image. Then based on all spectral similarities the image is completely classified. Format: GRID and shapefile feature class. Source: University of Trieste, Italy

5. Land cover/land use 2*: map containing the vegetation community, land cover, land use, main species (Nothofagus, Laurelia, Juncus, Pine etc.), vegetation height etc. Format: shapefile. Data provided by University of Chile. Source: University of Chile, Chile.

6. NDVI (Normalized Difference Vegetation Index): obtained from the Landsat satellite image (11/3/2001) applying formula (TM4-TM3/TM4+TM3) on ENVI software and from MODIS 13 product (6-21/3/2006). Format: GRID. Source: University of Trieste, Italy

7. EVI (Enhanced Vegetation Index): obtained from MODIS 13 product (6-21/3/2006). Format: GRID. Source: University of Trieste, Italy.

8. LAI (Leaf Area Index): obtained from the inversion of the empirical relationship between LAI field data measured with LAI-2000 Plant Canopy Analyzer instrument (and hemispherical photographs) and NDVI map of Landsat and MODIS. Format: GRID. Source: University of Trieste, Italy

9. Erosion (P-factor): map representing prevention practices factor, elaborated using bibliographical sources according to the typical P factors assigned to the classes selected on

the supervised classification. Format: GRID and shapefile feature class. Source: University of Trieste, Italy Bibliography used for the elaboration of the P factors:

- Rinos Mahoamed M.H., Aggarwal S.P., Ranjith Premalal De Silva. *Application of Remote sensing and GIS on soil erosion assessment at Bata River Basin, India.* In: http://www.gisdevelopment.net/application/geology/geomorphology/geogmf001a.htm

10. Erosion (C-factor): map representing cover factor, elaborated using bibliographical sources according to the typical C factor assigned to the classes selected on the supervised classification. Format: GRID and shapefile feature class. Source: University of Trieste, Italy. Bibliography used for the elaboration of the C:

    - Henderson, 2001. Palouse river tributaries subbasin assessment and TMDL. In: www.epa.gov/waters/
    - Honorato R., Barrales L., Peña I., Barrera F. Evaluación ente el cobre extraído con Edta y Dtpa en suelos desde la IV y la X región de Chile con y sin antecedentes de contaminación, Revista de la Ciencia del Suelo y Nutrición Vegetal. 1 (2001) 48 – 57
    - Ma, J. (2001). Combining the USLE and GIS/ArcView for Soil Erosion Estimation in the Fall Creek Watershed in Ithaca, NY. Cornell University CSS620- Spatial Modeling and Analysis
    - Raghunath , 2005. Potential erosion map for Bagmati basin using GRASS GIS. Proceedings of the Open source GIS-GRASS users conference 2002, Trento, Italy.

11. Erosion (C-factor): map elaborated using NDVI of MODIS (6-21/3/2006) to create C-factor map, based on the assumption that 0 and 1 are C-factor values for pure vegetation (dense forest) and for bare soil respectively and that all other land cover types will have C values between 0 and 1 and on tested linear relationship between NDVI and C-factor. Format: GRID. Source: University of Trieste, Italy

12. Erosion (C-factor): map elaborated using normalized blue, red, NIR and MIR bands of MODIS (6-21/3/2006) to create a C-factor map, using a transformation index. Format: GRID. Source: University of Trieste, Italy

13. Erosion (K-factor)*: map representing the soil factor, that is the degradation of soil related to slope and type of soil.. Format GRID and shapefile. Original source: Gobierno de Chile-Sistema Nacional de Informacion Ambiental (SINIA-Conama) provided by University of Chile, Chile.

14. Erosion (R-factor)*: map representing the rainfall intensity factor, that is the degradation of soil related to pluviometric factor and elevation. is the degradation of soil related to pluviometric factor and elevation. Format GRID and shapefile. Original source: Gobierno de Chile-Sistema Nacional de Informacion Ambiental (SiNIA-Conama) provided by University of Chile, Chile.

15. Erosion maps: maps obtained applying RUSLE (Revised Universal Soil Loss Equation) equation, that is an empirical equation designed for the computation of average soil loss. This equation was developed for detachment capacity limited erosion in fields with negligible curvature and no deposition and represents soil loss averaged over time and total area. The equation has the form $E = R\ K\ LS\ C\ P$ where E [*ton/(acre.year)*] is the average

soil loss and *LS* is the topographic (length-slope) factor derived from DEM. We elaborated three maps using the different C-factors. Format: GRID. Source: University of Trieste, Italy

16. DEM: downloaded from free site ftp://e0srp01u.ecs.nasa.gov/srtm/version2. Spatial resolution of 90 m. From this DEM maps of slope and aspects were obtained. Format: tiff and GRID. Source: University of Trieste, Italy

17. Road network*: Contains information about main and secondary roads of the study area and surroundings.. Format: shapefile feature class. Provided by University of Chile, Chile.

18. Sampling points: Location of the sampling points collected on the study area on March 2006 by a GPS. These sampling points were used for the location of the training areas in the satellite images for performing the supervised classification. Format: shapefile. Source: University of Trieste, Italy

19. Urban Areas and Main cities*: Location of urban areas in the study area. Format: shapefile. Provided by: University of Chile, Chile.

20. LAI sampling points: Location of the sampling points where LAI measurements were performed using the LAI-2000 Plant Canopy Analyzer (and hemispherical photographs) and collected with GPS on March 2006 at the study area. Format: shapefile. Source: University of Trieste, Italy

*D5.3 Report on meetings in each site

Dr. Fabio Giordano did the reports for Santos Bay, prof. Victor Marin did the reports for Chile

D5.4 Internet knowledge base structuring
D5.5 Internet knowledge base development – experimental phase
D5.6 Internet knowledge base

Preface
These deliverables may be summarized in only one report. The Internet knowledge was developed by the Trieste team on the basis of a WEB GIS available on interned structured according all the material presented in the Deliverable 5.2.

1. Introduction: Views on WP5 of which UTS, partner 5 is responsible.

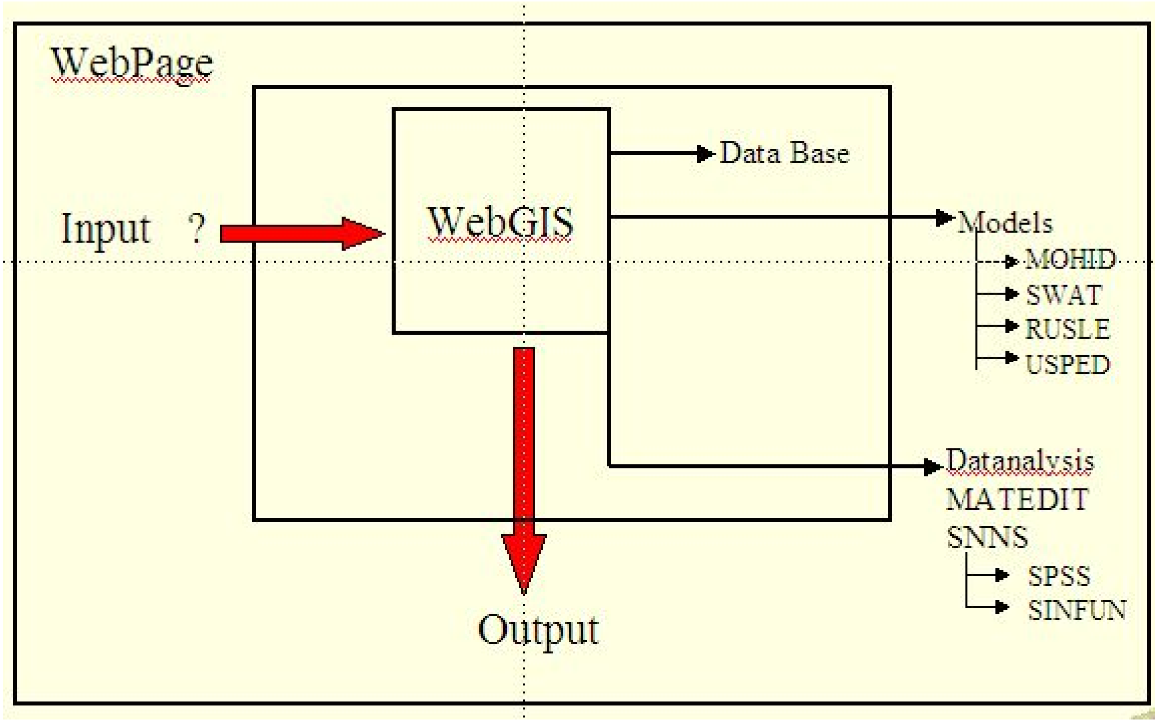
This package was thought for disseminating the results of the project and to offer a tool for learning about integrated coastal zone management. The tasks were indicated as:
T5.1 - Line training courses
T5.2 - Meetings with case studies
T5.3 - Knowledge base dissemination

As Feoli was stressing in the Aysen meeting this WP needed the cooperation of all the partners, with ideas and suggestions. It is clear that with only 10 man months it is not possible to generate real on-line training courses on integrated coastal management, this would need a specific project, however the work was directed with success to prepare and structure the material for an internet knowledge base that would be the basis for teaching and learning how to build scenarios using SDSS. This structure is ready and it consists in a WEB-GIS that was presented in the Aysen meeting.

2. **Internet knowledge base structuring**

A brief scheme of a webpage for Teaching – Learning is summarized in Fig. 1.

Fig 1. Structure of the web page of the knowledge base system



The tools used to create the internet knowledge base structure (WebGIS) of Fig. 1 are

- ArcSDE
- ArcIMS

- ArcSDE is a geographic application server that uses the leading commercial database management systems (DBMS) such as IBM DB2, IBM Informix, Microsoft SQL Server, and Oracle, to store feature-rich vector, raster, and survey data. It provides the infrastructure required to manage multiple users editing the same spatial database.

- ArcIMS provides the foundation for distributing high-end geographic information systems (GIS) and mapping services via the Internet.

ArcIMS software enables users to integrate local data sources with Internet data sources for display, query, and analysis in an easy-to-use Web browser. Fig 2 resents the structure linking the ArcSDE and ArcIMS

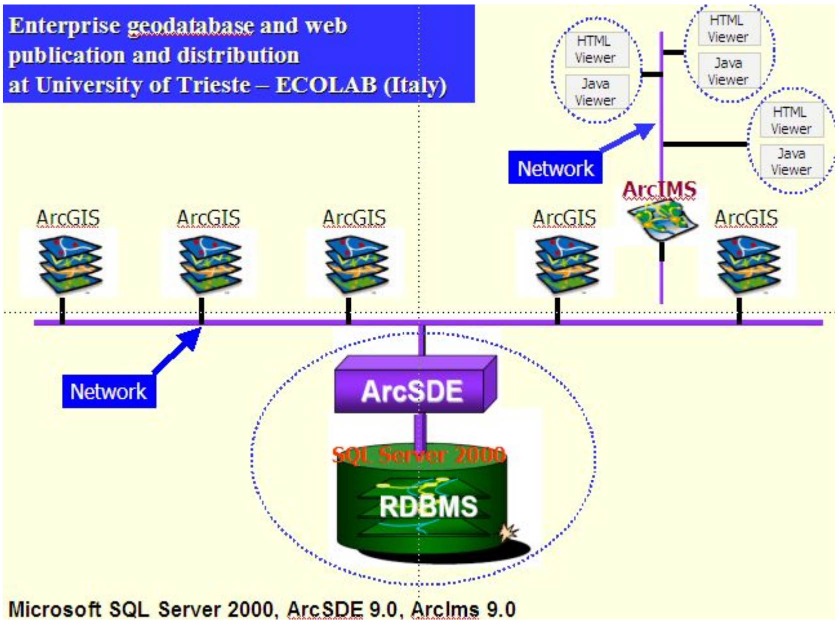


Fig. 2. Structure of the SQL server developed at the Department of University of Trieste (Ecolab).

The main characteristics of the WebGIS

- It contains a geodatabase that can be updated
- It has a geographic format
- It is not simple images but contains all spatial data
- It does not need any extra software, only an http:\\ connection
- It is an interactive GIS with all its characteristics and a structured database
- It is possible to upload the WebGIS on your computer GIS software

A preliminary WebGIS is already available on internet to be visited by EcoManage partners it contains the GIS of all the sites with the data collected by the Trieste team created with the software ArcMap 9.0 (see Appendix 2 of WP5 deliverables). The web site is the following.

http://ecoweb.units.it/website/brasil

This site has a restricted access which is control by a username and password provided by the University of Trieste.
Currently it is not possible to modify or download the information which will be possible in a forward step.

Appendix 2

ArcMap 9.0 modelling facilities used for SDSS application with data stored in the internet knowledge base.

"ArcMap9.0/Analysis Tool/Model" module is used for the elaboration of Santos SDSS. All the required data described in Deliverable 5.2 are available in Santos GIS of Deliverables 5.4, 5.5, 5.6. Figure 1 shows the maps representing the criteria used and how they are introduced into the Model tool of ArcMap o find the suitable map for further ubanization.

The main set of maps used for SDSS were:

- Landcover / landuse map (obtained from supervised classification of satellite image Landsat TM 7- April 2000)
- Dem (slope map obtained from surface analysis tool in ArcMap)
- Rivers and water bodies (obtained from local partners and classified images)
- Industries (CETESB database)
- Limits of conservation and protected areas (obtained from local partners)
- Erosion risk maps (obtained from RUSLE model)

The use of ArcMap modelling facilities is of great advantage for SDSS elaboration since in this way information can be easily updated and changed according to the user requirements and needs.

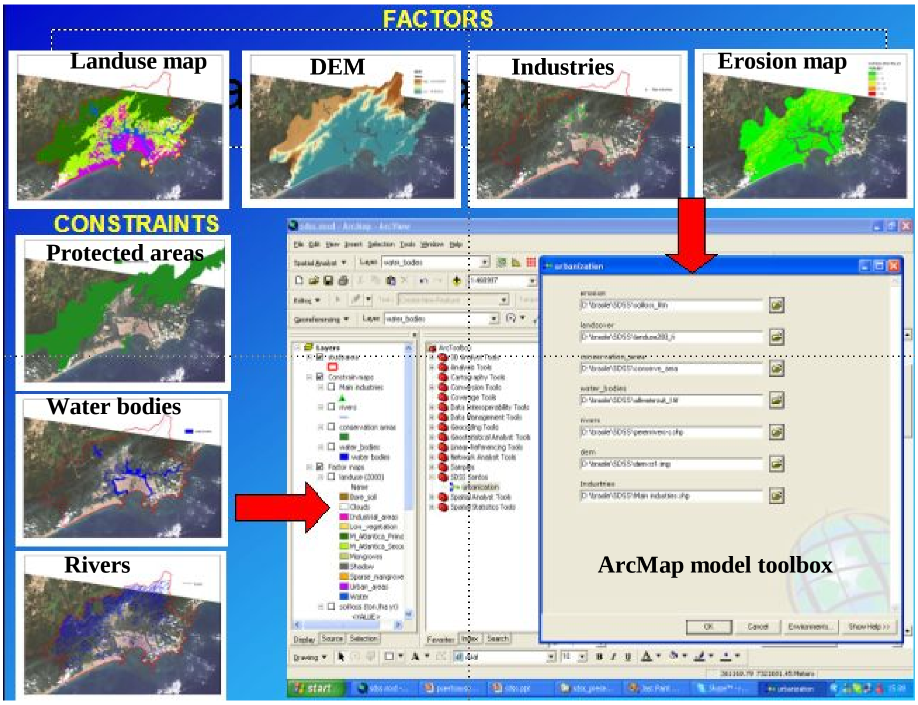


Figure 1 : ArcMap tool module and maps used in the elaboration of SDSS.

Once all maps representing factors and constraints previously defined were introduced into ArcMap modelling tool, the next step was the construction of the scheme model. Figure 2 represents the scheme model applied for getting the suitability map for urbanisation.

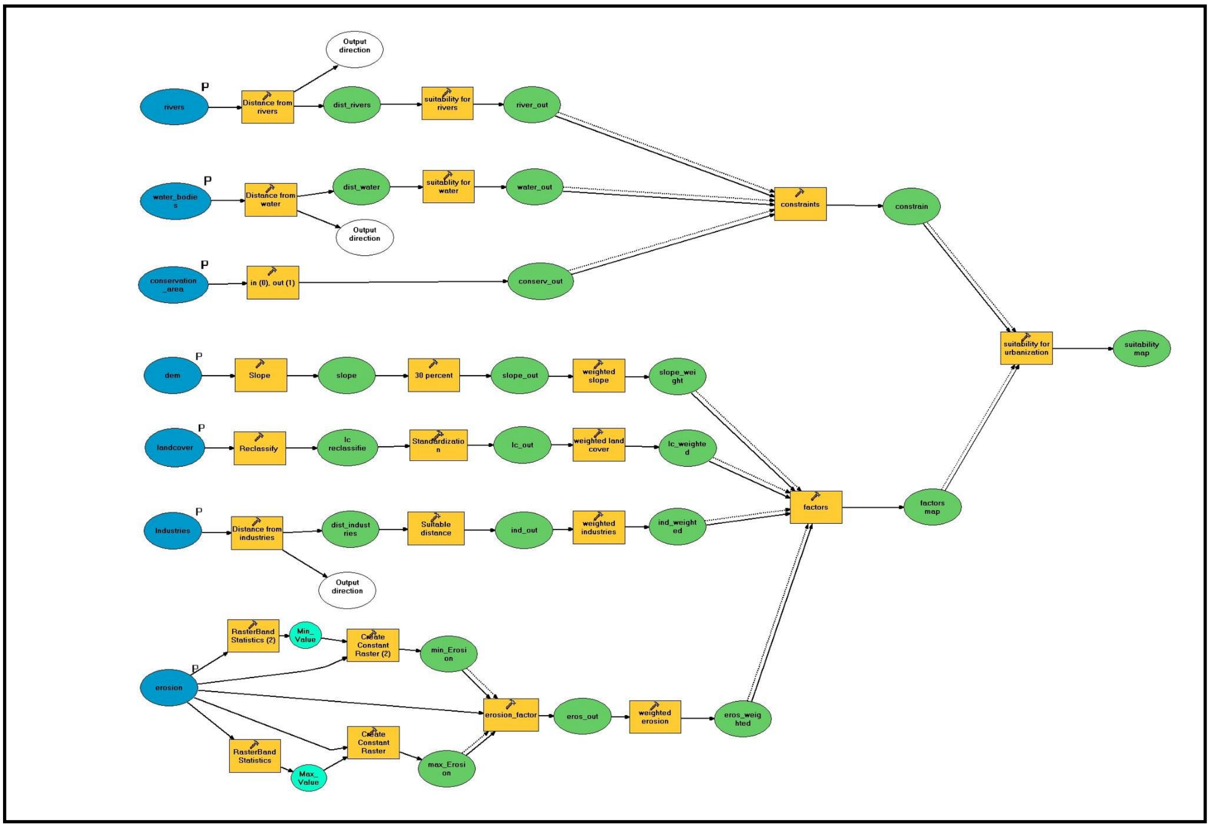


Figure 2: Model scheme used for the elaboration of suitability map of urbanisation in ArcMap 9.0.

All factors and constraints are multiplied separately, resulting in a single map for each one of them (Figure 3).

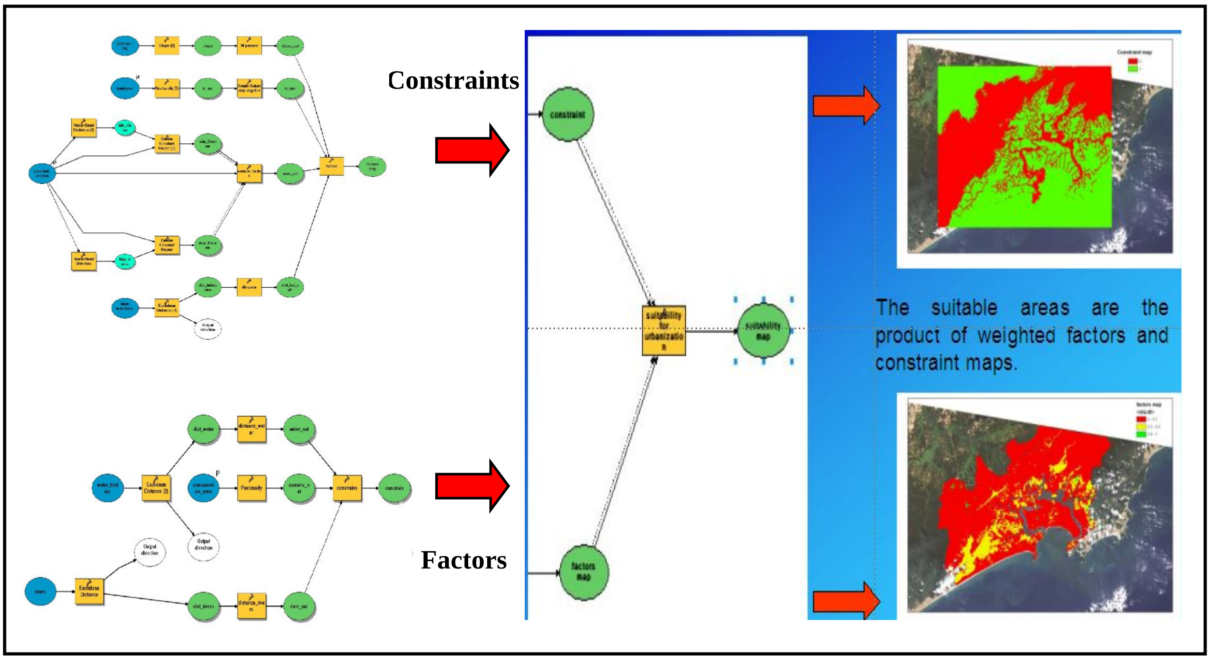


Figure 3: Multiplication of weighted factors and constraints.

Then the final output is given by the product of these single factors and constraints maps, which contain all the information and criteria previously defined. The final output is a suitability map that expresses the degree of "suitability" for urban development in the area of Santos. Those areas classified with high suitability will be the ones proposed for future urban settlements or for relocation of current ones. Figure 4 represents the final suitability map obtained by the application of modeling facilities in ArcMap 9.0 indicating the appropriate areas for urbanization activities in Santos, which was the main objective of the SDSS.

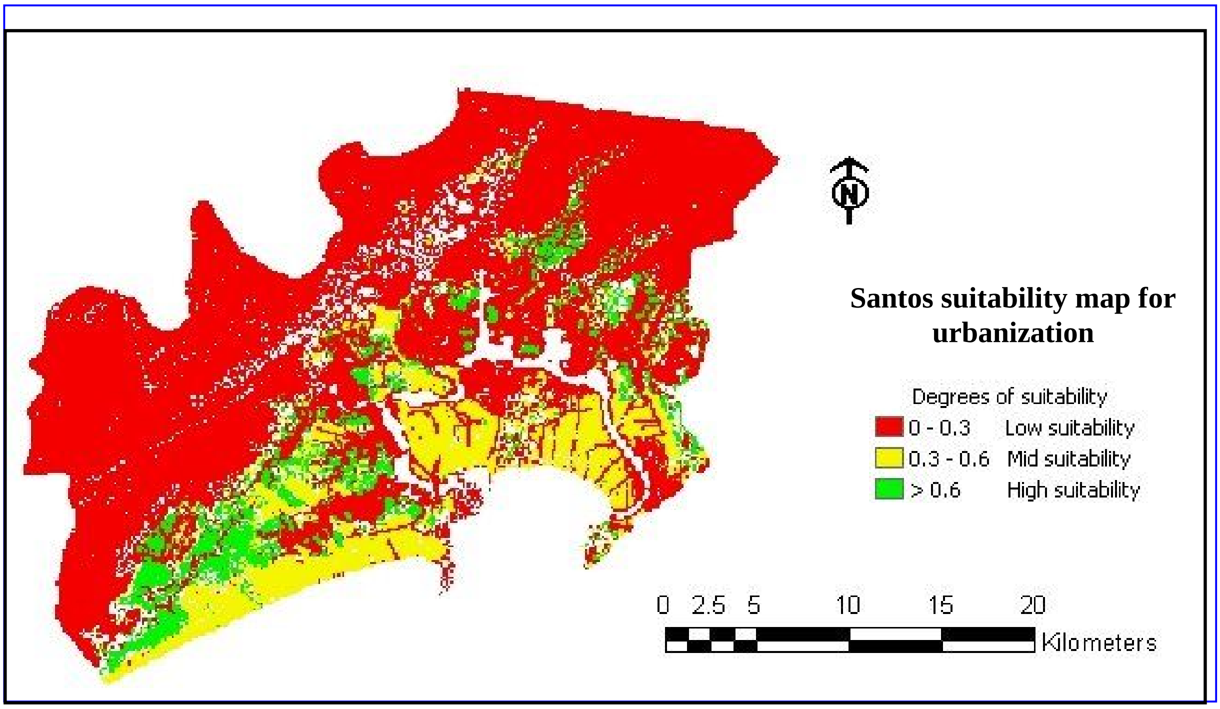


Figure 4: Suitability map for urbanization obtained by the product of the weighted factors and constraints maps.

In Figure 4 it is possible to appreciate the most suitable areas for urbanization indicated by green color, those in yellow indicate possible areas for urban development, while those in red are not considered appropriated for urbanization mainly because they represent protected areas of *Mata Atlântica* and mangrove forests. Also in this case most suitable areas for urban development are located near to the coast and at low elevations which was also defined on the suitability analysis performed in deliverable 4.17. Also proximity to water bodies is an important factor taken into consideration for urbanization activities, however in Santos some of these areas are not consider as suitable for urbanization since important mangrove reserves are located on the estuary coasts.