COORDINATION OF PUBLIC POLICIES FOR FLOOD PROTECTION USING REMOTE SENSING AND GIS TECHNOLOGIES FOR COASTAL URBAN LANDSCAPES AT WATER TERRITORIES

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ABSTRACT

This work deals with the management of landscape at water territories and water areas. The work is focused on a case study in the prefecture of Corinthia, Greece. Algorithms and remote sensing / GIS technology are used to develop a model of comparative temporal approach to the landscapes of principal urban area which is located at coastal zone to provide information for flood protection. Algorithms using remote sensing / GIS technology of best practices are also developed for the coordination of public policies in the field of integrated interventions at modern urban water landscapes compatible to the methods for flood protection.

INTRODUCTION

The prefecture of Corinthia is characterized by non homogeneous distribution of rainfalls and water resources (Voudouris *et al.* 2007). The coastal part of the study area is an agriculturally streamlined and tourism-developed area that bounds a well structured and densely populated urban environment. Extreme climatic events, droughts and floods occurred in the prefecture of Corinthia during the last decades and specifically floods devastate the study area due to human interventions along the stream banks, deforestation and rapid urbanization of the area in the absence of urban planning.

This study was undertaken in the framework of Netwet 3 Project, Interreg III B Archimed Programme to both form a model of comparative temporal approach to the landscapes of principal urban area located at coastal zone with regard to the damage caused to the urban landscape by urban floods and also to develop an integrated methodology -as demonstration example- for the coordination of public policies regarding the protection of the coastal, urban landscape of the Corinthian case study area. Geographic Information Systems constitute an essential part of the models, used for the creation of spatial and attribute databases, the analysis and management of relevant data, as well as for the production of land use/cover maps (Hatzopoulos 2008).

Today, it is broadly accepted the "participatory shift" of public policies aimed at landscape protection, management and planning and the necessity for participative decision-making tools development is recognized. This requirement has been acknowledged after the expansion of the landscape concept, involving not only aesthetic or ecological issues, but also a social dimension of the landscape and more importantly, its nature as a public good. Among the specific measures of European Landscape Convention (Article 6), it is stated that each Party undertakes to assess the landscapes taking into account the particular values assigned to them by the interested parties and the population concerns. As the coastal landscape is a meeting ground between a wide range of interests (economic, environmental, social), the participatory processes need to be approached into a conflict management framework (Santorineou et.al. 2008, Davos et. al. 2007).

STUDY AREA

Figure 1. Location map of the study area showing geographical features.

The study area is located in the NE part of Peloponnesus in southern Greece (Fig. 1) covering the discharge section of the following river/torrent basins: Asopos, Zapantis, Rachianis and Xerias (Fig. 2). The Corinthia prefecture is surrounded by sea and mountains with maximum elevation value 1100 m. The total land is occupied by low-lands, semi-mountainous and mountainous areas. The topographic relief slopes gently from north to south and varies from 0 to 40 m above sea level.

The region is characterized by a semi-arid climate. Rainfall distribution in Corinthian prefecture shows a decrease for eastward and for northward movement. The mean annual rainfall increases with altitude (34 mm per 100m). About 85% of total annual rainfall occurs during wet period (Voudouris & Antonakos 2002).

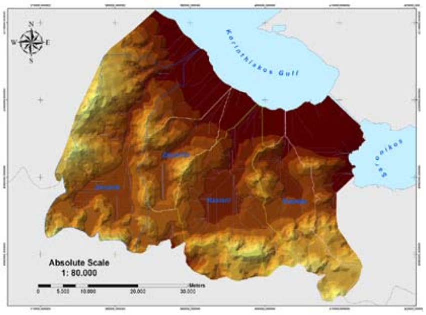

Figure 2. Delineation of basic watersheds

Mean annual precipitation is as low as 426 mm while during the drought of 1989–1992 precipitation was down to 330 mm. The mean annual temperature is 18.3°C while the mean annual potential evapotranspiration is 978 mm.

For this investigation a precipitation grid (Fig. 3) was created by using the Inverse Distance Weighted (IDW) interpolation method with monthly rainfall data from 10 gauging stations of Corinthia prefecture. Since the influence of input points to an interpolated value is distance related, the resulting interpolated surface demands a sufficiently dense network to obtain good results; an uneven or sparse network will not sufficiently represent the surface (Tsanis & Gad 2000). Information for evapotranspiration and direct recharge were not easy to be found so these data were not used.

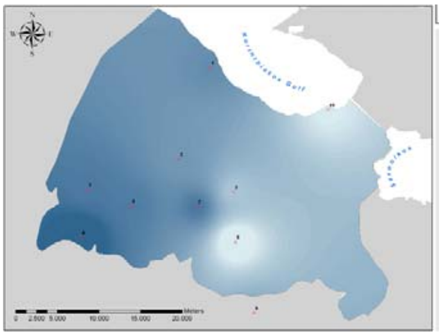

Figure 3. Distribution of monthly precipitation (range: 48-113 mm)

According to Voudouris (2006), a major part of the study area is covered by intensive cultivations (vineyards, citrus fruits, apricots, olive groves). Specifically, olive tree orchards and cultivated lands cover over the half percentage of the study area. A temporal series of Landsat TM satellite images were analyzed to determine the land cover for the dates of 10 June 1987, 21 June 1991 and 20 May 2000 (Fig.4). The recognized classes per image are: urban area, barren soil, olive tree orchards – evergreen shrubs, forest and cultivated land. There is a replacement of shrubs and low vegetation (green colour) by bare soil (brown colour) and infiltration of agricultural areas (yellow colour) in shrubs and low vegetation. With regard to the coastal area, cultivated lands are decreased due to the intense built-up growth. On the contrary, in higher altitudes the cultivated lands are increased over shrubs and low vegetation. Thus, the decrease of cultivated lands is rather misleading and does not appoint the continuously increased pressure of human activities and interventions in the natural environment. The land cover information is necessary for hydrological modeling as this kind of information is used for the determination of soil groups and the specification of curve numbers in the model.

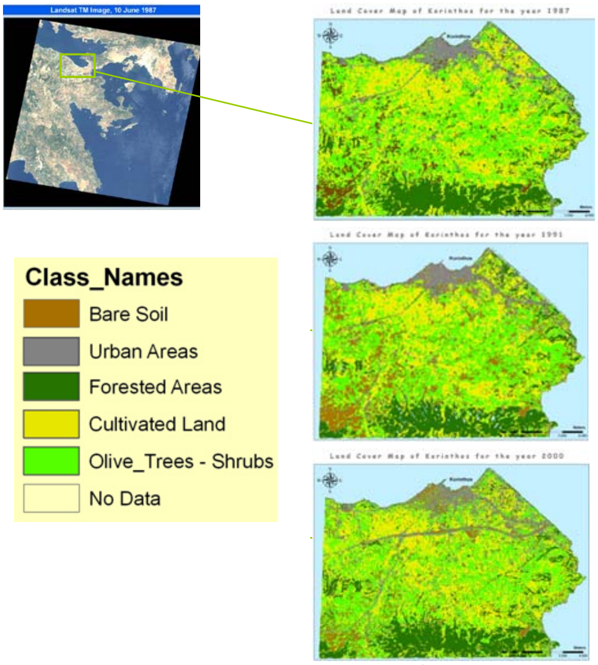

Figure 4. Landsat TM image and Land cover/ use of the study area the years 1987, 1997 and 2000 respectively.

Due to lack of a soil type map for the study area, a map was constructed for the needs of the present study by the help of the Institute of Geological and Mineral Exploitation and published data as guidelines. Soils are classified by the Natural

Resource Conservation Service into four soil Groups based on the soil's runoff potential. The four Hydrologic soil group values range from A – D. "A" soils are light, sandy porous, well drained soils while "D" soils are heavy, clay, compact, and poorly drained. The produced hydrologic soil group contains 4 different soil types: **A** for low-, **B** for small-, **C** for moderate- and **D** for high runoff potential.

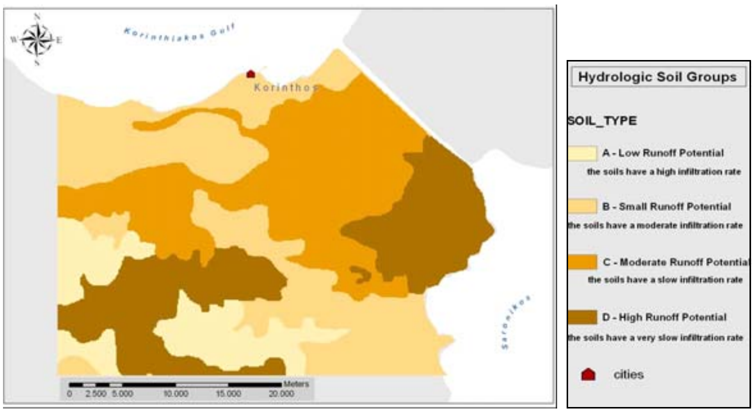

Figure 5. Hydrologic Soil Groups of the study area.

METHODOLOGY DEVELOPMENT & APPLICATION

Temporal Model

DEMs typically require some type of pre-processing prior to hydrologic modeling in order that errors inherent into the data to be removed. This type of processing can greatly increase the accuracy of a DEM. After digitization of contour lines, a 20m DEM is used for terrain representation & drainage pattern improvement. The methods used are: AGREE method developed at the University of Texas at Austin and the Fill Sinks method that modifies the elevation value. Both the flow direction and flow accumulation grid were derived from the Fill Sinks grid and were used as intermediate themes.

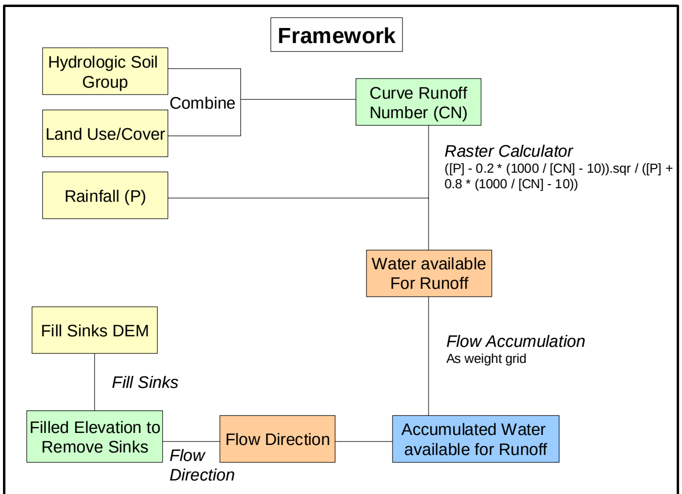

Figure 6. Framework for the creation of the principal layers as input data to the temporal model.

The watershed boundary, the precipitation grid, the hydrologic soil group grid and the land cover raster files were used as basic files for the implementation of a temporal approach model, namely for the years of 1987, 1991 and 2000. The methodological framework for the creation of the principal layers as input data to the temporal model is represented in Figure 6.

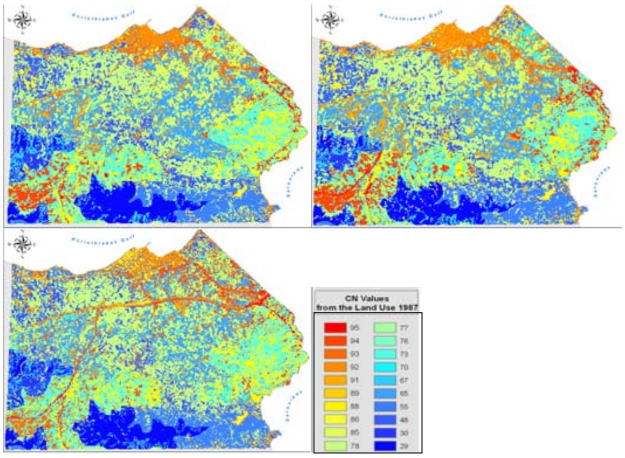

Figure 7. NRCS Curve Number grid for years 1987, 1997 and 2000 respectively.

A combination of a hydrologic soil group (soil) and a land use and treatment class (cover) is a hydrologic soil-cover complex. Each combination of the file represents a curve number value. In the combination file produced, 20 combinations were created each of which has a curve number value (Fig 7). This process runs three times, same as the number of the land cover data. The Runoff Curve Numbers (Table 1) got identified by the National Engineering Handbook (NRCS 2004) and Baloutsos et al. (2000). The lowest curve number value is 29 representing the surface that has great potential to retain water (mostly forest areas) and the higher curve number value is 95 representing areas where the rainfall can be stored by the land surface only to a small extent (mostly urban and residential areas). Areas with high curve number values produce a large amount of direct runoff.

Table 1: Curve number value per land cover type

Land cover	**Hydrologic Soil Group**			
	A	**B**	**C**	**D**
Residential	89	92	93	95
Forest	29	29	70	76
Shrub	30	48	65	73
Barren Soil	77	86	91	94
Agriculture	67	78	85	88

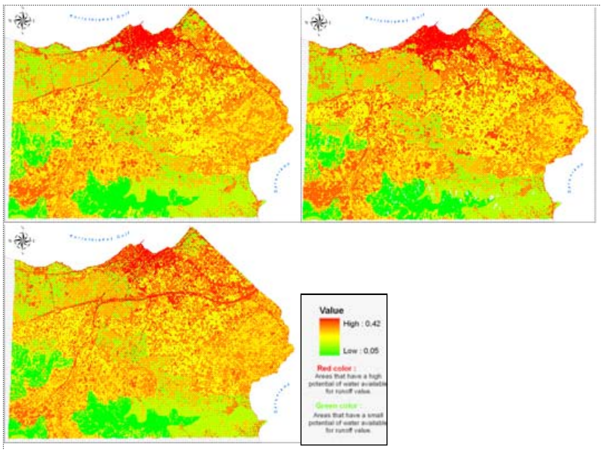

Figure 8. Available water for runoff grid for years 1987, 1997, 2000 respectively.

From the “water available for runoff” themes (Fig. 8) results that at the upper watersheds reaches there are only a few areas with high potential for soil erosion because they have high potential water available for runoff value Areas with high potential of water available for runoff are starting with urban areas (red color), cultivated land (orange color), finishing with olive trees and shrubs (yellow color). The NRCS runoff curve number method is a simple, widely used and efficient method for determining the approximate amount of runoff from a rainfall event in a particular area.

Landscape change models

The methodology involves the development of two landscape change models and their comparison over their relative ability to decrease the flood risk vulnerability of the Corinthian landscape. The first model adopts a participatory decision-making framework, taking into account the perceptions of a multitude of stakeholders in order that a future coordinated landscape change scenario to be spatially formulated. On the other hand, the second model is based solely on spatial and temporal data in order that future land cover allocation patterns to be forecasted in case that the current trend of landscape change will be continued.

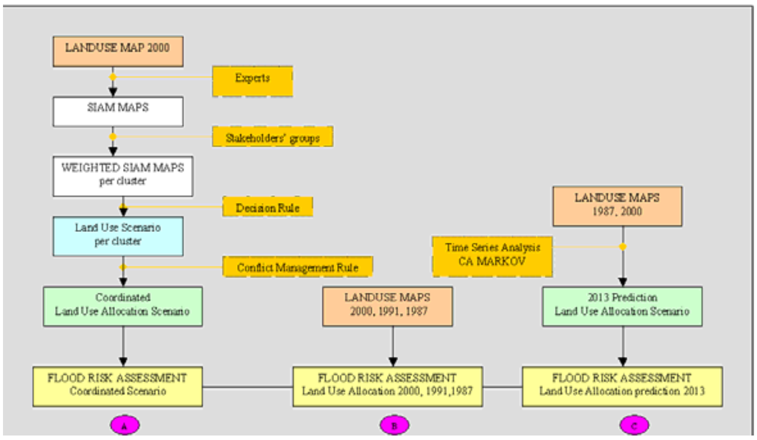

Figure 9. Framework for the creation of the landscape change models.

The methodology provides an assessment of the existing and future states (scenarios) of the landscape, according to territorially defined goals and objectives. Since the focus is put on protection of the landscape from flood events, the pre-existing land cover allocation patterns and the future-oriented scenarios are evaluated on the basis of their relative performance to a flood risk assessment index. The flow diagram of the whole methodology is presented in Figure 9.

Participatory landscape change model

After the finalization of all necessary data manipulations, a first map was produced in IDRISI Andes software as the basic data input of the model representing land cover allocation patterns for the year 2000 in the landscape evaluation units (LEU's) selected. As a landscape evaluation unit is defined each sub-area being examined for future land cover changes. Next, the decision alternatives are expressed as alternative future land cover types per LEU. Spatially, the alternatives are the feasible states in which a homogeneous group of cells can be converted within a forecast time horizon of 13 years (i.e. 2000-2013). Five alternatives per landscape evaluation unit have been identified: (a) Urban, (b) Barren Soil, (c) Forest, (d) Agriculture & (e) Makia – Olive Trees. The evaluation criteria express the factors affecting land cover change dynamics and constitute the basis on which the alternatives are evaluated. Specifically, three general evaluation criteria for the Corinthian case study have been determined (Table 2).

Spatial Impact Assessment Matrix (SIAM) is the basic data input of the model, expressing the performance of every alternative to each evaluation criterion. A normalization scale ranging from 0 (no performance) to 255 (very high performance) is chosen. The construction of SIAM can be possible via the usage of especially designed questionnaires distributed to experts (*expert choice*), who can be asked to evaluate alternative directions of landscape change according to the selected criteria. For the purposes of the case study, a theoretical Spatial Impact Assessment Matrix has been constructed.

Table 2: Definition of Evaluation Criteria for Corinthian case study

EVALUATION CRITERIA	DEFINITION
Environmental Landscape Protection (ELP)	The extent to which the land cover contributes to the prevention of flood events
Economic Landscape Development (ELD)	The extent to which the land cover contributes to the economic growth of the landscape.
Social Landscape Development (SLD)	The extent to which the land cover contributes to the social renewal of the landscape, protects the public health and improves the quality of human environment.

Concerning the set of the participating stakeholders, the incorporation of all different perceptions related to a specific landscape evaluation problem can be achieved via the construction of a stakeholder tree (Davos & Lejano 2001). Specifically designed questionnaires can be used in order to extract criteria weights. The participating stakeholders can be asked to rank the criteria in ordinal as well as in cardinal way, and then the direct ratio approach (Davos 1987) may be used in order to extract the *individual normalized priority values* per participant. Taking as inputs these values, the identification of clusters (*potential coalitions*) expressing statistically similar priorities for evaluation criteria (*coalitional priorities*) was possible through the conduction of a k-means Cluster Analysis conduction in SPSS software. The classification of stakeholders into groups of statistically similar priorities that can be viewed as potential coalitions is followed by the logical assumption that these coalitions could cooperate to support the alternatives that best satisfy their values. For the purposes of this case study, the following theoretical cluster priorities to evaluation criteria have been produced (Table 3).

Table 3: Theoretical cluster priorities to evaluation criteria

CLUSTERS	ELP weight	ELD weight	SLD weight
1st cluster	**0.5**	0.2	0.3
2nd cluster	0.3	0.3	**0.4**
3rd cluster	0.3	**0.4**	0.3

Taking inference from this Table, the 1st cluster could be characterized as a *coalition of environmental interest*, as it gives its highest priority to the criterion of Environmental Protection of Landscape. Accordingly, the 2nd cluster could be a *coalition of social interest*, assigning its highest priority to the "Social Landscape Development" criterion. Finally the 3rd cluster could be characterized as a *coalition of economic interest*, as its members express high priorities to the Economic Development of Landscape.

Taking as inputs the SIAM provided by the experts, SIAM maps were constructed and readjusted in order to reflect the relative weights (criteria priorities) of the different stakeholder groups. For every alternative, the Weighted Linear Combination (WLC) aggregation procedure of the evaluation criteria has been selected. According to this method, the criteria (*factors*) are standardized to a common numeric range, and then combined by weighted averaging. The result is a continuous mapping of suitability that may then be masked by one or more Boolean *constraints* to accommodate qualitative criteria and finally thresholded to yield a final decision (Jiang & Eastman 2000). In the framework of the present study, outputs of this sub-model are the aggregated land cover suitability raster images produced per cluster.

These images were used as inputs for the construction of corresponding landscape change scenarios. In this step, the alternatives evaluation results were translated into different future scenarios, each of which represents the different preferences of the potential stakeholders' coalitions. The individual scenarios were spatially formulated by the conduction of a multi-dimensional choice procedure, named as MDCHOICE. This algorithm resolves conflicts between competing objectives by means of a multiple ideal-point procedure (Eastman 2006) and it has been used as an *inter-cluster* conflict management rule. The weight value is multiplied by the image values prior to checking the threshold criteria and choosing the maximum or minimum value. Final output of this sub-model is a landscape scenario per potential coalition.

The coordinated landscape change scenario has been spatially constructed via the application of MOLA (Multi-Objective Land Allocation) procedure, which is the selected conflict management rule *among clusters*. MOLA provides a procedure for solving multi-objective land allocation problems for cases with conflicting objectives. Specifically it determines a compromise solution that attempts to maximize the suitability of lands for each objective. During an iterative process, MOLA reclassifies the ranked-suitability images to perform a first-stage allocation according to the specific areal needs, checks for conflicts and then allocate them based on the weighted minimum-distance-to-ideal-point-logic (Eastman 2006). Final output of this implementation step is the coordinated landscape change scenario for all clusters (Fig. 10).

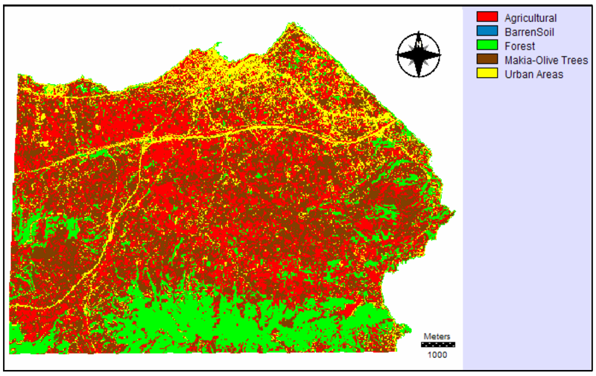

Figure 10. Coordinated landscape change scenario.

Non Participatory landscape change model

The aim of this kind of analysis is to investigate what may happen if the current trends of landscape change will be continued, without the adoption of a participatory process of decision-making. Within this framework, a landscape change scenario for 2013 has been projected, taking as inputs the land use/cover data of the years 1987 and 2000. Two kinds of IDRISI modules have been utilized: (a) Markov Chain Analysis and (b) the combined CA-Markov Analysis. The CA-Markov Analysis is a combined land use/cover prediction procedure that adds an element of spatial contiguity, as well as knowledge of the likely spatial distribution of transitions to Markov chain analysis. According to the cellular automata (CA) logic, the land use at time t+1 depends on a set of rules (transition rules) taking into account the land use at time t and the neighboring land uses. The CA sub-model in IDRISI Andes software uses as input a raster group file, listing the conditional probability images (i.e. outputs of Markov sub-model). These images are reclassified via the application of a 5 x 5 contiguity filter. The CA-MARKOV module uses MOLA procedures in order that a projected landscape change scenario for the year 2013 to be produced (Fig. 11).

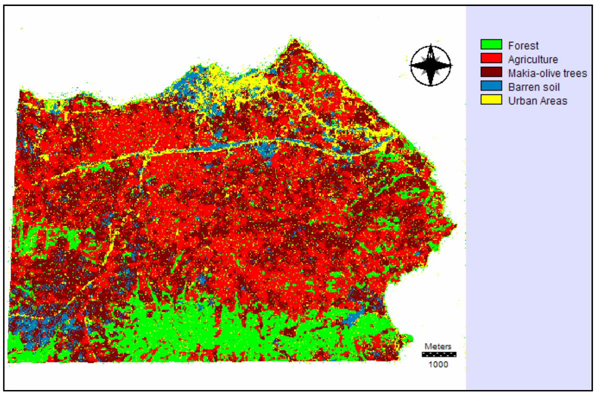

Figure 11. Non Participatory landscape change scenario.

Flood Risk Assessment

The landscape change scenarios created by the participatory and the non-participatory models have been compared over their relative ability to decrease the flood risk vulnerability of the landscape. Specifically, a flood risk assessment index was produced (Table 4) indicating the relative vulnerability of different land cover types to flood events. The index was extracted through a qualitative classification of runoff curve numbers attached to the hydrologic soil-cover complexes.

Table 4: Flood risk assessment index

LAND COVER TYPE	FLOOD VULNERABILITY
Urban areas	1st level (Very high vulnerability)
Barren soil	2nd level (High vulnerability)
Agriculture	3rd level (Medium vulnerability)
Makia-Olives	4th level (Small vulnerability)
Forest	5th level (Very small vulnerability)

In the framework of this research, the flood risk assessment images were constructed by reclassifying pixel values stored in landscape change scenarios into new categories indicating the relative flood vulnerability per land cover type (Fig.12-Fig.13). Following the same logic, three more flood risk assessment images were also constructed (data not shown) using as inputs the land cover maps of the years 1987, 1991 & 2000. The comparison of the two landscape scenarios on the basis of their performance to the flood risk assessment index yielded the following major results: (a) the percentage of the areas with high vulnerability to flood events is zero when the participatory approach is applied. On the contrary, if the non-participatory methodological framework is applied, the percentage of the areas facing a high risk to flood events is similar to that of the year 2000; (b) the percentage of the areas with very high vulnerability to flood events is similar to that of the year 2000, in case that the participatory decision-making approach is applied. With the application of the non-participatory framework, the percentage of these areas tends to be increased.

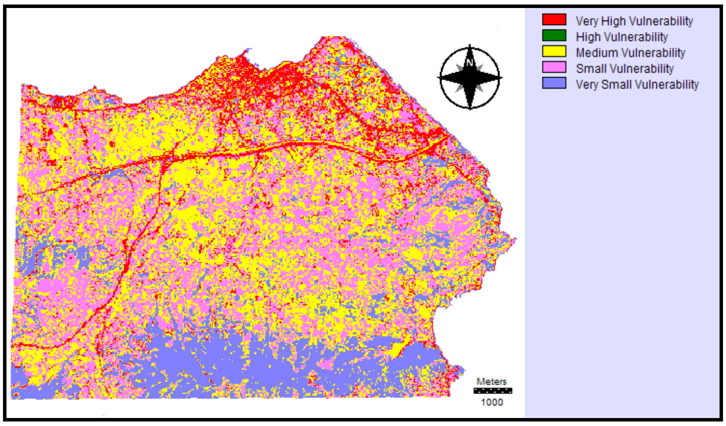

Figure 12. Flood risk assessment of the coordinated landscape change scenario

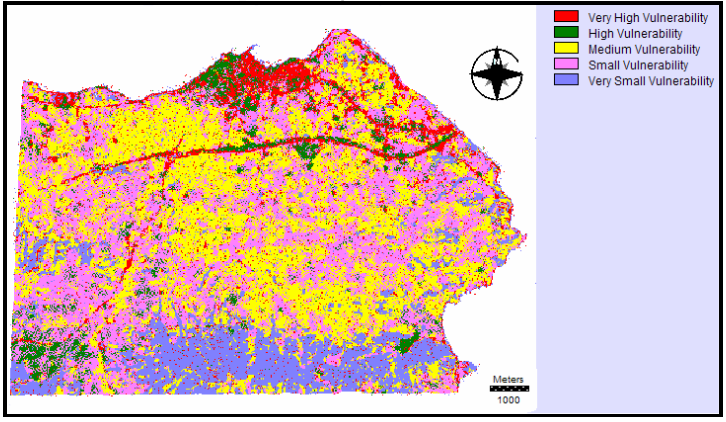

Figure 13. Flood risk assessment of the non-participatory landscape change scenario

CONCLUSIONS

This study demonstrated an efficient way of locating vulnerable areas to flood hazard by making use of high resolution DEM and satellite images of moderate resolution. It consists of a methodology of low-cost and time-saving analysis that can be used to flood risk assessment in an efficient way. Also, this study involved the development of two landscape change models and their comparison over their relative ability to decrease the flood risk vulnerability of the Corinthian landscape. The comparison of the final spatial outputs showed that the percentage of the areas facing a very high or high-risk vulnerability to flood events is decreased when participatory conflict management approaches are incorporated into landscape change models. More generally, it seems that a coordinated participatory decision-making approach can lead to a higher level of landscape protection.

In this regard, the present study demonstrated the need to give emphasis to the following guidelines of best practices for the coordination of public landscape policies. It is stressed that the guidelines are focused on issues related to the design of spatial landscape models.

1. Use of innovative technological tools to read landscape

- GIS tools to read the spatial dimension of landscape
- MCE tools to read the social dimension of landscape
- Time-Series & Scenario analysis to read the temporal dimension of landscape

2. Clear definition of landscape protection objectives

- Case study: protection of landscape from flood events

3. Investigation of future landscape change scenarios and their evaluation according to territorially defined goals and objectives

- Link scenarios with specific public landscape policies (e.g. coordinated scenarios as outcomes of participatory decision-making approaches)
- Evaluation of scenarios according to a flood risk assessment matrix

4. Incorporation of participatory decision-making approaches into a conflict management perspective

- Adoption of a people-centered approach
- Incorporation of expert and non-expert views into the analysis
- Clear definition of landscape evaluation criteria & decision alternatives
- Distribution of especially designed questionnaires to stakeholders
- Identification of potential coalitions (clusters) among participants
- Clear spatial definition conflict management rules
- Use of *inter-group* and *among-groups* conflict management rules

ACKNOWLEDGEMENTS

The results presented here were partly funded by the European Commission within the project NETWET 3 coordinated by the Center of Euro-Mediterranean

Regions for the Environment. The “Institute of Geological and Mineral Exploitation” of Athens gratefully provided meteorological data.

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