ANALYTIC HIERARCHY PROCESS (AHP) AND GEOGRAPHICAL INFORMATION SYSTEMS (GIS): AN INTEGRATED SPATIAL ASSESSMENT FOR PLANNING STRATEGIC CHOICES

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ABSTRACT

In the contemporary debate regarding environmental assessment and integrated approaches, a Spatial Decision Support System (SDSS) designed to help a user or a group of users reach more effective decisions by solving semi-structured spatial problems can be supported by Geographical Information Systems (GIS) combined with an Analytic Hierarchy Process (AHP). This paper explores the potential of Multi-Criteria Spatial Decision Support Systems (MCSDSS), denominated Integrated Spatial Assessment (ISA), for the field of land-use planning. Such a system takes into account both technical knowledge regarding the decision problem at hand and the lay knowledge of the local community in the construction of shared planning choices. Through the empirical investigation of an operative case study, an integrated evaluative approach implemented by means of MCSDSS can go beyond spatial and hierarchical limits - taking into account the different components, clarifying weights and recognizing different priorities - to define appropriate strategies, considering social participation and dynamic dialogue among different experts in keeping with sustainability principles.

Keywords: Analytic Hierarchy Process, Geographic Information System, Integrated Assessment, Multi-Criteria Spatial Decision Support System

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1. Introduction

Assessing the impacts of policies, plans, projects and programs requires particular attention to the values of existing resources and the affected communities. Defining what is relevant to an assessment requires a higher level of benchmarking that can enable a broader perspective within the evaluation process in order to balance community values with sustainable development goals. Recognizing multiple interdependent values creates the conceptual and empirical foundations for understanding just how these values can be applied to a local development process. This means becoming aware of the "complex social values" of resources (Fusco Girard, 1987; Fusco Girard and Nijkamp, 1997), taking into account the community's point of view. Today "hard" values - the tangible, material and monetary ones - are dominant, so that "soft" values - the intangible, immaterial and non-monetary ones - are often forgotten. Recognizing tangible and intangible values is the basis for collective decision-making that includes the development and definition of goals, sharing of knowledge, negotiation and compromise, problem-setting and problem-solving, and needs evaluation along with attention to issues of justice and equity (Sinclair, Sims, and Spaling, 2009). This means supporting stakeholders and communities in clarifying values, becoming more adaptive and pro-active, responding to change, setting personal and collective goals, and participating in planning and design decision-making processes. Through integrated evaluation approaches, it is possible to reach a balance between preservation and transformation while respecting values and existing forms of capital (human, social, cultural, environmental, economic, etc.). With this perspective, it is essential to consider the different levels of analysis and the many dimensions of evaluation including specific attention to emerging problems, local needs, stakeholder interests, and protection and enhancement of scarce resources (Wiek and Walter, 2009). An integrated evaluation approach can go beyond spatial and hierarchical limits to consider the different components, clarify weights, recognize different priorities and define appropriate strategies while also considering social participation and a dynamic dialogue among different experts (Lee, 2006).

The different approaches are described in the literature as forms of "sustainability assessment" evaluated in terms of their potential contributions to the implementation of sustainability. Many are actually examples of "integrated assessment" (Pope, Annandale, and Morrison-Saunders, 2004) deriving above all from Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) (Therivel, 2010). Indeed, the term "integration" implies that integrated assessment should be more than the sum of separate environmental, social and economic assessments. According to Eggenberger and Partidário (2000), "integration" means that a new entity is created that establishes new relationships influencing single entities having specific characteristics and dynamics. If this viewpoint is taken into account, it holds that integrated evaluation can become a "key tool" in supporting the decision-making process especially when uncertainty, complexity and values of different social groups are many, differentiated and conflicting (Cerreta and De Toro, 2010). Integrated evaluations not only consider the input of data expressing the impacts of different solutions but they are also "open" to broad public participation in order to offer more information for the evaluation process itself and, in addition, make decision-making processes and their results more acceptable (Munda, 2008). Participation becomes essential not only in examining and evaluating choices on the social, ethic, political, economic, environmental levels but also in legitimating choices and making them acceptable to the community itself. In this view, it is important to combine different approaches within a single framework that integrates different evaluation tools (Finnveden, Nilsonn, Johansonn, Personn, Moberg, and Carlsonn, 2003). In particular, innovative tools that could be useful to consider are those that offer the possibility of combining Multi-Criteria Analysis (MCA) and Multi-Group Analysis (MGA) with Geographical Information Systems (GIS), Internet Technology, Spatial Decision Support Systems, and Cellular Automata Models (Rotmans, 2000). Moreover, integration of different evaluation models with GIS (Malczewski, 1999) becomes decidedly important in the construction of a Spatial Decision Support System (Geneletti, 2004; Vizzari, 2011). In keeping with this perspective, the principal aim of this paper is to advance the contemporary debate on environmental assessment and integrated approaches through an empirical investigation of an operative case study in order to generate, at the same time, a rich understanding of the specificity and complexity of the single case and to provide a solid framework for analyzing the potential and problems of combining AHP and GIS in a Multi-Criteria Spatial Decision Support System.

The first part of the article analyzes the characteristics of the SDSS with particular reference to MCSDSS, highlighting the potential of an integrated approach through the Integrated Spatial Assessment (ISA) procedure proposed by the authors. The second part discusses the characteristics of the ISA approach through its application to the Strategic Environment Assessment (SEA) of the City Plan of Cava de' Tirreni, a town in Southern Italy, in order to produce maps of the susceptibility of potential locations for the plan's strategic visions.

2. Multi-Criteria Spatial Decision Support Systems as Tool for Integrated Assessment

A Spatial Decision Support System (SDSS) is defined as an interactive, computer-based system designed to support a user or a group of users in reaching more effective decisions by solving semi-structured spatial problems (Malczewski, 1999; Dye and Shaw, 2007) in which hard and soft data interact. Spatial decision-making problems can involve the evaluation of many decision alternatives based on multiple qualitative and/or quantitative criteria. A large amount and variety of spatial data can be involved. GIS provides useful functions to help face and resolve these spatial decision-making problems. Spatial decision-making problems are multi-faceted challenges (Eldrandaly, 2010). Not only do they often involve numerous technical requirements, but they also concern economic, social, environmental and political dimensions with potentially conflicting values and goals. Solutions to these problems involve highly complex processes of spatial data analysis and frequently require advanced means for addressing conditions of physical suitability while considering multiple socio-economic variables. Standard GIS software is not designed to handle different values, variables and relationships and select and use information in different ways. Current GIS lack mathematical modeling applications, iterative equation solving, and the simulation capabilities necessary for many spatial decision-making situations. In order to consider these needs, SDSS can facilitate such decision conditions through an application that allows users to specify their criteria and preferences interactively through an easy-to-use interface allowing the exploration of possible options, along with analytical functions that can generate feasible solutions based on specified criteria and preferences. The development of SDSS is explicitly designed to support decision-making processes for complex spatial problems and provides a framework for integrating database management systems with analytic models, graphic display capabilities, the expert knowledge of decision makers and community preferences. An SDSS can include the integration of a geographic database management system with analytical modeling capabilities, a visualization component, and a user-friendly decision-making interface to help users reach more effective decisions regarding semi-structured spatial decision problems (Dye and Shaw, 2007).

Multi-Criteria Decision Making (MCDM) and a wide range of related analytical techniques offer a variety of decision-making procedures that help represent and integrate choices with available MCDM methods in order to solve "real-world" GIS-based planning and management problems. In the decision-making process regarding real-world GIS-based problems, related spatial and non-spatial data and acceptable techniques require an interactive system incorporating expert knowledge (Karnatak, Saran, Bhatia, and Roy, 2007). A variety of territorial-related information (social, economic and environmental) can be easily combined and related to the characteristics of the different options for territorial use, facilitating the construction of appropriate indicators and improving impact forecasting, in the end leading to a priority classification of various options. Integration of Multi-Criteria Analysis, Multi-Group Analysis and GIS can be exceptionally fruitful in cases characterized by strong conflict in which the roles of local actors and their relationships and goals are considered structuring elements for the process of information construction in a spatial and dynamic evaluation model (Joerin and Musy, 2000). In particular, the integration of the Analytic Hierarchy Process (AHP) and Geographical Information Systems (GIS) could be of particular importance in land-use management (Thirumalaivasan, Karmegam, and Venugopal, 2003; Al-Shalabi, Bin Mansor, Bin Ahmed, and Shiriff, 2006; Nekhay, Arriaza, and Guzmán-Álvarez, 2009; Şener, Şener, Nas, and Karagüzel, 2010). As compared to traditional forms of GIS use, it could become possible to evaluate data covering not only current conditions but also (Sumathi, Natesan, and Sarkar, 2008):

1. spatial characteristics of proposed options;
2. implementation of "what if" data analysis investigating potential scenarios and verifying the importance of the different influencing factors;
3. temporal modification of data following option implementation;
4. expressed preferences of local agents;
5. conflict analysis among the various stakeholders;
6. evaluation of various options in order to obtain a preference priority list;
7. visualization of results through graphic representation.

Spatial analysis combined with AHP has been used in recent years to support evaluation especially in the field of land-use planning. This paper proposes extending this integration to the context of Integrated Assessment in order to consider not only the technical aspects of a decision-making problem but also the involvement and participation of the local community in planning choices. With respect to traditional GIS use, we propose to take into account not only existing conditions data but also the spatial characteristics of proposed options, data that changes over time, the representation of agents' preferences, conflict analysis, and impact assessment of the different options. Therefore, it could be possible to configure a decision support system which includes "social creativity" as a key component in the decision-making process, with the "reflexive community" as a necessary interlocutor. In this way, individual and social creativity can be integrated to face complex problems through innovative approaches.

In this light, Integrated Spatial Assessment (ISA) (Cerreta and De Toro, 2010) can be useful in decision-making as a tool that includes technical and political evaluations and refers to complicated and complex value systems in conflicting and changing contexts. The integration of Problem Structuring Methods, Public Participation GIS, Multi-Criteria and Multi-Group Decision Support Systems and Geographic Information Systems sustains a decision-making process that allows both the analysis of the complexity of human decisions within a flexible environment in which collective knowledge and learning take on a significant role in the processes, as well as the possibility of exploring a spatial development strategy in keeping with sustainable and complex values. Indeed, combining AHP with GIS overcomes the limitations of certain techniques through the application of different methods deriving from multiple disciplines to define a more complete and integrated framework for analysis and evaluation. This kind of integration gives rise to a "spatial multicriteria and multigroup analysis." Multicriteria spatial decision-making problems typically involve a set of geographically-defined alternatives from which a choice of one or more options is made with respect to a given set of evaluation criteria. Multicriteria spatial analysis differs greatly from conventional multicriteria techniques due to the inclusion of an explicit geographic component. It requires information regarding criterion values and the geographic locations of alternatives in addition to decision makers' preferences for a set of evaluation criteria. This means that the results of the analysis depend not only on the geographic distribution of attributes but also on the value judgments involved in the decision-making process. Therefore, two considerations are of fundamental importance for multicriteria spatial analysis: the GIS component (i.e., data acquisition, storage, managing and organizing spatial data, changing and updating the information, etc.) and the multicriteria analysis component (i.e., aggregation of spatial data and decision makers' preferences into discrete decision alternatives). Multicriteria Spatial Decision Support Systems (MCSDSS) are part of a broader field of Spatial Decision Support Systems (SDSS); in this field, several specific application frameworks for designing MCSDSS have been proposed (Carver, 1991; Eastman, Kyem, Toledano, and Jin, 1993; Jankowski, Nyerges, Smith, Moore, and Horvath, 1997; (Karnatak, Saran, Bhatia, and Roy, 2007) defining a sharable framework that can resolve real-world spatial decision problem most efficiently. The use of spatial data in a GIS context helps in the manipulation, examination and presentation of geographic information (Vanderhaegen and Muro, 2005). GIS allows databases to be connected to spatial features using geographic space as the unifying factor, visualizing and analyzing data in an understandable and communicative way. Indeed, GIS can be used in all stages of the preparation of environmental assessments, especially because of its capacities for spatial data integration. GIS stores, integrates, analyses and displays data and can be employed for data preparation, spatial analysis and the presentation of results. In environmental assessments, spatial data is of use in the screening and scoping phases, in project description, in the establishment of the environmental baseline, the definition of impact mitigation and control, public consultation and participation, and monitoring and auditing. When compared to conventional procedures, applying geo-spatial techniques in environmental studies offers other important advantages such as the identification of the spatial and temporal variability of the impacts (Patil, Annachhatre, and Tripathi, 2002; Vanderhaegen and Muro, 2005).

3. Integrated Spatial Assessment (ISA) for the Cava de' Tirreni[1] City Plan

The Integrated Spatial Assessment (ISA) approach was applied to the new City Plan of the municipality of Cava de' Tirreni in the Province of Salerno in Southern Italy. Throughout the experiment, the aim was to create a methodology that could help identify the interests involved, create broader cohesion regarding environmental protection and preservation of cultural heritage, stimulate the usability of the territory while respecting existing resources, and finally define territorial impacts deriving from plan strategies and actions. In particular, "location susceptibility" maps were created in order to express the propensity of an area to "receive" a given function taking into account potential impacts through multicriteria assessment (AHP) integrated with GIS. Using the typical approach of Strategic Environmental Assessment (SEA) but translating it into a more complex evaluation process defined as ISA, we sought to integrate territorial and environmental aspects with plan strategies and choices while recognizing the important role of environmental effects within the decision-making process as well as the selection of alternative options. In this sense, the use of multicriteria assessment plays a privileged role as a decision-making tool (Figure 1).

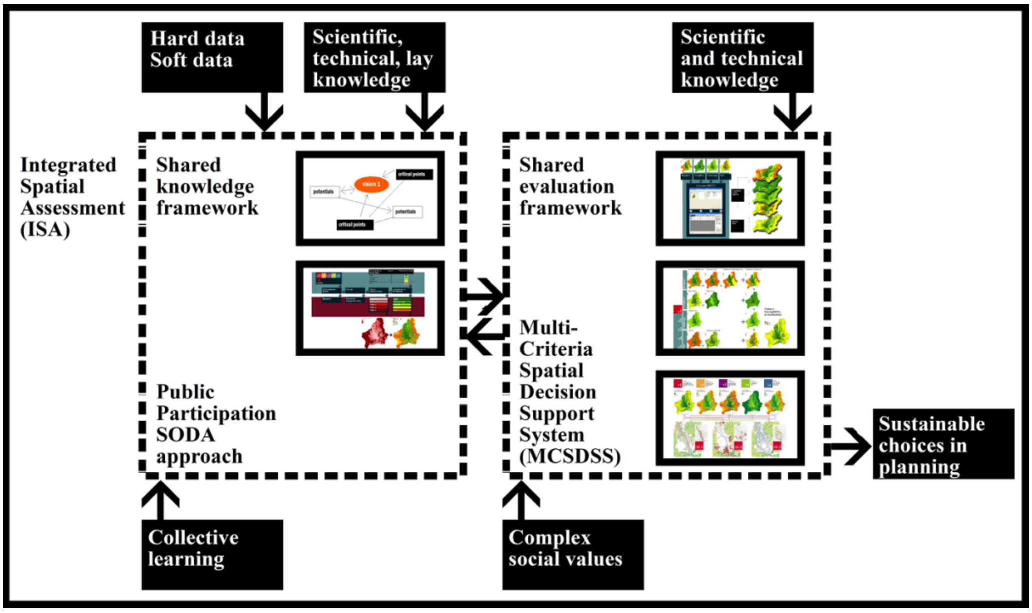

Figure 1 The Integrated Spatial Assessment approach in Cava de' Tirreni City Plan.

[1] The working group was organized as follows: Planning and scientific coordination, Carlo Gasparrini with Cinzia Panneri, Paola D'Onofrio, Mirella Fiore, Vincenzo Rizzi, Luigi Innamorato, Alessia Sannolo, Anna Terracciano, Pasquale Inglese, Daniele Cannatella; Geomorfology, Silvana Di Giuseppe; Agronomy, Maurizio Murolo; Landscape, Vito Cappiello with Anna Aragosa; Economic and financial feasibility, Ettore Cinque with Andrea Mazzella; Infrastructure and Mobility, Giulio Valfrè with Vincenzo Cerreta (D'Appolonia SpA); Strategic Environmental Assessment, Maria Cerreta, Pasquale De Toro, Saverio Parrella. We thank the technical staff of Cava de' Tirreni Municipality for their support and collaboration.

In Strategic Environmental Assessment (SEA), ISA can be considered a “tool” for creating and identifying territorial impacts deriving from plan strategies and actions. Therefore, ISA can be considered a learning process seeking to create choices and make decisions in flexible, inclusive and participative terms, revealing explicit and hidden conflicts and interests while enhancing local potential. We created a GIS that seeks effective integration of different information emerging during the decision-making process. In particular, for the assessment of plan alternatives, the Analytic Hierarchy Process (AHP) (Saaty, 1980) multicriteria method was integrated with GIS to predict, in spatial terms, the plan’s impact on different environmental characteristics.

Public meetings, in-depth interviews, and data and information collection were implemented with the main goal of defining a permanent interaction “platform” supporting dialogue and mutual learning among citizens, experts and municipal administrators. Public meetings created direct dialogue with citizens and stakeholders and a common ground for discussion among citizens, professionals and the municipality. The main goal was both to obtain deeper knowledge of Cava de’ Tirreni, with special focus on the most important issues for future urban, social, economic and cultural transformations, as well as to pinpoint collective needs. Thus, “common knowledge” (citizens, associations, civil society, etc.) and “expert knowledge” (technicians and administrations) interacted continuously. Three main topics were considered during the meetings regarding the development of Cava de’ Tirreni: *What is the shared vision of the future? What strategies should be used? What actions should be undertaken?* For the public consultation process, a questionnaire was formulated in which associations and citizens were asked to express their points of view regarding the city’s present and future. Then, in order to further broaden participation, the municipality sent a survey to families to reveal citizen needs and project-ideas for improving and developing the city.

During the participative phase, five shared “Visions” of the future were generated. They were: “Cava as a beautiful and identity-bearing city”, “Cava as a regenerated and friendly city”, “Cava as a modern and productive city”, “Cava as a territorial hub”, “Cava as an ecological city”. The visions reflect the community’s perception of complex social values and express its important resources on a number of different levels. The visions were analyzed using the Strategic Options Development and Analysis (SODA) approach (Rosenhead and Mingers, 2001), a decision-support system that allows complex problems with non-structured qualitative data to be faced starting from “cognitive maps.” Using the Decision Explorer 3.1.0 software, cognitive maps were created from verbal protocols whose contents were structured according to a formal and methodological approach. The cognitive maps represented the structure of the meeting discussions and were able to maintain a rich amount of data and manage the complexity of the information.

Consistent with the hierarchical structure of the decision-making process, the visions were broken down into general goals, strategic axes and strategic actions. In detail, the strategic actions were linked to three “core projects” that became the main references for direct implementation in the operative phase. The core projects are the synthesis of the issues that emerged during the participative and consultative process and identify the key transformation and preservation projects within the infrastructural, spatial, functional and symbolic relations systems.

In order to determine possible locations for the different planning choices, the Analytic Hierarchy Process (AHP) integrated with the GIS tools (Chen, Blong, and Jacobson, 2001; Malczewski, 2004) allowed decision-making to go beyond the simple overlay of different themes through pairwise comparisons of the criterion established for each hierarchical level. For each of the five visions, a "location susceptibility" map was generated expressing the territory's propensity to receive a given strategic action considering its potential impacts; the lower the territorial and environmental impacts caused by an action, the greater the susceptibility of the territory to receive it.

By considering the typical SEA approach and translating it into a more complex evaluation process defined as ISA, we sought to integrate social, territorial and environmental aspects in the development of plan strategies and choices while simultaneously recognizing the important role of stakeholder perceptions and environmental effects within a collective decision-making process seeking to identify alternative opportunities.

4. Location Susceptibility Maps for Strategic Visions

The Analytic Hierarchy Process (AHP) organizes the decision-making process hierarchically. The basic AHP process involves the perception, breakdown and synthesis of a decision problem in order to provide a methodology for modeling unstructured problems in the economic, social, and management sciences. The definition of a hierarchy is an abstraction of a system's structure used in order to study the functional interactions of its components and their impacts on the entire system. This abstraction can take several related forms, all of which are essentially derived from overall goals moving through sub-goals, to the forces that affect these sub–goals, to the people who influence these forces, to the people's goals and policies, strategies, and finally to the outcomes resulting from these strategies (Saaty, 1980). From a procedural point of view, this approach consists of three main phases: 1. construction of a suitable hierarchy; 2. establishing priorities among the elements of the hierarchy by means of pairwise comparisons; 3. verification of the logical consistency of the pairwise comparisons (Saaty and Peniwati, 2007; Saaty and Vargas, 2000).

In the present case-study, each vision produced during the participative phase was organized according to a tri-level hierarchical structure: 1. environmental themes; 2. criteria; 3. values/characteristics.

Spatial indicators referring to the nature of the areas linked to a value judgment were associated with the values/characteristics in the third hierarchical level, expressed on a five point scale:1. high location susceptibility ; 2. medium–high location susceptibility; 3. medium location susceptibility; 4. medium–low location susceptibility; 5. low location susceptibility (Figure 2).

To conduct "spatial assessment," an extension of the AHP method within an ArcGIS (Marinoni, 2004) environment was used to obtain "location susceptibility" maps. This program was written in Visual Basic using ArcObjects, the ArcGIS development platform. The program was not developed as a separate executable file but runs as a VBA macro in the ArcGIS environment. The VBA module which implements AHP is a useful tool for facilitating land use assessment. Indeed, the module accesses an external dynamic link library (EigenUtl.dll) which performs the eigenvalue and eigenvector calculations of the preference matrix and returns the criteria weights. Together with this dynamic link library, the VBA macro fills an important gap in ArcGIS functionality; this made it possible to obtain a pairwise comparison of the criteria referring to each hierarchical level.

In order to apply the AHP method to each location susceptibility class, a numerical value (score) and a chromatic scale were associated with the five judgments. To produce the graphic representation of the results, the color given to every pixel is related to every score according to the conventional range from dark green to orange. We selected four main “environmental themes” and identified some important criteria relating to territorial analysis for each. The same weight for all the visions was assigned to each criterion, while for each environmental theme pairwise comparisons were made creating five matrices for each vision (Figure 3). Regarding the environmental themes on the first level, according to the judgements from the working group experts and the values/characteristics, we obtained pairwise comparisons for the following themes: biosphere, geosphere, landscape and soil.

The priority vector for each vision expressing the weight of the environmental theme is illustrated in Figure 2. The consistency ratio for each vision ranges from 0,0000 to 0,057; less than 0.10 is considered acceptable. Through the AHP method application, it is possible to combine the weights of criteria obtained through pairwise comparisons with scores associated with the different location susceptibility classes, obtaining the related “susceptibility maps” in synergy with the GIS environment.

It is possible to obtain an overall value for every pixel as a linear combination of the weights of the criteria from the score related to location susceptibility taking into account specific values/characteristics (Figure 4). For each vision we obtained the following location susceptibility maps (Figures 4-5-6-7-8):

1. classification map of values/characteristics for the biosphere environmental theme (taking as criteria: territorial biopotential index, degree of biodiversity, infrastructure fragmentation index);
2. biosphere location susceptibility map;
3. classification map of values/characteristics for the geosphere environmental theme (taking as criteria: slopes stability, seismic zoning);
4. geosphere location susceptibility map;
5. classification map of values/characteristics for the landscape environmental theme (taking as criteria: landscape units);
6. landscape location susceptibility map;
7. classification map of values/characteristics for the soil environmental theme (taking as criteria: land use, cultivations productivity);
8. soil location susceptibility map;
9. composite location susceptibility map.

Taking into account the environmental themes and hierarchy criteria and putting the data together from all criteria in the first hierarchical level, we obtained the maps in Figures 5 to 9, in which the colours ranging from dark green to orange express the location susceptibility (from high to low) of the strategic actions called for in each vision.

The same process was applied to all the visions obtaining a location susceptibility map for each. This kind of assessment can truly support planning activity optimizing the propensity of each area and, most of all, locating strategic actions in places in which territorial and environmental impacts can be minimized. The operation's underlying logic was the "sustainable spatial planning" of territory. However, it must be underlined that a City Plan is not an automatic output of the susceptibility maps. The planner takes into account susceptibility maps and designs the plan in conformity with them but, of course, it is possible to find many solutions that are congruent with the susceptibility maps for each function. In this way, it was possible to move from visions to three technical "core-projects" to guide the city's transformation (Figure 10).

5. Discussion

The three "core-projects," representing the conclusion of the MCSDSS can synthesize the complexity of the decision-making process in which different forms of knowledge are compared.

The collective process of identifying and creating visions and related actions for transforming Cava de' Tirreni made it possible to combine the contribution of common knowledge – that could develop visions reflecting the points of view of citizens and different stakeholders (representative of the main age classes that make up the local population, of families, of the main categories of economic and productive activities, of local associations involved in different fields) - with the contribution of expert knowledge (experts in the fields of urban planning, geomorfology, agronomy, landscape, economic and financial feasibility, infrastructures and mobility) to identify significant environmental issues and structure an integrated decision-making platform.

Therefore, while visions and their possible actions were constructed with the involvement of common knowledge, the evaluation of an area's susceptibility to transformation was carried out with the support of experts thus allowing the selection of criteria and indicators to explain the context's fundamental characteristics.

It was therefore possible to obtain the relative location susceptibility map for each vision; it is clear that evaluation supported the planning phases optimizing the characteristics of each area and, most importantly helped located activities where it is preemptively possible to minimize territorial and environmental impacts, creating an overall strategic planning framework. The plan's visions and actions - designed through the constant interaction of different forms of knowledge - are an integral part of a transparent and shared spatial decision-making process that can reduce social, environmental and economic conflicts even during the early decision construction phase.

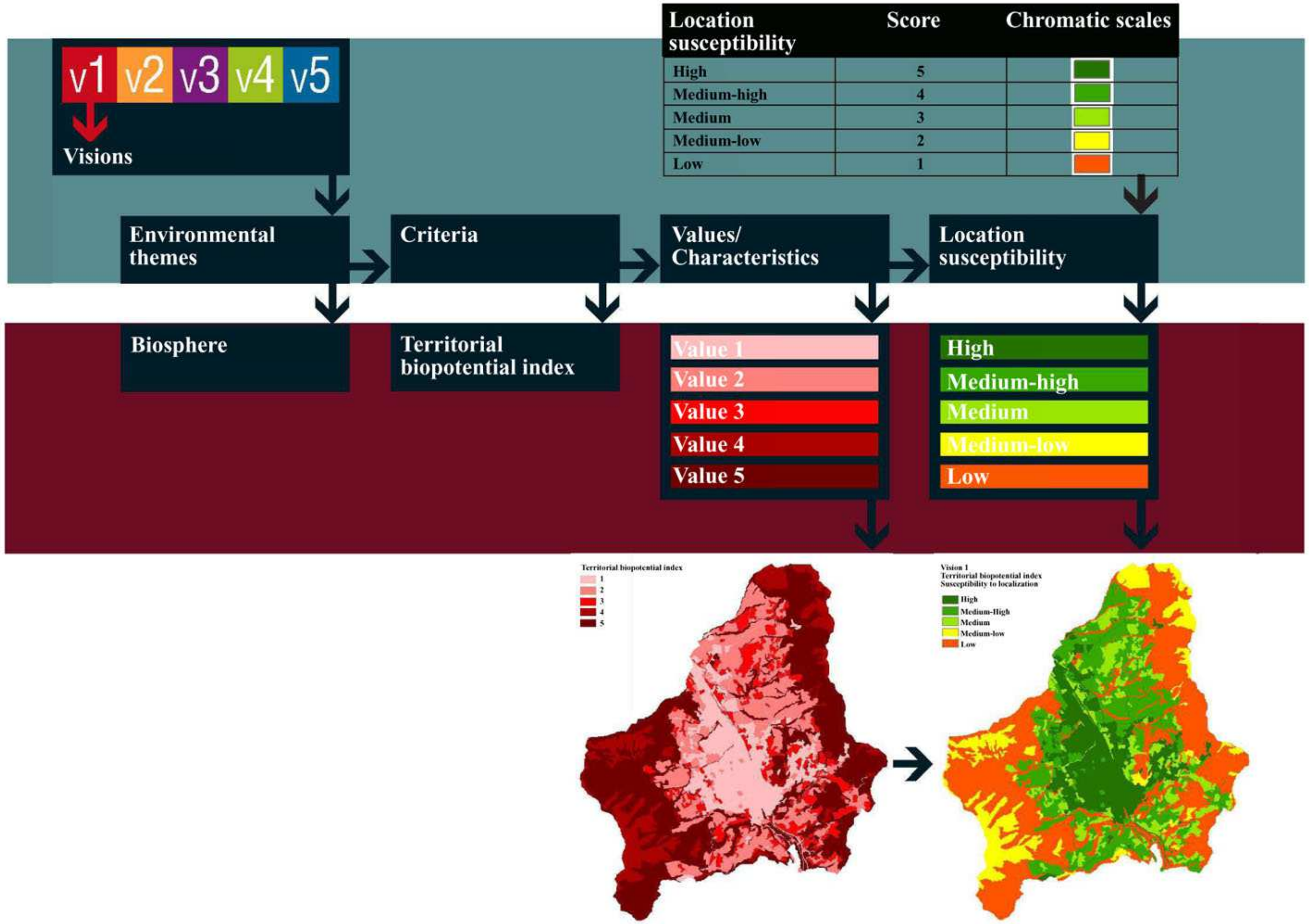

Figure 2 Example of spatial indicators for one vision.

Pairwise comparisons matrix for Vision 1

	Biosphere	Geosphere	Landscape	Soil
Biosphere	1	2	1/3	1/3
Geosphere	1/2	1	1/4	1/2
Landscape	3	4	1	2
Soil	3	2	1/2	1

Pairwise comparisons matrix for Vision 2

	Biosphere	Geosphere	Landscape	Soil
Biosphere	1	1/2	1	1/2
Geosphere	2	1	2	1
Landscape	1	1/2	1	1/2
Soil	2	1	2	1

Pairwise comparisons matrix for Vision 3

	Biosphere	Geosphere	Landscape	Soil
Biosphere	1	2	1/2	1/2
Geosphere	1/2	1	1/3	1/3
Landscape	2	3	1	1
Soil	2	3	1	1

Pairwise comparisons matrix for Vision 4

	Biosphere	Geosphere	Landscape	Soil
Biosphere	1	3	1	2
Geosphere	1/3	1	1/3	2
Landscape	1	3	1	2
Soil	1/2	1/2	1/2	1

Pairwise comparisons matrix for Vision 5

	Biosphere	Geosphere	Landscape	Soil
Biosphere	1	2	2	1
Geosphere	1/2	1	1	1/2
Landscape	1/2	1	1	1/2
Soil	1	2	2	1

Priorities vectors and consistency ratio

	Vision 1	Vision 2	Vision 3	Vision 4	Vision 5
Biosphere	0,1479	0,1667	0,1891	0,3511	0,3333
Geosphere	0,1063	0,3333	0,1091	0,1609	0,1667
Landscape	0,4612	0,1667	0,3509	0,3511	0,1667
Soil	0,2845	0,3333	0,3509	0,1368	0,3333
Consistency	0,0437	0,0000	0,0038	0,0572	0,0000

Figure 3 For each vision: pairwise comparison matrix, priorities vectors and consistency ratio.

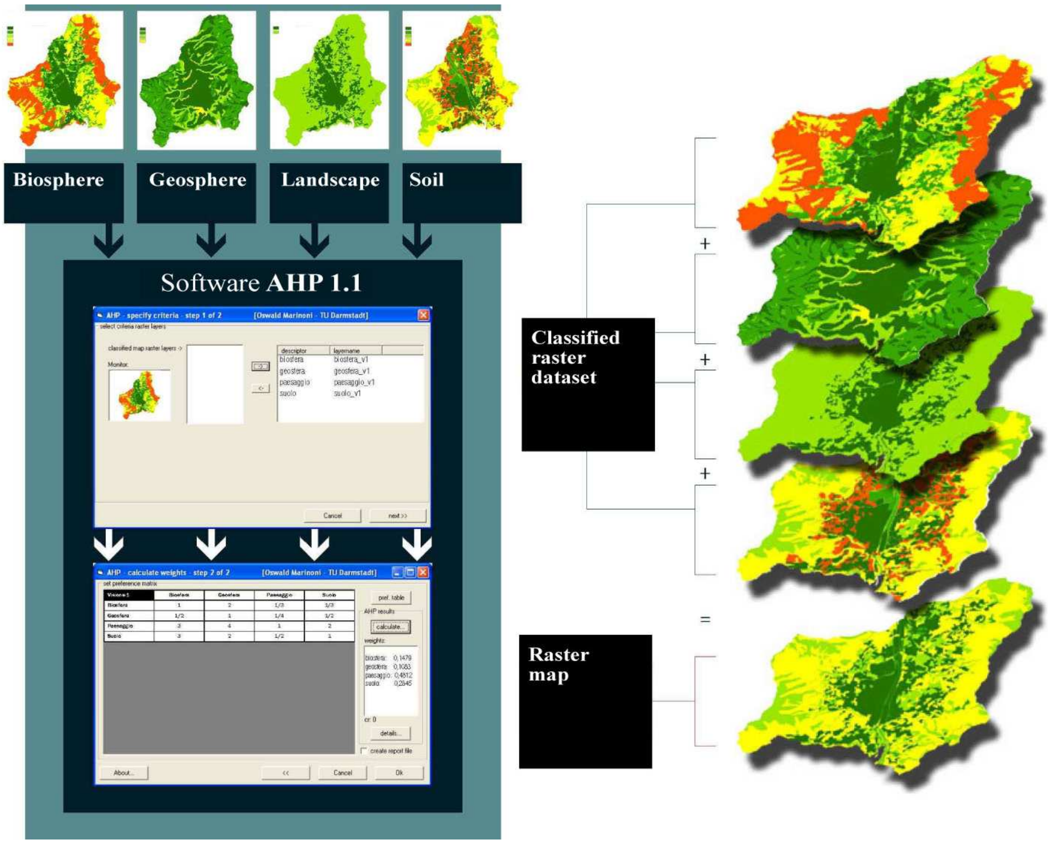

Figure 4 Synergy between AHP and GIS.

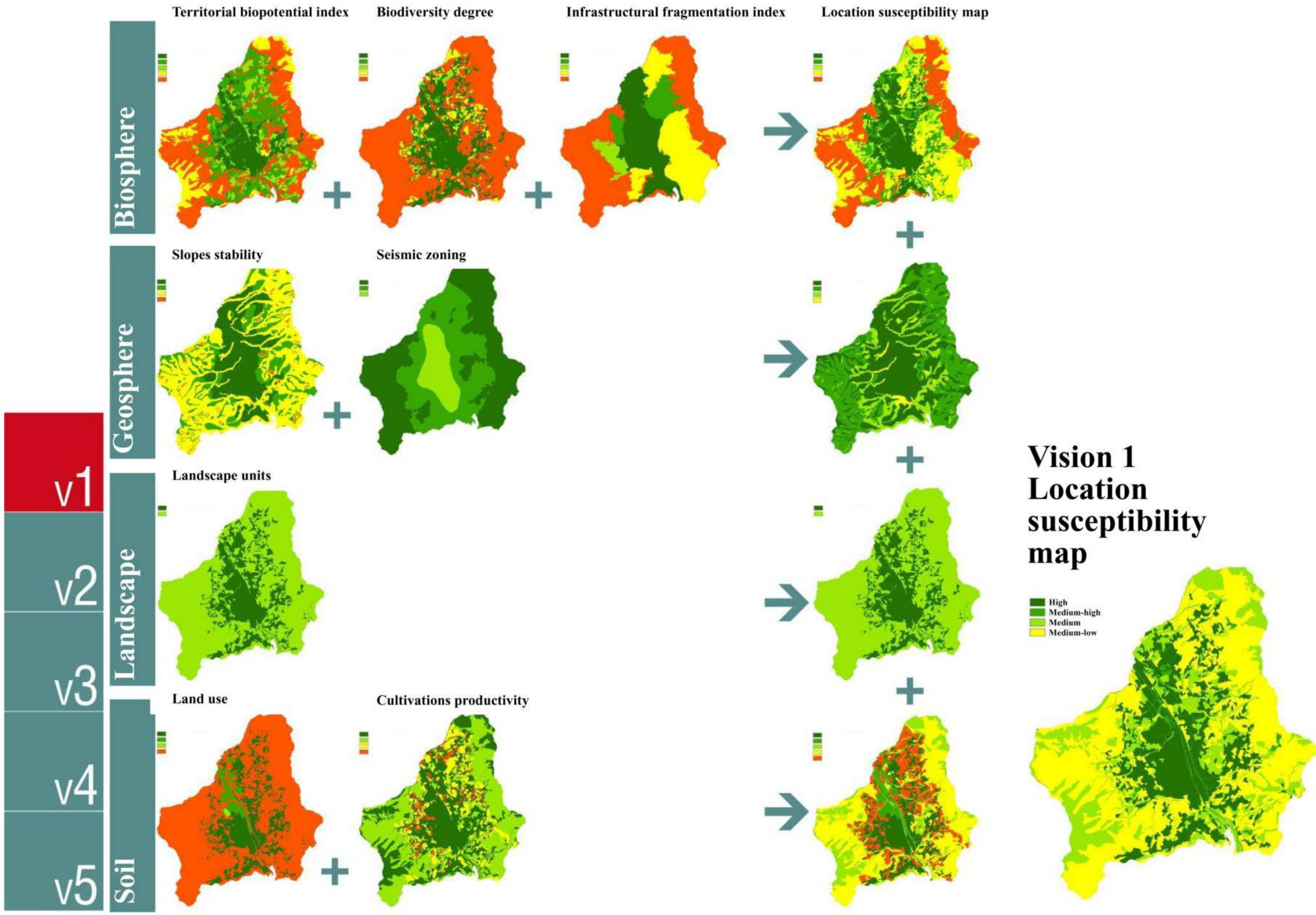

Figure 5 Location susceptibility for Vision 1.

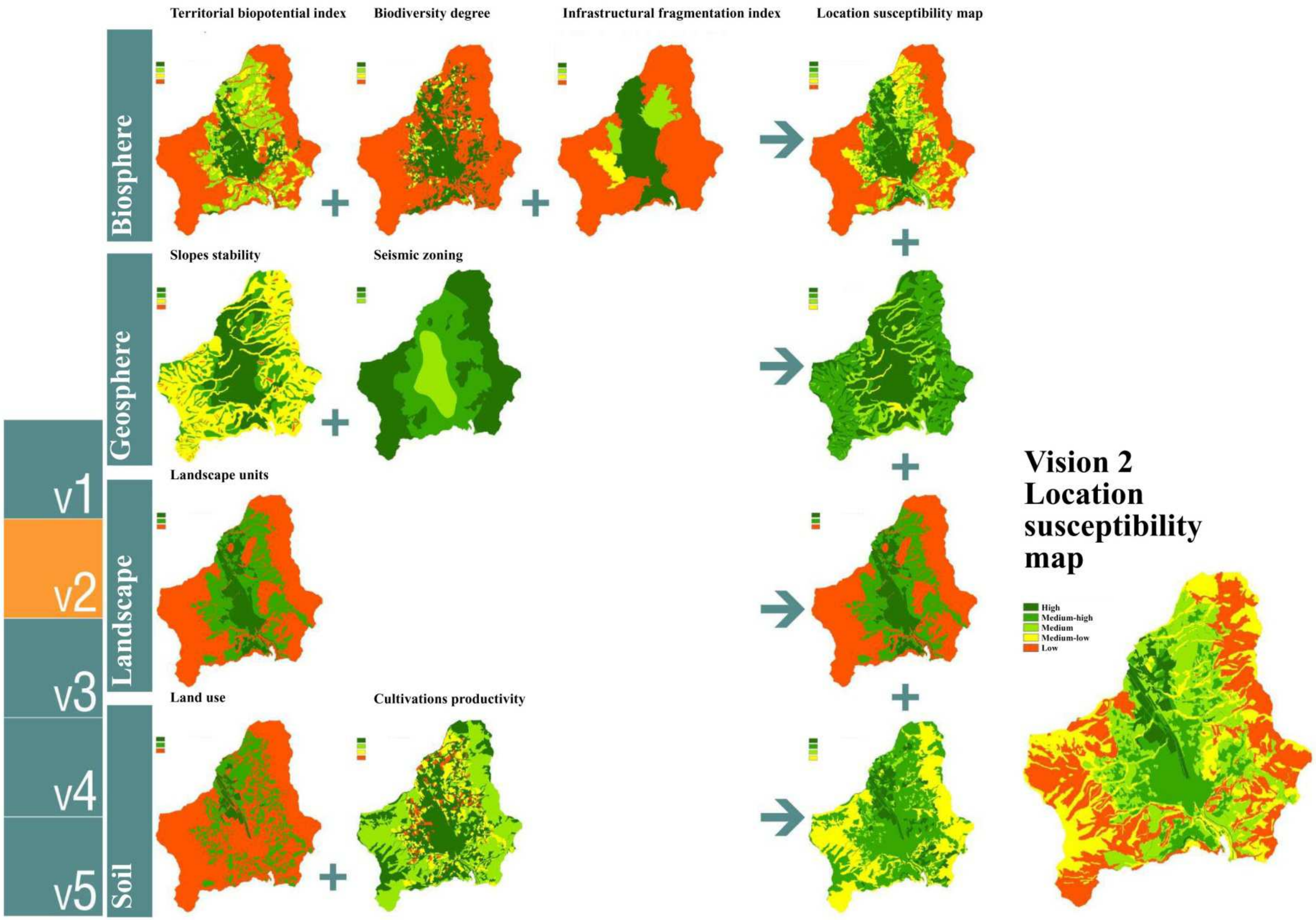

Figure 6 Location susceptibility for Vision 2.

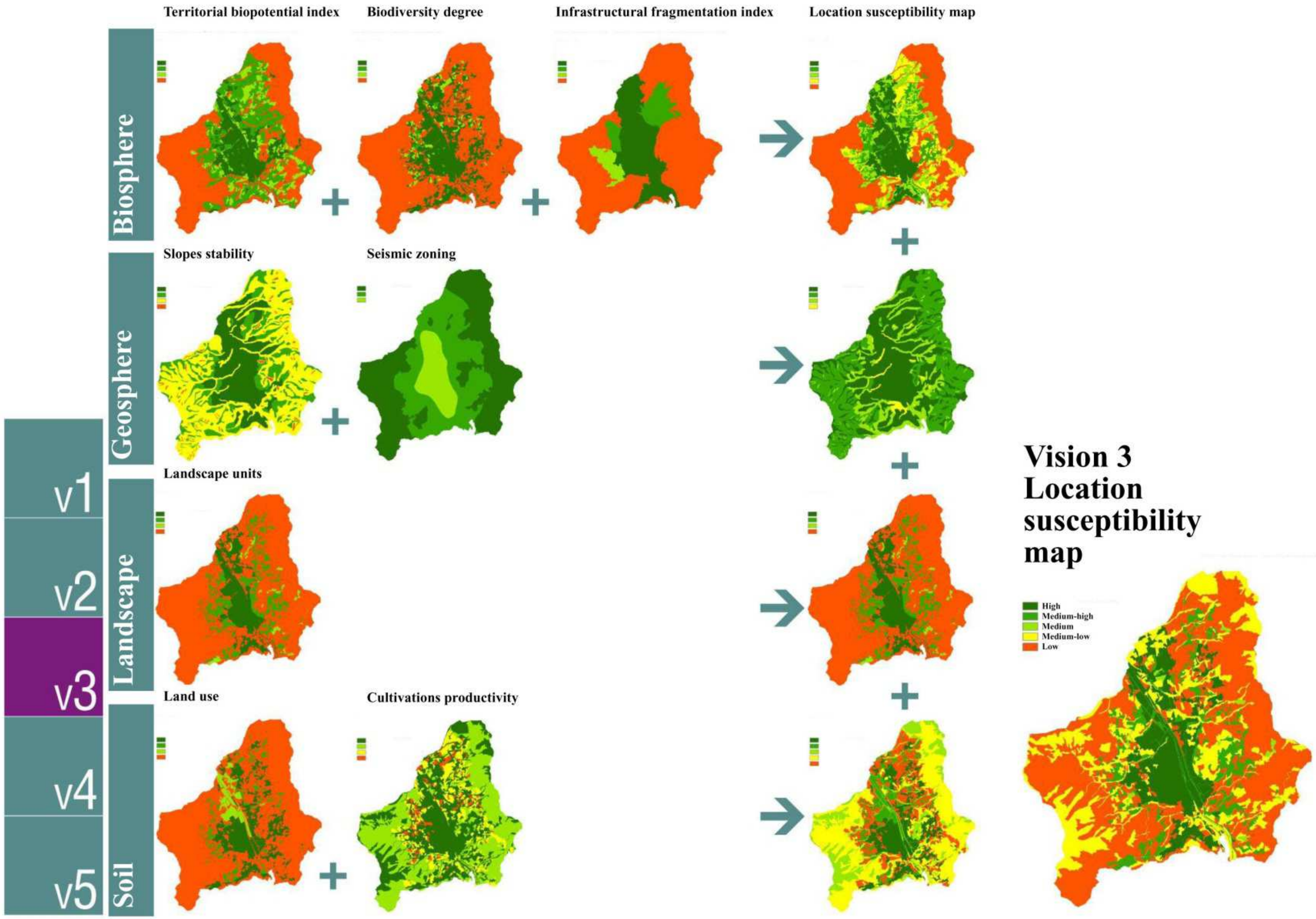

Figure 7 Location susceptibility for Vision 3.

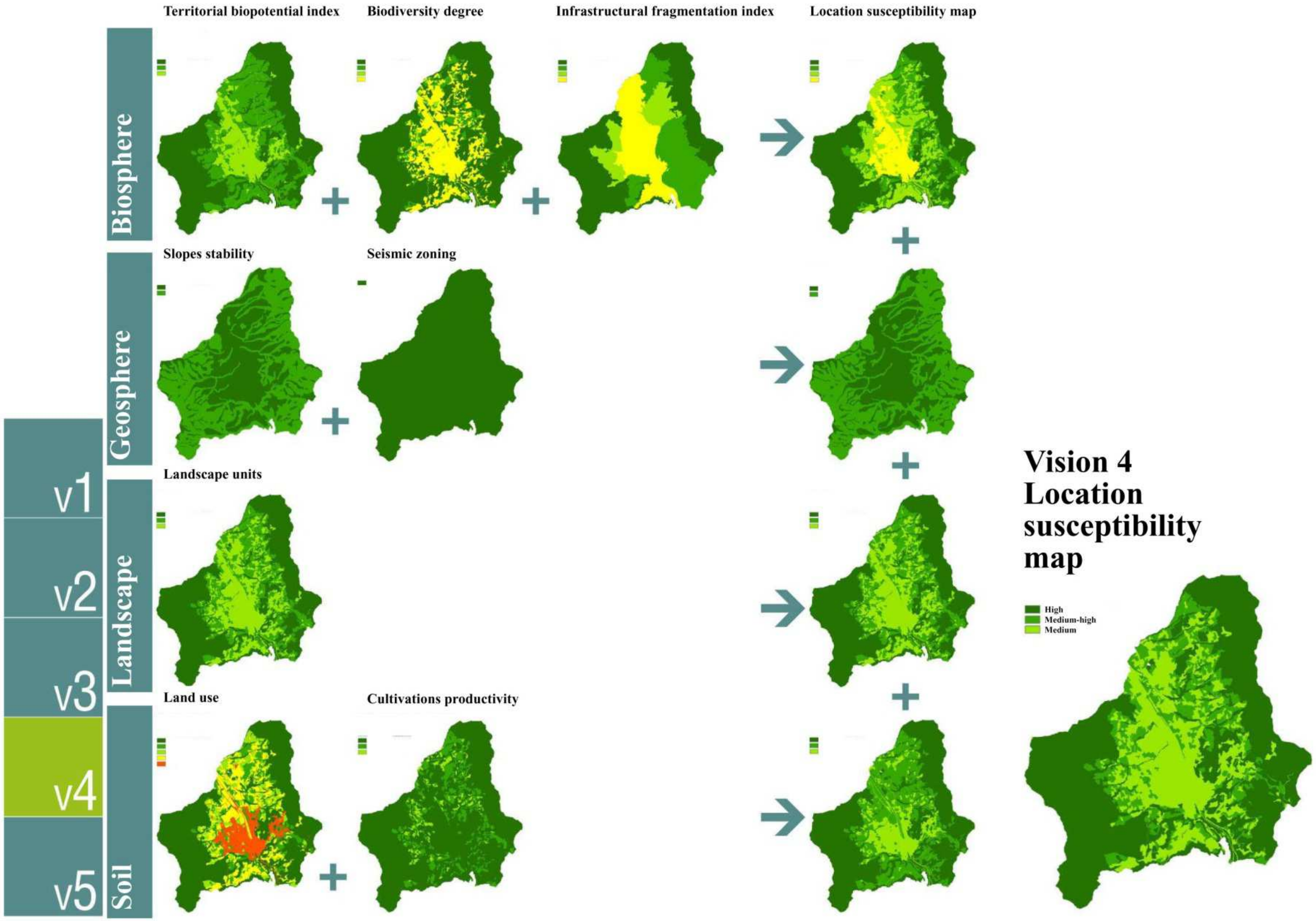

Figure 8 Location susceptibility for Vision 4.

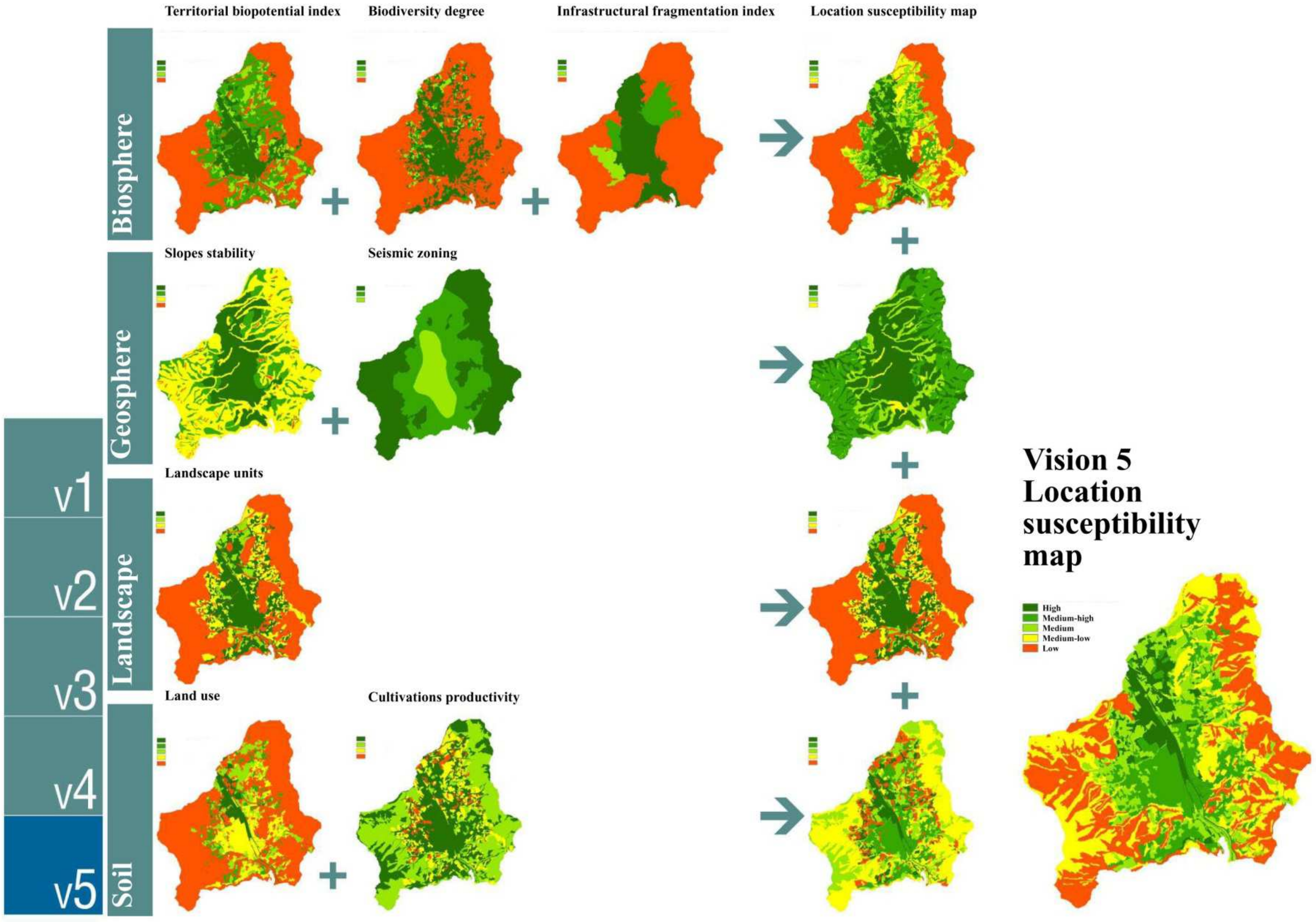

Figure 9 Location susceptibility for Vision 5.

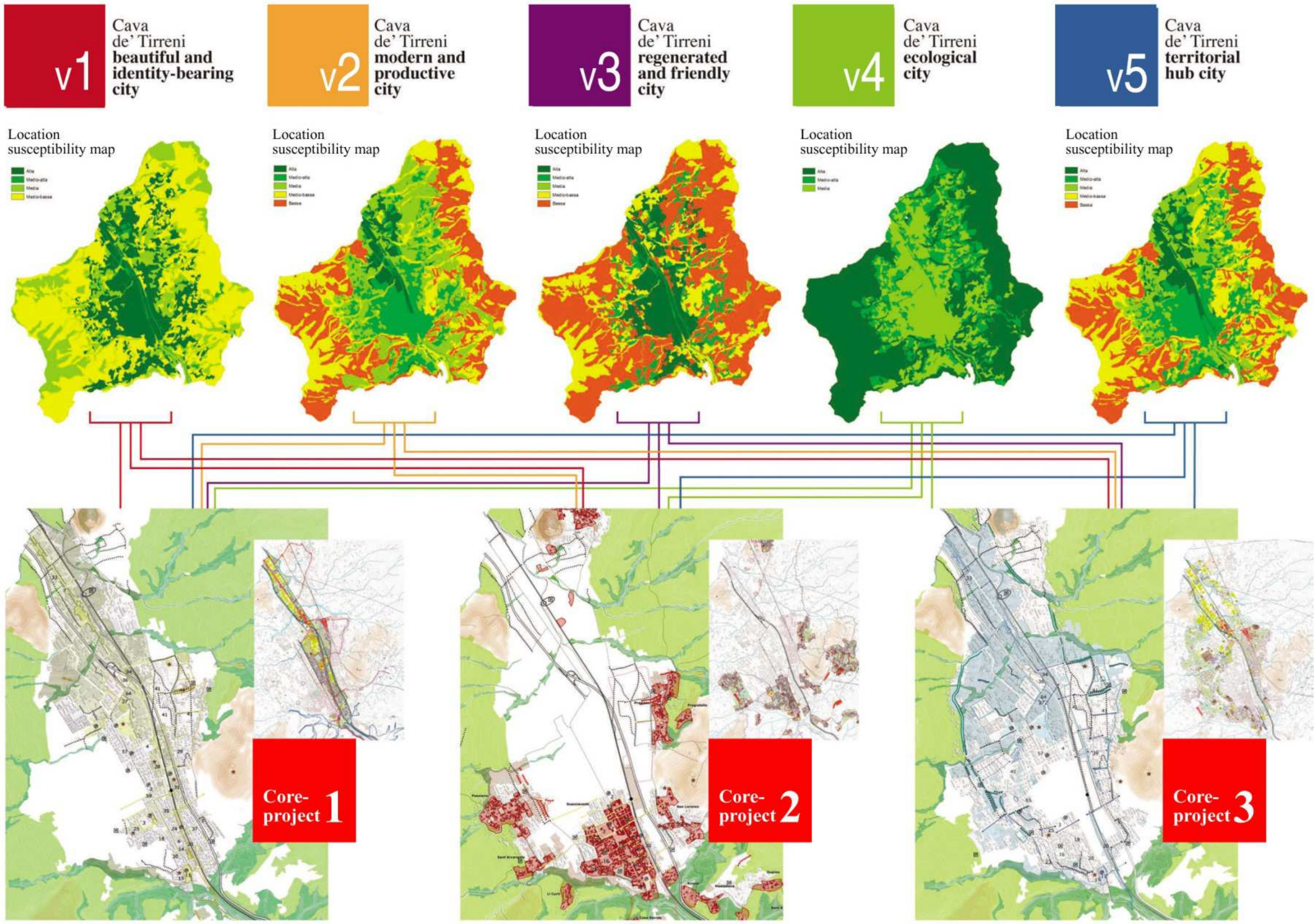

Figure 10 From Visions to core-projects.

6. Conclusions

The decision-making process carried out in the Cava de' Tirreni City Plan points out how GIS combined with AHP can make full use of GIS functions such as spatial analysis, data processing and inquiry where complex data and their mutual influences can be included to describe the position of each factor in space. AHP renders the analysis more flexible. Characterized by relative ease in handling multiple criteria, it is simple to understand and effective in managing qualitative and quantitative data. At the same time, GIS helps develop a satisfactory man/machine interactive interface.

In the Cava de' Tirreni City Plan, combining AHP with the GIS method, the ISA approach shows that:

1. it is possible to improve synthetic evaluation by developing the GIS capability of spatial analysis and AHP capability of multilayer analysis. The evaluation results and the distribution pattern obtained for each vision represent effective ways to communicate a territory's complex characteristics;
2. it is useful to create a large and flexible multi-component system in which there are continuous and dynamic exchanges of information among various subsystems/environmental themes, selecting the correct factors for establishing comprehensive spatial indexes and/or indicators;
3. GIS can be used in preparing spatial statistics and clustering processes to reveal the most suitable areas for site selection, managing and analyzing large volumes of spatial data from a variety of sources. Furthermore, it can handle and simulate the necessary economic, environmental, social, technical, and political constraints;
4. AHP is a powerful tool for solving complex problems with interactions and correlations among multiple objectives;
5. it allows decision-makers to understand the current status of the integrated characteristics of a local context more clearly and to help administrators understand the interactions among visions and core-projects in order to identify and implement shared actions. Therefore, the integration of GIS and AHP methods provides a mechanism with which complex issues can be thoroughly explored and immediate feedback for decision-makers can be provided.

The ISA approach used in the case study could be considered the basis for increasing the level of integration of local and expert knowledge in a more extensive participatory GIS process geared towards the involvement of different kinds of knowledge in order to improve the completeness of hard and soft data and the consistency of the overall evaluation. Recognizing the important role of environmental impacts within a public decision-making process along with the selection of alternative options, we used a typical SEA approach, translating it into a more complex evaluation process defined as ISA in order to integrate territorial and environmental aspects with the definition of plan strategies and choices.

In this kind of decision-making process, local communities can contribute actively to the implementation and updating of GIS data thus improving the evaluation of alternative strategies and actions. Therefore, in addition to supplying experts with valuable information for increased territorial understanding, they are also made much more aware of the characteristics and values of their own contexts.

An integrated evaluation approach can move beyond spatial and hierarchical limits, considering the various components (historical, cultural, environmental, economical, social, anthropological, etc.), clarifying weights, recognizing priorities, and defining the correct strategies while taking into consideration social participation, interdisciplinarity and integration.

In this perspective, the use of Multi-Criteria Analysis plays a privileged role as a decision-making tool. Indeed, through the hierarchical construction of decision goals, it was easy to involve the local community and different experts in obtaining shared visions, strategies and actions. This contributed to the creation of a richer and more complex knowledge framework and to the bottom-up construction of planning ideas. Indeed, the different maps obtained through GIS use were the expression of multidimensional interaction regarding the meaning and role of the different evaluation criteria together contributing to plan design. They helped improve the technical effectiveness and, at the same time, the transparency of the evaluation process leading to decisions that reflect different needs and expectations. Through such evaluation processes, it is possible to help communities and experts become more aware not only of their own views and preferences but also of those of others, in order to define participated and shared solutions. In this sense, assessment has become a fundamental part of planning, and ISA can be seen as the preventative verification of environmental and territorial sustainability and, at the same time, a tool for stimulating the identification of alternative solutions within a spatial decision-making process.

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