A Spatial Multicriteria Assessment Decision Support System (SMCA-DSS) for East Naples: Towards a Water Opportunity Map

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Abstract. The objective of this study is to present the methodological process for the elaboration of a Spatial Multicriteria Assessment Decision Support System (SMCA-DSS) oriented to the definition of a Water Opportunity Map for a Naples Eastern Area, in Italy. The proposed approach extends the formalization of multicriteria methods and social network analysis in Geographical Information Systems (GIS), including spatial structure and temporal dynamics. The combined application can be useful in spatial decision making process for urban planning, supporting and modelling operations for urban land-use change. Analysing the opportunities for the storm-water management, the paper explores possible shared scenarios of transformations identifying the main effects on the local context.

Keywords: Spatial Multicriteria Assessment Decision Support System (SMCA-DSS), Analytic Hierarchy Process (AHP), Dynamic Actor Network Analysis (DANA).

1 Introduction

An innovative approach to water management can help to reduce the conditions of vulnerability of the city [1]. In particular, the growing interest in the processes of urban water management has led to a gradual paradigm shift [2] [3] [4], related to the effects of climate change and increasing urbanization too. The introduction of new concepts in the management of urban water is reflected in approaches which emphasizes above all the strong connection between urban planning and organization of services. Many approaches highlight the need for an 'integrated approach' that considers the urban water cycle as a whole and is based on a multidisciplinary and intersectoral institutional structure [5] [6] [7]. In line with these assumptions, some authors consider the urban water system as a complex adaptive system [7] or a socio-technical system [3], rather than as a technical system.

Despite the need for new approaches to be applied to urban water management, in general decision-making processes are characterized by a rational approach such as 'cost/benefit' [8], structured according to a logical hierarchy, dominated from expert

B. Murgante et al. (Eds.): ICCSA 2013, Part IV, LNCS 7974, pp. 572–586, 2013.

knowledge and from recognizing as a sufficient result the pursuit of meaningful goals at national, European and international level.

The international literature describes numerous innovative technologies for urban water management at the local level that could be implemented, but which in reality are only applied to a number of pilot and experimental projects, and emerges as the institutional capacity to implement and maintain the innovations is an important component in the process of transition for the systems of water management [9] [10] [11]. Pahl-Wostl [12] [13] pointed out that the inertia of the technical system together with that which connotes social norms and established habits represent some of the most common obstacles to change, from a survey conducted by Brown and Farrelly [14] it was found that the main socio-institutional barriers that prevent an innovative management of urban water are closely linked to the inability to change the established way of working by stakeholders.

According to Brown et al. [15] the social changes and technological developments should interact to influence the implementation and dissemination of innovative approaches in the management of water resources at the urban level. In particular, it shows how they can be integrated approaches of Large Technical Systems (LTS) [16] [17], of MultiLevel Perspective (MLP) [2] [18] [19] [3] and of Transition Theory [20], whose interaction can be defined as innovative approaches to improve the management systems of water resources in urban and regional planning.

In order to implement the concept of integration, the evaluations can be of support to the elaboration of decision making process. The literature offers a wide range of definitions related to integrated assessments, in some cases conceived as interdisciplinary models able to capture the different aspects of the chain of cause-effect, as well as to take into account the different sectors involved [21], in other cases considered such as interdisciplinary processes able to combine, interpret and communicate knowledge from different scientific disciplines in such a way that the whole cause-effect chain of a problem can be evaluated from a synoptic perspective that exceeds the limits of a mono-disciplinary point of view and is able to provide useful information to decision-makers [22]. Therefore, integrated assessments allow to deal with complex issues using knowledge and expertise from different disciplines and processed by the same stakeholders involved in the decision.

The processes of planning and evaluation pose the need to build a path of constant interaction, in which the construction of the choices consider essential to make use of a decision support system structured according to a multi-dimensional approach, which is useful both to understand the specificity of the context and to outline responsive actions able to minimize the negative impacts and maximize the positive ones. A multi-dimensional approach has to be based on the characteristics of the decision problem considering the most suitable methods, able to meet the specific requirements in adequate and satisfying terms. In particular, the development of an appropriate Decision Support System can allow to accompany the construction of choices and the assessment of impacts, based on approaches that will improve the understanding and use of data, information and methods, as well as process management [23].

In this perspective, the Multicriteria Decision Support System Assessments (MCA-DSS) are useful for analyzing and evaluating the effects in the processes of plan, establishing a methodological and operative link between the multi-criteria assessment methods and decision support systems in order to compare alternatives based on multiple factors and define the preferred solution also with the support of GIS [24] [25] [26] [27] [28] [29] [30].

This paper presents a Multicriteria Decision Support System Assessment structured as part of the research project 'Urban open spaces urban resilient to storm-water system in climate change', FARO 2010 Programme, coordinated by prof. Federica Palestino, University of Naples Federico II, oriented to define an innovative approach to water management in urban areas.

2 An Experiment for East Naples

2.1 The Methodological Approach

As part of the case study East Naples has been experienced a methodological process useful to recognize the present and emerging values, create cohesion on the issues of environmental protection and conservation of the environment, and to identify innovative ways of intervention aimed at stimulating the spread of resilient and sustainable uses of the land. The methodological approach is conceived as a tool for the construction of choices and the exploration of the relevant factors in the decision-making process and can be represented in a cyclic and dynamic learning process, which starts from the acquisition of expert knowledge provided by members of the research group and is developed through the analysis of the context and interpretation of the views of the community, the development of transformation scenarios, the assessment of impacts and the identification of possible actions. This structure is related to the use of methods and tools to support the different activities of elaboration and definition of the assessment process.

Some European experiences emphasize the need to address the issue of planning and management of resources in an integrated approach, in many cases declined by an 'Urban Water Plan' or an 'Urban Water Management Plan' [31] which are able to include processes of territorial management based on a pro-active approach to water management, taking into account some principles [32]:

1. anticipate rather than react, with greater attention to climate change and the effects of subsidence;
2. pay greater attention to the spatial dimension with appropriate integrated assessments;
3. apply the strategy of the three phases: storing-retaining-draining.

In some cases, the 'Urban Water Plan' was structured using some significant approaches and tools, based on the interaction and dialogue between knowledge and disciplines, such as the Water Testing-Water Assessment (WA) [33] [34].

Similarly, in some cases, the approach of the Water Opportunity Map (WOM) has been applied [35], which has the purpose to develop suitability maps that allow you to

identify the various opportunities that a territory can offer with specific reference to water resources. In operative terms, the approach of the Water Opportunity Map (WOM) is articulated into some main phases:

1. establish a 'starting point', which is a cognitive framework of reference useful to identify potential and criticalities of the territory;
2. identify a set of appropriate criteria and indicators, in general distinct from the prevailing two categories: criteria relating to landscape and criteria relating to the water system;
3. develop a Water Wish Map (WWM), taking into account the results of the analysis of objective data and points of view of stakeholders;
4. analyze the results and revise the criteria and indicators;
5. assess the degree of 'suitability', understood as the susceptibility of the territory to receive suitable transformations;
6. analyze the possible emerging conflicts;
7. elaborate the Water Opportunity Map (WOM), able to integrate the results from the previous analyses, outlining a program of strategies and meaningful actions for an integrated management of water resources.

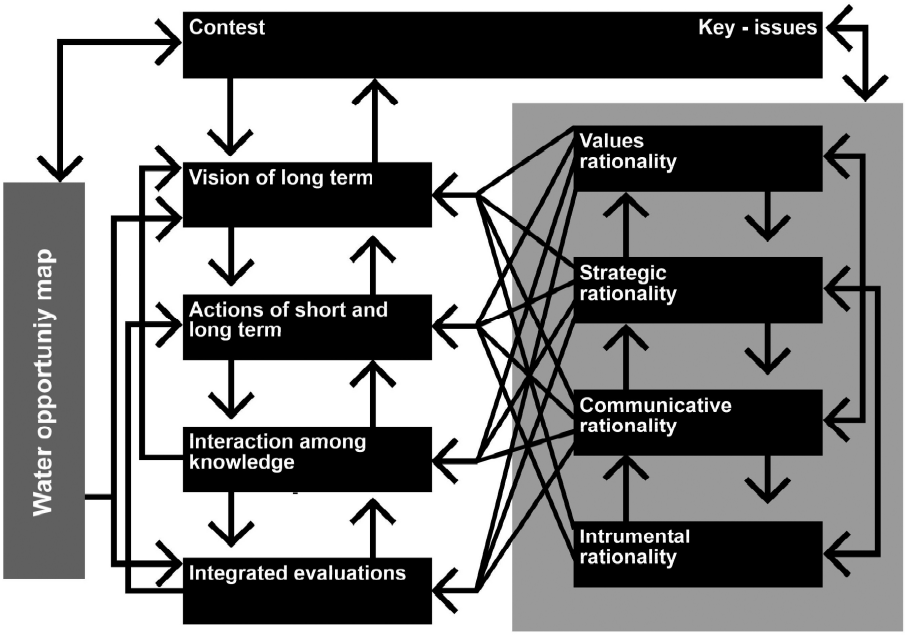

Fig. 1. The Water Opportunity Map: an integrated process

In this perspective, the Water Opportunity Map (WOM) stands as an integrated process that allows to identify a long-term vision for the context in question, but also to identify the actions of short and long term.

At the same time, WOM represents an instrument of dialogue between knowledge making use of integrated assessments to support decision-making. WOM can be understood as an approach able to allow the interaction between different rationality: a rationality for values, a strategic rationality, a communicative rationality and an instrumental rationality (fig. 1).

As part of a decision-making process oriented to the territory, maps represent a significant tool to promote communication among the various stakeholders and the community, to make a spatial evaluation of impacts and allow the choice among alternatives, in order to support interactive decision allowing feed-back and incremental and flexible actions.

2.2 A Water Opportunity Map (WOM) for East Naples

During the analysis of the territory of East Naples the need for a structured decision-making process has outlined, able to explore opportunities for transformation starting from an environmental theme particularly critical as water resources. It has emerged as an integrated management of the territory can be oriented to the identification of a system of hydrographic connections, defined 'Blue connections', able to restore part of the ecological and territorial balance severely compromised and to strengthen the system of water resources through appropriate interventions.

At the same time, it has emerged as the system of the water connections can be integrated with that of the green system. Thus it was introduced the system of 'Green connections', conceived as the network of green infrastructure which could integrate the existing ones, in many cases characterized by remarkable critical conditions.

In this perspective the WOM for the territory of East Naples could be structured starting from the opportunities identified as relevant for the water system closely related to that of the green system.

In order to explore potential opportunities in the case-study area it was structured a Dynamic Spatial Decision Making Process, through which the environmental complexity has been analyzed taking into account a selection of essential elements in order to provide useful and strategic information that represents the multi-dimensional characteristics of the territory. Therefore, the methodological tools used in this process were the followings (fig. 2):

1. for the construction of local resources knowledge, it has been identified a system of spatial environmental indicators able to analyze existing conditions, considering the existing values, and to highlight the expected values;
2. for the analysis of territorial and environmental characteristics, it has been developed a GIS which collects and structures the available data relating to the territorial system;
3. for the evaluation of opportunities for territory transformation, it has been integrated the Analytic Hierarchy Process (AHP) [36] [37] with GIS in order to define, in spatial terms, sustainable strategies of intervention;
4. for the evaluation of the community preferences, it has been analyzed a sample of interviews by the method Dynamic Actor Netwok Analysis (DANA) [38] in order to identify the preferences of the community.

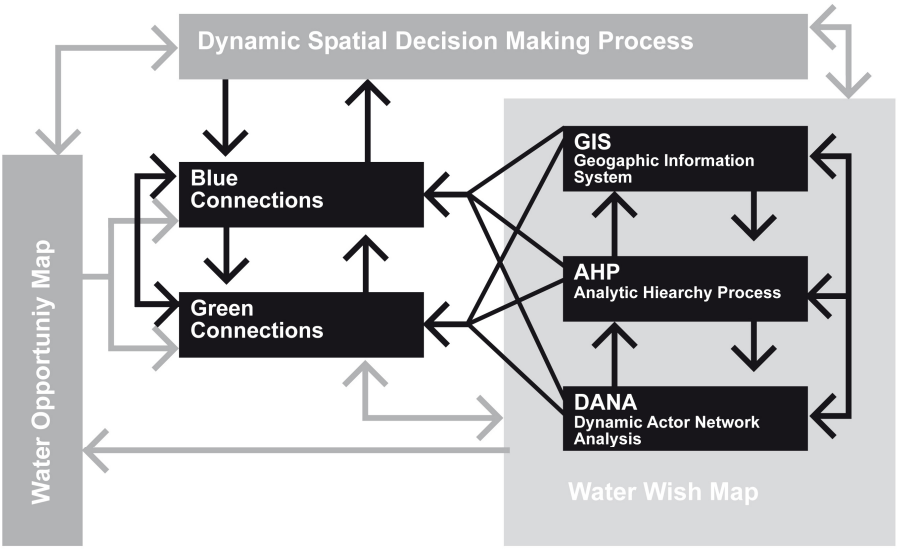

Fig. 2. The phases of the methodological process

To evaluate the different opportunities for realization of the two scenarios identified as relevant, the Blue connections and the Green connections, it has been structured a Multicriteria Spatial Decision Support System Assessment (SMCA-DSS) by combining the potential of GIS with that of the Analytic Hierarchy Process (AHP) [36] [37].

The AHP method structures the decision-making process in a hierarchical form and, from an operative point of view, is divided into three phases:

1. construction of an appropriate hierarchy;
2. determination of priority between the elements of the hierarchy by means of pairwise comparisons;
3. control of the logical consistency of the pairwise comparisons.

The application of AHP method in the GIS system allows you to go beyond the simple overlay of different themes and to make a pairwise comparison of the criteria for each hierarchical level [39] [40].

Taking into account the analysis carried out by the different components of the research group and the thematic studies provided by official sources, it was possible to organize two hierarchies, one for Blue connections and another one for Green connections. For each of them, the 'suitability maps' were built, through the application of AHP method integrated into the GIS, which express the greater or lesser capacity of the territory to implement a strategic action, taking into account the potential impacts. The hierarchical structure for each scenario is composed of four levels: criteria of the first level; criteria of the second level; criteria of the third level; indicators. To the indicators it has been associated a judgment expressed on a scale from zero to five points, to which it has been assigned a colour selected according to the conventional range from dark green to red:

- high suitability to transformation (score 5, dark green);
- medium-high suitability to transformation (score 4, light green);
- media suitability to transformation (score 3, light yellow);
- medium-low suitability to transformation (score 2, dark yellow);
- low suitability to transformation (score 1 orange);
- no suitability to transformation (score 0, red).

Taking into account the methodological structure, the suitability maps were drawn for each scenario, where dark green indicates a 'high' opportunity while red indicates 'nothing' opportunity.

For each level of the hierarchy related to the Blue connections and the Green connections pairwise comparisons were conducted, building nine matrices for the third level, six matrices for the second level, and one matrix for the first level.

The elements of the matrices represent the relative importance expressed on the Saaty's nine-point scale, where the symmetrical terms are characterized by the reciprocal value. Before the application of AHP method, the spatial indicators have been elaborated, taking into account of data and information provided by the experts of the research team and the previous studies on the context. Using the raster technique for processing the maps, for each pairwise comparison and for each pixel it was possible to obtain a total value as a linear combination of the weights given to the criteria by the score assumed for the suitability to transformation. The hierarchy adopted for the criteria is illustrated in fig. 3.

Fig. 3. The hierarchy

In order to elaborate a spatial evaluation, it was used an extension of the method AHP within ArcGIS [41] [42] [43], obtaining the 'suitability maps to transformation'. Through this approach, it was possible to obtain not only an overlap of the different themes analyzed, but it has been structured a pairwise comparison between the criteria of each hierarchical level and the criteria of the upper level, assigning a weight on a scale from 0 -1 to each criterion by calculating the principal eigenvector of the matrix of pairwise comparison.

In fig. 4 it is shown the hierarchical structure set for the two scenarios, the Blue connections and the Green connections, in which the same criteria are classified and weighed using the same rating scale but taking into account that correspond to different objectives. In fact, in the case of Blue connections we analyze the attitude of the territory to identify opportunities for transformation for the realization of a scenario that favors the water and its potential for integration and recovery, while in the case of Green connections we consider the attitude of the territory to implement the changes oriented to the enhancement of green infrastructure. In fig. 5 there is the synthesis of the two evaluation processes, that define the final two maps able to identify opportunities for intervention for the two scenarios.

By the approach outlined, the evaluation can support the planning process, analyzing the potential of each area and enabling to identify new opportunities for development involving a prior minimizing of possible negative impacts. Starting from the suitability maps, it is possible to guide land use in a consistent manner, reducing the consumption of environmental resources. Moreover, the spatial dynamics can be analyzed and described according to a multidimensional approach that includes the many complexities of the involved issues, improving the communication process between stakeholders and experts and making transparent the construction of the decision-making process.

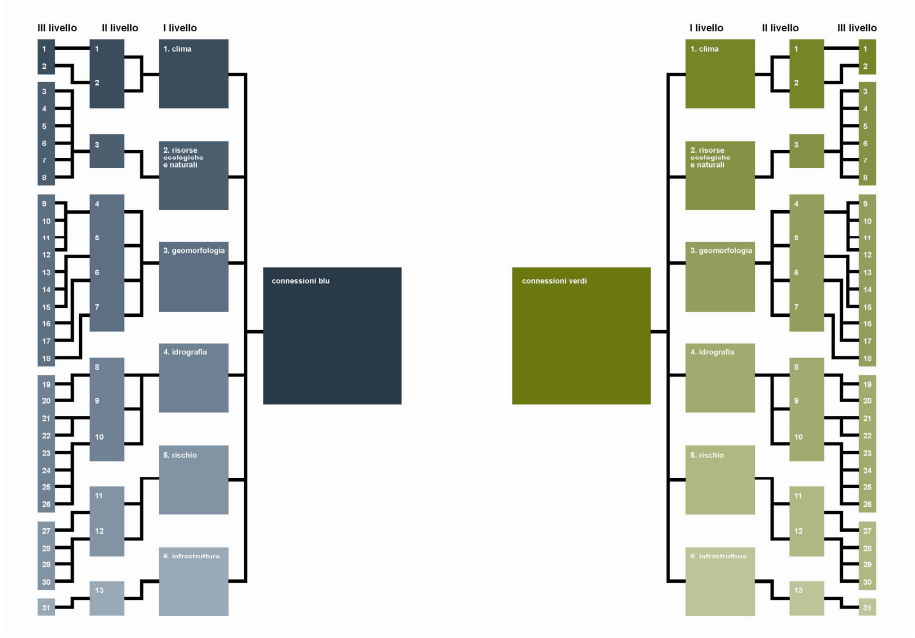

Fig. 4. The hierarchy for Blue connections and Green connections

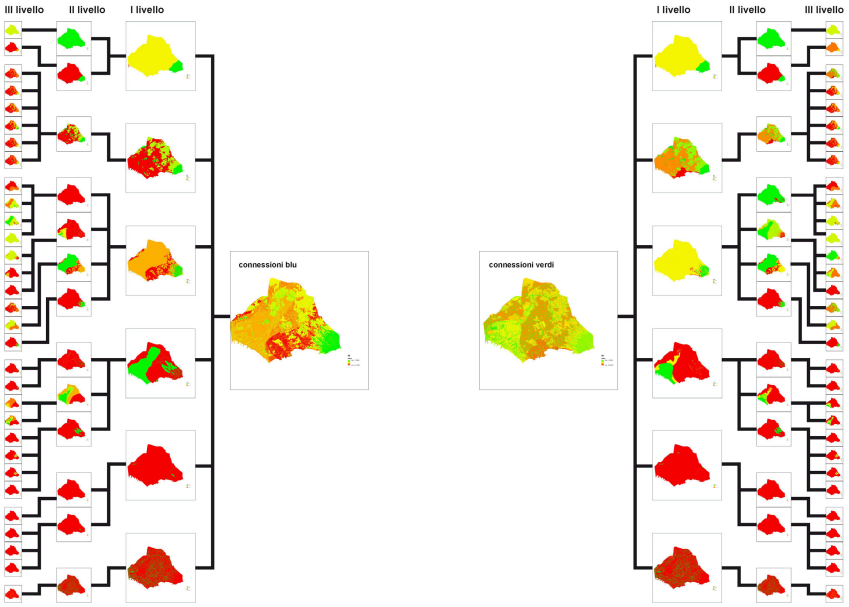

Fig. 5. Blue connections and Green connections: suitability maps

In order to develop a multi-methodological decision-making process for East Naples, conceived as the integration of a dynamic system (able to examine the evolution and change over time), a deliberative system (able to include all perspectives and the views of interested parties), an inclusive system (able to take into account the quantitative and qualitative aspects related to the different components) and a spatial system (able to identify the territorial impact through their spatial representation) [40] [44] the results of the survey conducted in the area have been analyzed. Starting from the 104 interviews conducted in the neighborhoods of Barra, Gianturco, Ponticelli and San Giovanni and addressed to a significant sample of actors, the related cognitive maps were drawn on by applying the Dynamic Actor Network Analysis (DANA), using the software DANA v.1.3.3 [38] [45]. The DANA is an approach based on the assumption that the behavior of the stakeholders can be influenced by their subjective perception of the situation. The DANA uses individual perceptions of the different actors as a starting point for a comparative analysis, and the different perceptions are molded into maps that show the causal relationships, identifying the factors and tools considered relevant by the actors, together with the causal relationships which exist between the elements themselves [45]. This information can be used in the processes of stakeholder engagement in order to develop policies and intervention strategies and evaluate possible alternatives.

For East Naples, the input information has been gathered through the interviews conducted in the area. In particular, the decision problem was structured in four arenas identified according to the areas selected for the survey: Barra, Gianturco, Ponticelli, and San Giovanni. For each arena the related stakeholders were identified and divided into four age groups, based on the characteristics of the sample under investigation.

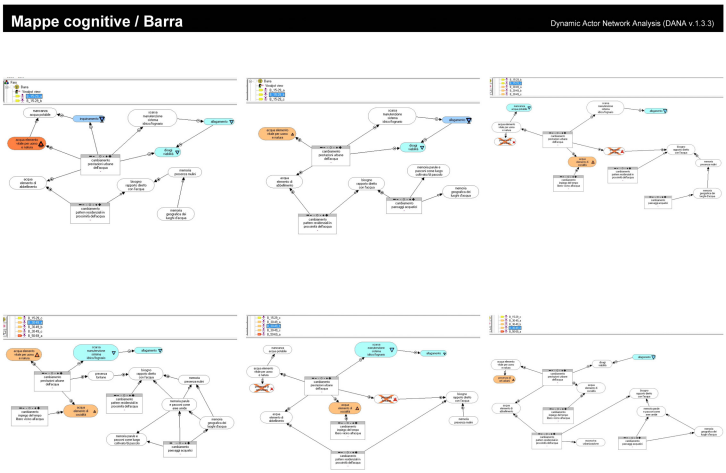

Fig. 6. Example of cognitive map for the neighbourhood of Barra

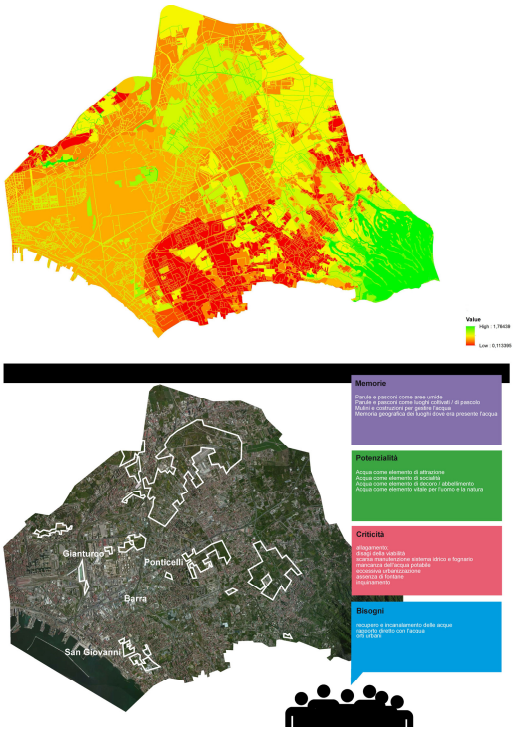

Fig. 7. Water Wish Map for the Blue connections scenario

The decision-making system was divided into: arenas (with respect to the identified areas), actors (divided by age and arenas), and factors (which are the attributes of the system, the attributes of the actors and actions). In particular, the factors were defined taking into account the three sections of the interview:

- sense of the water;
- evolution of needs, uses and methods of water management;
- critical aspects and potentials arising from the presence of water.

The factors considered to build the cognitive map were taken from interviews and aggregated into four groups distinguished by attaching tags: critical aspects, potentials, needs and memories.

The different cognitive maps (fig. 6) were examined by making a series of analyzes on each arena, and considering the four arenas aggregated. Therefore, the results obtained enable us to understand both the issues considered important for all actors, both for each arena.

The results of the analyzes performed with the DANA can be translated into operative terms if crossed with the results of spatial multicriteria analysis done for the scenario Blue connections, contributing to the elaboration of a Water Wish Map (fig. 7), useful for synthesizing opportunities emerged from the evaluation of the different environmental issues and perceptions of the different actors interviewed, divided into potentials, critical aspects, needs and memories. The Water Wish Map is the first step for the development of a Water Opportunity Map that is able to integrate environmental, social and economic issues and that constitutes the basis for a strategic program of multidimensional interventions, as an input to develop a plan for integrated management of water resources, and as a support for the construction of a decision-making process transparent and responsive to local resources.

3 Conclusions

The methodological process elaborated allows to highlight how the evaluation, conceived in integrated terms, can be a support to the construction of the choices, enhancing the vocations of each area and, above all, locating actions where previously it minimizes the territorial and environmental impacts and reduces conflicts. Recognizing the operational validity and improving the transparency of the evaluation process allow to explain the potential of the interaction between planning, design and evaluation, and to explore the field of integrated assessments tools [46] [47] [48] [49].

Through evaluative paths structured according to integrated approaches it is possible to build a pro-active dialogue between decision-makers, planners and evaluators, helping to outline participated and shared solutions. The integration among different approaches and techniques is fruitful especially in decision-making processes in which the sharing of knowledge and expertise is a key component of the process. In addition, a spatial and dynamic evaluative model [50] [51] [52] [53] allows to analyze the characteristics of the existing context and to consider the spatial characteristics of the proposed options, the data change over time due to the

implementation of the alternatives, preferences and conflicts expressed by the various stakeholders, the evaluation of different options in order to obtain a shared ranking [54] [55] [56] [57].

Through an integrated approach it is possible to outline the structure of a decision-making process able to include both technical evaluations that political ones, but also to take into account the point of view of local communities, dealing with a complex and constantly evolving territorial context. In this perspective a MCA-DSS must be able to consider a wide range of environmental resources and respond to the needs of simple applicability and flexibility. In particular, a Spatial Multicriteria Assessment Decision Support System (SMCA-DSS) allows to include the territorial dimension in the context of assessments, supporting complex decision making processes, including the point of view of experts and various stakeholders, overcoming the gap between scientific approaches and operative approaches.

In the practice of the evaluation it is evident the need to use integrated approaches that consider multidimensional techniques and tools able to promote dialogue and interaction between different knowledge, in which the evaluation becomes an integral part of the planning process and allows to make explicit the potentials and critical aspects of alternative transformations. The integration of multi-criteria analysis, multi-group analysis and GIS can be particularly useful when there are relevant social and environmental conflicts, in which the role of local resources and actors, their relationships and objectives can be considered as a structuring element for the development of a spatial and dynamic model of evaluation.

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