Architecture and Planning Journal (APJ)

Volume 21 | Issue 1
ISSN: 2079-4096

Article 4

January 2010

VISUALIZATION-BASED DECISION SUPPORT FOR OPTIMIZING SITE SELECTION:QUARRIES IN LEBANON; WHERE TO?

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Ibrahim, Maher Y.; Soliman, Ahmed M.; and Al-Hagla, Khalid S. (2010) "VISUALIZATION-BASED DECISION SUPPORT FOR OPTIMIZING SITE SELECTION:QUARRIES IN LEBANON; WHERE TO?," *Architecture and Planning Journal (APJ)*: Vol. 21 : Iss. 1 , Article 4.
Available at: https://digitalcommons.bau.edu.lb/apj/vol21/iss1/4

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INTRODUCTION

By definition, site selection is a process of determining the fitness of a given tract of land for a defined use (Steiner, McSherry et al., 2000). Usually, the land use or activity is known but its location has yet to be determined (Pettit et al, 2000). In another words, it is a planning task that requires from the planner to search for a site that match entitled project programming, determining the suitability of a particular area for a defined land use. In a site selection exercise, the analyst strives to determine the optimum location that would satisfy the proponents' selection criteria. The selection process attempts to optimize a number of objectives desired for a specific facility. Such optimization often involves numerous decision factors, which are frequently contradicting, and the process often involves a number of possible Sites each have advantages and limitations (Eldrandaly, 2003). Suitability analysis has been used in the last decade to assist planners in site selection problems. It requires the consideration of a comprehensive set of factors and balancing of multiple objectives in determining the suitability of a particular area for a defined land use (Al-Shalabi, 2006).

The years that followed the civil war in Lebanon witnessed a boom in construction nationwide as the sector's contribution to GDP rose to 9.4%. The central government launched a series of large-scale projects in an effort to rehabilitate the country and revive its former prosperity. These projects had a great impact not only on the other economic sector but also on the environment. It required an enormous amount of construction material (cement, sand, rocks). This resulted in the

Figure **1: Unregulated distribution of quarries**

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decimation of the mountains due to over exploitation of mineral extraction sites and quarries. Quarrying and sand mining is very controversial in Lebanon and symbolizes for many the whole environmental situation. Decades of free and uncontrolled quarrying and sand extraction have deeply affected the Lebanese landscape and endangered its soil and geological constitution (Figure1). Yet the solutions are still unconvincing and inefficient ranging from simple banning of such activities to illicit authorization in response to political pressures (NEAP, 2003).

This paper is divided into two parts, the first, investigates the ability of using GIS-based visualization methods and techniques to support spatial decision-making. Based on literature review, the theoretical study demonstrates how optimizing site selection process could be addressed using this approach. However, this part gives detailed definitions to site selection and suitability analysis in addition, it presents a review on overlay techniques; a fundamental visualization concept in GIS applied to this case. It also reviews the conceptual approach of land suitability analysis and implementation of these concepts is presented together with an example of a case study: 'Quarries in Lebanon; where to?'. The second introduces the problem of uncontrolled quarrying and sand extraction in Lebanon that have deeply affected the Lebanese landscape and endangered its soil and geological constitution.

APPROACHES TO GIS-BASED LAND-USE SUITABILITY ANALYSIS

Over the last few decades, GIS-based land-use suitability techniques have increasingly become integral components of urban, regional and environmental planning activities (Brail and Klosterman, 2001). It aims at identifying the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity (Hopkins, 1977; Collins et al., 2001).One can distinguish three major groups of approaches to GIS-based land-use suitability analysis: (Malczewski, 2003) (i) Computer-assisted overlay mapping, (ii) Multicriteria evaluation methods, and (iii) Artificial Intelligence (AI) (soft computing or geocomputation).

- Computer-assisted overlay mapping

The GIS-based approaches to land-use suitability analysis have their roots in the applications of hand-drawn overlay techniques used by American landscape architects in the late nineteenth and early 20th century (Collins et al., 2001). McHarg (1969) advanced the overlay techniques by proposing a procedure that involved mapping data on the natural and human-made attributes of the environment of a study area, and then presenting this information on individual, transparent maps using light to dark shading (high suitability to low suitability) and superimposing the individual transparent maps over each other to construct the overall suitability maps for each land use. Now, the overlay procedures play a central role in many GIS applications (O'Sullivan & Unwin, 2003) including techniques that are in the forefront of the advances in the land-use suitability analysis such as: GIS-based visualization techniques (Jankowski et al., 2001) and to be specific map-overlay visualization that can perform computational overlays such as intersection, clipping and buffering operations (Richards & Egnhofer, 1995) The computer-assisted overlay techniques were developed as a response to the manual Method's limitations of mapping and combining large datasets. Rather than manually mapping the values of a series of suitability factors in gray—or color scales, the models are stored in numerical form as matrices in the computer. The individual suitability maps can then be analyzed and combined to obtain an overall suitability map.

- Multicriteria-decision making methods

The methodology which emerged in the 1970s and which seemed to be well suited to support the planning and the public decision-making processes was Multi Criteria Analysis (MCA) (also referred to as multiple criteria evaluation MCE) (Nijkamp 1993; Voogd, 1983). Important features of MCE are its relative simplicity and its ability to handle the discrete decision situations where the choice-possibilities are measurable and the data have a quantitative and/or a qualitative character (Jankowski, 1995). Quantitative values relate to the weighting of importance given to data whilst the qualitative character of the data can be described in terms of environmental, social and economic importance (Pettit &Puller, 1999). MCE methods involve: ``the weighting of independent criteria in terms of judged Relative importance or judged relative value'' (Smith, 1980). In the urban planning context this means that weighted values can be assigned to spatial data layers and potential future land use scenarios can be formulated. Two predominant MCA methods that have been advocated by theorists and utilized by model builders are the weighted linear combination (WLC) and analytical hierarchy process (AHP) techniques (Pettit,

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1999).

AHP technique enables planners and decision-makers to assign weightings of importance to each of the decision variables using a pairwise comparison matrix. The matrix contains all possible combinations between the planning criteria, as shown in equation. AHP is suited for problems where there are a small number of planning criteria (decision variables) and has been implemented in a number of land use modeling applications (Eastman 1993). As the number of planning criteria increases, the pairwise comparison between alternative solutions can become nearly impossible. Also, as the number of planning criteria increases it becomes harder to detect the consequences of 'tweaking' specific criteria, and consequently the relative impact an assigned relative weighting may have on the decision space.

$$C = \begin{vmatrix} C_{11} & \cdots & C_{1l} \\ \vdots & & \vdots \\ C_{j1} & \cdots & C_{jl} \end{vmatrix}$$

Equation 1
Where C_{ji} is the criterion, j represents the criteria, and i represent the alternatives (Jankowski 1995).

The WLC technique requires the planner and/or decision-maker to assign weightings of importance to each planning criteria (decision variables). These weights are multiplied by the utility value of each variable and summated in order to define a final suitability score. Similar to AHP, WLC has been incorporated in a number of land use modeling applications (Eastman et al. 1995; Jankowski 1995; Klosterman 1999; ESRI 2004).

$$S = \sum (w_j x_j).\Pi c_k$$

Equation 2
Where: S = suitability; j= a decision factor; k = a constraint; c = the criterion score of constraint k; wj = weight such that a value of 1 is important down to a value of 0; xj = criterion score of factor j; Σ = the sum; and Π = the product. (Eastman, Jin, Kyem & Toledano, 1995).

- Artificial intelligence methods

Recent developments in spatial analysis show that AI (computational intelligence) offers new opportunities to land-use suitability analysis and planning. Broadly defined, AI includes the modern computational techniques that can help in modeling and describing complex systems for inference and decision making. The major area of AI is soft computing. From this perspective, AI seeks to develop systems that attempt to mimic human intelligence without claiming an understanding of the underlying processes. AI is a general term covering a number of methods such as evolutionary algorithms (EAs), genetic programming, artificial neural networks, cellular automata (CA) and fuzzy systems (Malczewski, 2003). The term of geocomputation is sometimes used to cover these new computer-based techniques for analysis and modeling geographic data and solving spatial problems (Openshaw and Abrahart, 2000).

QUARRIES IN LEBANON; WHERE TO?

Keeping with the study's perspective, the spatial scenario approach (Figure 2) is developed to investigate the potentials of GIS based visualization in dealing with land suitability task. The, stakeholder participation is chosen as an appropriate methods. However, spatial scenario approach enables planners to create maps of a range of plausible future for possible quarrying locations in Lebanon. These forecasting maps are used to discuss the need for, and consequences of, future planning. The participation of stakeholders in planning and decision-making is of utmost importance for the success of these processes (European Commission, 2001). Participation strengthens commitment, increases user satisfaction, creates realistic expectations of outcomes, and builds trust.

Carr & Zwick, (2007) defined Land-Use Conflict Identification Strategy (LUCIS) as a goal-driven GIS model that produces a spatial representation of probable patterns of future land use. The LUCIS model requires that three stakeholder groups, one to represent each of the three land-uses types, serves as advocates for their respective category. Each group rates all lands in a defined study area for their relative suitability to support the land-use category they represent. The three results are compared to identify areas of potential conflict. LUCIS can be applied to any land-use project, but it can also be effectively used in a classroom setting or by a single group to predict the potential for the future land-use conflict. In this case, role- playing is employed to capture bias (Thompson, 1978). Role playing simply requires that members of each group concentrate on the optimum suitability to accommodate their particular land use without regard for the motivations or preferences of the other group. Building on the basis of LUCIS model, a framework of the case study is accomplished through four Phases:

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- Phase I, develops three scenarios to illustrate the possible future state of Lebanon region. Each of the scenarios affects the land uses functionality, which influences possible quarrying locations. The evaluation of each of the three land use scenarios is undertaken in the light of core policy objectives as outlined in the NPMLT.
- Phase II, formulates a number of key development objectives, and associated spatial criteria. It performs land suitability analysis in a GIS through the use of multiple criteria evaluation (MCE) techniques. It also depicts number of visualization techniques according to their role within the land suitability analysis.
- Phase III, optimizes the suitable sites through the overlapping of the non conflict areas among different scenarios.
- Phase IV, presents the final plan to be discussed with different stakeholders in a meeting to designate certain areas with preference.

SCENARIOS

Three scenarios are developed to illustrate the possible future state of the quarrying activities in Lebanon. They are based on coherent and logical sets of assumptions that reflect the driving forces lying behind these scenarios. Each of these scenarios is based on a specific land use pattern used as an urban development trend in Lebanon. They are (a) nature conservation, recreation and tourism, (b) residential expansion, and (c) sustainable development.

Nature conservation, recreation and tourism

In the first scenario, nature conservation, it assumes that the region of Lebanon is regarded as a resource for the realization of nature conservation point of attraction for tourism and recreational activities. By conservation, we mean all measures that contribute to increased diversity in landscapes, and on the species level. Conservation takes place not only in segregated areas, but also in areas with intense agricultural production. An underlying assumption of the conservation scenario is that there is public awareness of the endangerment of nature-dependent livelihoods. In this manner, environmental awareness has increased and environmentally friendly behavior has been promoted and is generally accepted. This change in attitudes explains society’s unwillingness to pay for environmental damage caused by industry or private individuals. As a consequence, actions that pollute or destroy have become

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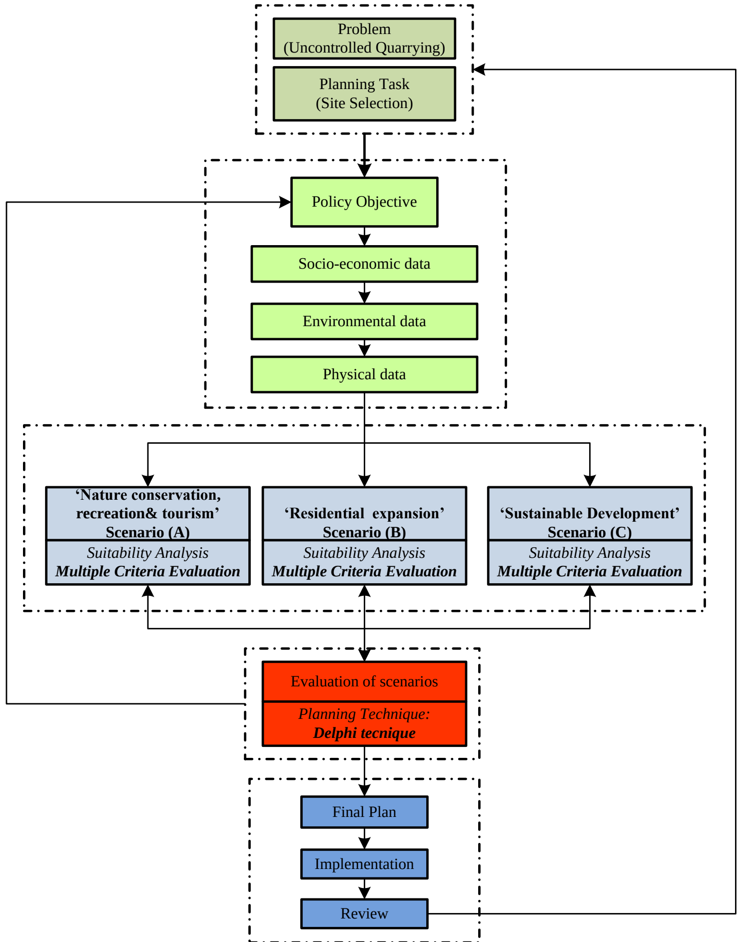
increasingly expensive, whereas environmentally friendly techniques have become cheaper and environmentally friendly behavior is supported.

Figure 2: Spatial Scenario Framework (Source: the authors).

In addition, this scenario assumes that the region of Lebanon has a primarily recreational, and tourism functions. Recreation means the totality of activities that promote "relaxation", as opposed to "work". Tourism is necessarily connected to movement; recreation in general is not. Whereas tourism covers the actions and visions of people travelling from one place to another, recreation also includes the actions and visions of people with permanent residence in the locality in question (Tress &Tress, 2002).



Residential expansion

In the second scenario, urban expansion, foreseen Lebanon as an area that is seriously damaged during the Lebanese Civil War, it requires the government efforts directed toward reconstruction of the country's war-damaged economy. We assume that the countryside in Lebanon region is regarded as a resource for housing and habitation. Tress &Tress, 2002 discussed residential expansion, or the spread housing developments, as a one aspect of the broader urbanization process itself, which includes population increase, increase in number of towns, extension of built-up areas, and spread of urban lifestyles and cultures. Residential expansion focuses only on the extension of built-up areas for residential purposes. Here, urbanization is not seen as a concentration of people and dwellings in towns, but as the opposite, a decentralized spread through the countryside. The process describes the movement of people from highly urbanized areas to the countryside. At the same time, people in the countryside are confronted with urban functions and urban lifestyles. Agricultural areas close to residential areas have been absorbed by built-up housing. Small villages and towns have become "urban centers" of residential expansion. Many new one-family homes and some apartment buildings with more units have been built, in addition to pre-existing buildings used for housing and commercial purposes.

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Sustainable Development

The third scenario focuses on urban development at different levels, maximizing economic and social development while minimizing adverse environmental impacts. Incorporating areas of both environmental and economic significance and allowing trade-offs to occur between these sometimes conflicting concerns. Thus it complies with sustainable development principles. In addition, this scenario foreseen urban area corresponds to the country's large agglomerations. These areas were defined taking into consideration their expansion for the coming 25 to 30 years. At present, they already contain 2/3 of the resident population of Lebanon, and the majority of industrial and tertiary activities of the country (NPMLT, 2005). These areas are able to receive all kinds of dwellings, activities, natural and landscaped areas, various technical facilities and equipment, etc. The only excluded land use therein concerns quarry activities. The most hazardous industries could be established within these areas, but on specific dedicated lands, separated from dwelling areas by a buffer zone of non-polluting industries and open spaces. High construction densities could be accepted within the center of urban zones, the outskirts being endowed with specific regulations adapted to their situation and location. A greater flexibility for approvals should be provided to real estate enterprises (hotels and restaurants, non-polluting industries, etc.), and for the establishment of hazardous facilities and industrial zones outside villages and cities. However, this flexibility should be coupled with stricter regulations in terms of architecture and compatibility with the surrounding landscape.

The main agricultural areas of national interest have been delineated within the rural regions taking into consideration the best agricultural lands of the country, as well as the perimeters concerned by irrigation projects. Hence, the natural land use in this area should be limited, theoretically, to agriculture. The villages, other than the relay-cities, should conserve their rural aspect, because this constitutes an essential asset for their attractiveness and the quality of life for residents. The mixed rural areas are areas that contain small cities and villages, agricultural lands with modest dimensions or low productivity, as well as natural areas that could have an importance at a local level, but not at a national level. These areas are located outside the major agricultural areas of national interest. The cities and villages of these areas benefit from agricultural, local trade, internal tourism and eco-tourism income. Land use in natural areas is necessarily restrictive. Three entities are distinguished: The high mountains above 1900 m altitude; The Cedar and mountain tree plantation corridor; Valleys, forests of quality and other zones of ecological continuity. It is also vital that the woods and forests located on Meshaa lands be preserved, without allowing any activity that might affect their development such as quarries or grazing. Concerning private forests, it is appropriate to take actions to save them not to become extinct under the growing pressure of real estate activities. Hence, the authorities, Government and Municipalities, should avoid road developments in forest areas. Strict urban planning regulations should also orient constructions towards non-forest areas.

THE LAND SUITABILITY FRAME WORK

The land-suitability analysis consists of a number of generic steps. First, the land use and location to be analyzed must be established. Five key objectives pertaining to the development of a quarries location were formulated. Next, the collection of data and formulation of necessary data layers must be undertaken, resulting in the formulation of land suitability constraints and opportunities. These were selected on the light of literature and planning guidelines of National Physical Master Plan of the Lebanese Territory (NPMPLT, 2005).

Basically, MCE methods provide a framework for processing derived weighted values. In the planning and GIS context this means that weighted values are derived and assigned to spatial data layers. These weights are based upon the relative importance of the initial goals and objectives set within the planning process. The conceptual linkage between planning and MCE processes is depicted in (Figure 3). The opportunities and constraints are transformed into decision spaces based upon user requirements, as specified through use of GIS spatial operator's. Both constraints and opportunities are stored as factors. These factors are derived through a kind of exploratory analysis function such as spatial queries, buffering or data classification. In iterative process opportunities and constraints can be changed, along with their assigned weights, quantifying the three planning scenarios in order to derive the optimal land suitability map.

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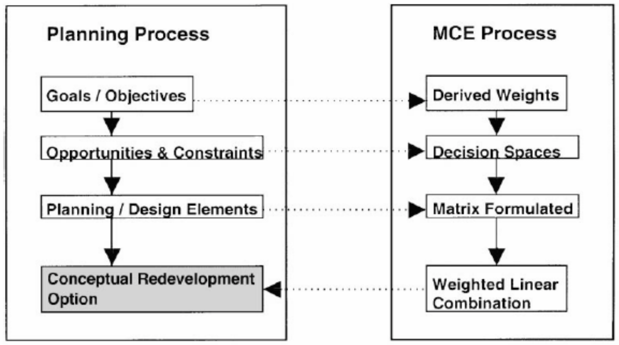

Figure 3: The MCE process linked to the planning process (Pettit & Pullar, 2000).

The derived weights are applied to these decision spaces in order to formulate a matrix which links the graphical and attribute data through a user-defined rating value. The matrix, in turn, is the MCE representation of a planning element, where the set of values assigned by the planner to each of the spatial factors which comprise the planning element are assigned a combined row and column location within the MCE matrix. A cross-tabulation of all factors using the MCE process is undertaken to compute the results. These data layers are subjected to an overlay process, similar to the one devised by McHarg (1969). The final phase within the MCE process, which is incorporated within the planning prototype, is based upon a technique known as weighted linear combination (WLC). This involves masking out all the areas with absolute constraints, and then summing the weighted factors for each unique area to create a final land suitability map (Eastman, 1997). The result is a final map/plan which comprises different potential cost surfaces. What is important in our case study that the MCE process may be undertaken numerous times in order to generate a series of alternative plans.

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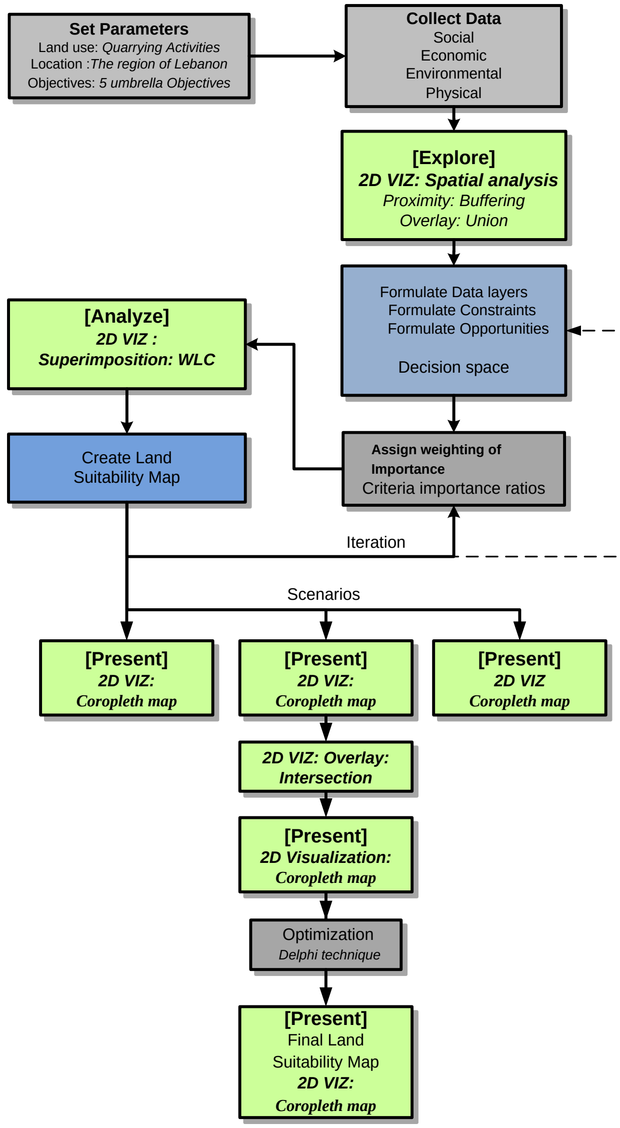

Figure 4: Suitability analysis framework highlighting on visualization techniques (Source: the authors).

Following ***our research*** track, we draw land suitability process from the visualization perspective, in order ***to*** depict a number of visualization techniques been used in our case study, classified according to their relevance to the three main fields of visualization: explore, analyze, present (Figure 4).

FORMULATION OF THE OBJECTIVES AND SPATIAL CRITERIA

Site selection objectives are formulated from the qualitative information obtained as a result of the information gathering process. The objectives should be in accordance with existing planning legislation, reports, and policies. Five 'umbrella' objectives have been formulated from the core objectives outlined in the NPMPLT (National Physical Master Plan of the Lebanese Territory) and the ABQUAR project (Alleviating Barriers for Quarries Rehabilitation in Lebanon). Each of the 'umbrella' objectives is quantifiably represented using spatial criteria that have been assigned relative weightings of importance. The spatial criteria have been formulated from GIS data layers obtained from various state and local government agencies.

These, five key objectives pertaining to the development of quarrying in Lebanon are:

- Select suitable sites that do not detrimentally impact upon areas of agricultural and rural life in the Lebanon region.
- Protect natural areas of national interest

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- Ensure that the sitting of quarrying activity does not detract from the existing urban agglomeration and cultural heritage within the city.
- Select areas that are away from vulnerable areas like rivers, springs, water resources, flood areas and landslides.
- Select quarrying sites that are in close proximity to urban centers and geologicaly suited for quarrying activities.

These wide scope qualitative objectives draw the umbrella under which a number of specific quantitative spatial criteria are addressed (figure 5).

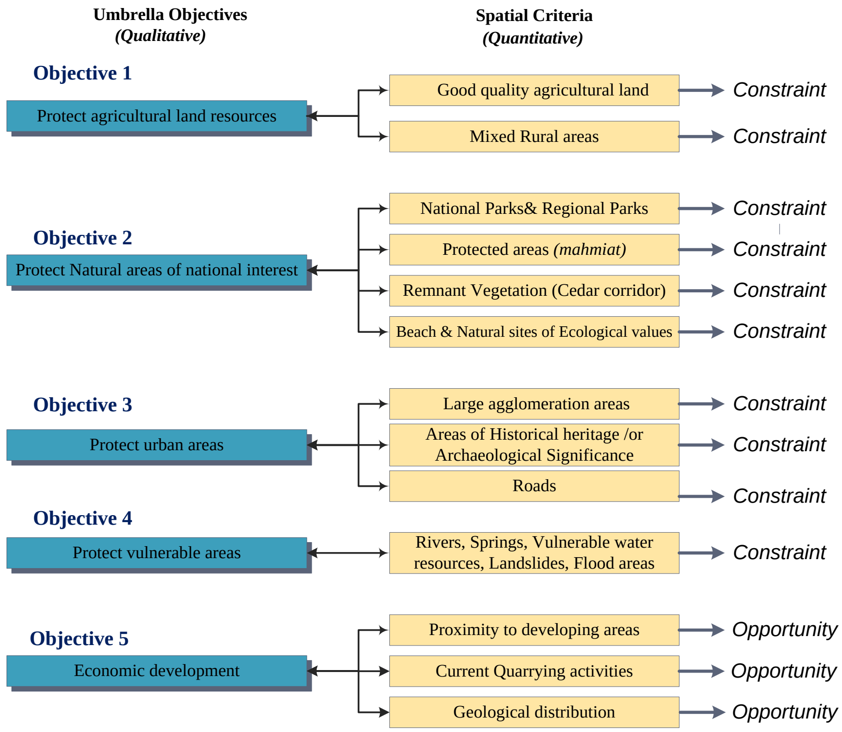


Figure 5: Associations Between Umbrella Objectives and Spatial Criteria (Source: the authors).

VISUALIZATION: EXPLORATION

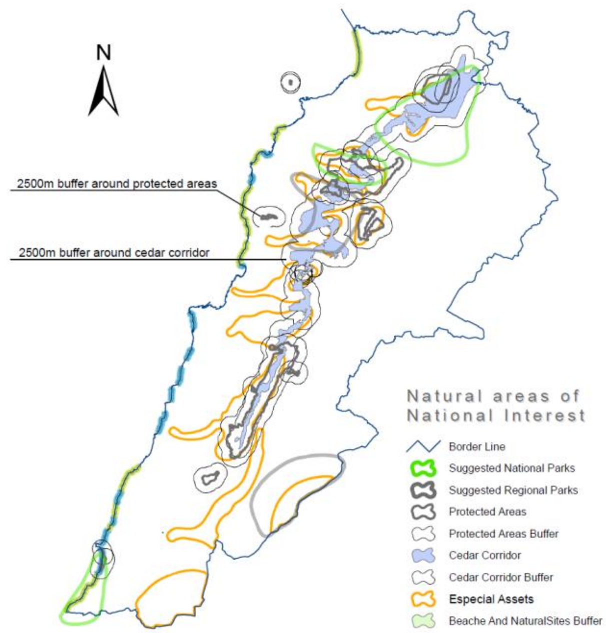
Data exploration includes looking for all trends in data, and elaborating the relationships among data sets. This procedure is developed to find any pattern or unexpected trends as well as to be able to characterize accurately the data's structure and content. This can be done within the land suitability framework when looking for a number of opportunities and constraints which needs to be derived as part of the site selection process.

Each of the five key objectives –mentioned above- can be quantitatively defined by a number of opportunities and constraints (as seen in figure 6). These are transformed into decision spaces based upon user requirements as specified in MCE through use of GIS spatial operators (Petit & Pullar, 2000). They form the foundation for the final land suitability analysis.

This stage usually starts with data preparation which may involve cleaning data, selecting subsets of spatial data using spatial queries and to exploratory analyses using spatial analysis methods like proximity buffers and simple overlay. In order to identify the most relevant, variables and determine the complexity and/or the general nature of models that can be taken into account in the next stage.

VISUAL EXPLORATORY ANALYSIS

Spatial analysis is fundamental to GIS. Most of the current spatial analysis techniques are based on the two-valued Boolean logic, which is crisp, deterministic, and precise in nature. To perform land suitability analysis using a GIS, it is needed to represent each derived opportunity and constraint as a spatial data layer. However, this needs suitable spatial data layers that quantitatively depict the necessary information.



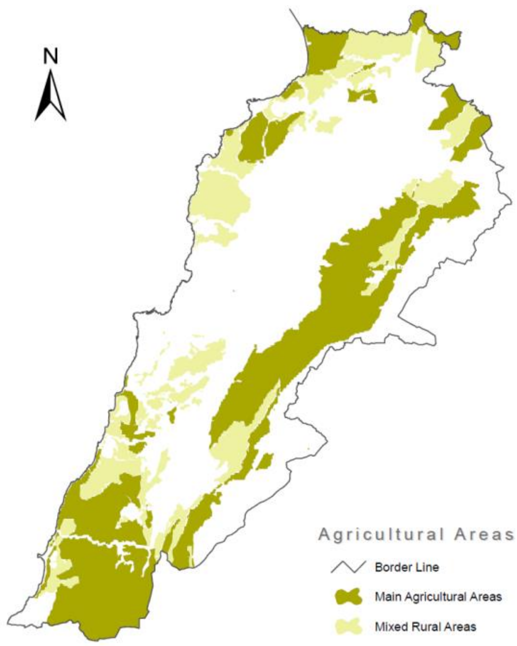


Figure 6.a: Objective one Protect Agricultural resources. **Figure 6.b: Objective one Protect Agricultural resources.**

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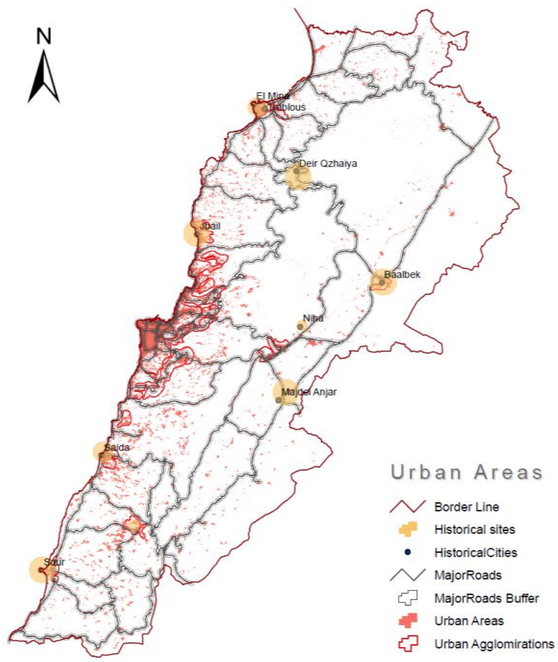

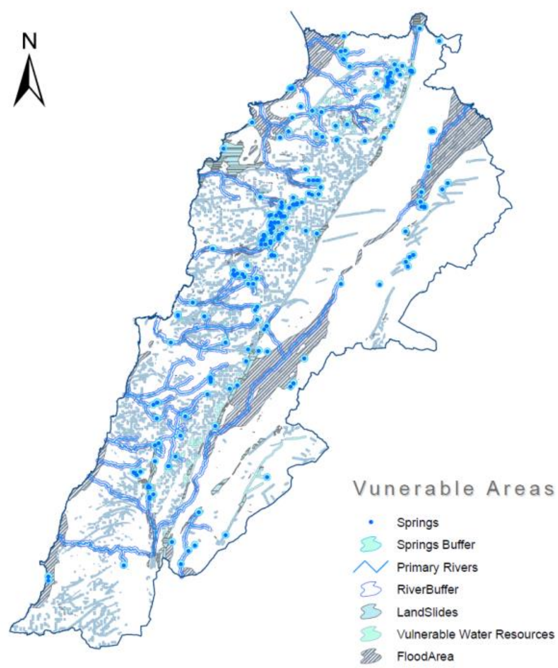

Figure 6.c: Objective three Protect Urban areas. **Figure 6.d: Objective four Protect Vulnerable areas.**

Spatial queries - spatial queries, involve using logical expressions in order to define a subset of data. When applied to spatial data a logical expression is performed on the attribute data table associated to the graphics Logical operators such as `and' and `or' can be incorporated within the query builder to enable complex expressions to be built. For example, you can select a number of land parcels, and add and edit attributes required in the formulation of spatial opportunity and constraint data layers (Agricultural land, rural area).

Buffering - Within the GIS, a number of buffers may be constructed around protected areas, remnant vegetation, beaches and natural sites of ecological values which represent a part of the environmental constraint spatial data layer. Proximity may be included as a layer in MCE by spatial buffering techniques. Buffers are generated based upon a selected set of features and a buffer distance. The buffer distance is chosen to reflect the spatial scope of interactivity between the source and other locations; for instance, proximity of urban centres in relation to possible

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quarrying locations (Figure 6.e). Multiple buffers generated around the target (urban centers) to model varying degrees of influence. These buffers are included as layers in the overlay procedure and evaluated along with other criteria in MCE.

Overlay (Union) - The integration of spatial information enables source data layers to be overlaid to create a new data layer that can be used in the land suitability analysis process. For example the resulting buffer data layers may then be combined into a final spatial environmental data layer through the use of the union operation, as shown below.

The five principal objectives governing the site selection process have been formulated, and the key spatial data layers associated with delineating each objective have been derived and organized into GIS project. The key spatial data layers have been combined in a single spatial opportunity or constraint that depicts each of the principal objectives.

VISUALIZATION: ANALYSIS

In order to evaluate potential solution in the planning process, represented by a composite form of spatial opportunities and constraints, it must be integrated through an evaluative technique to formulate planning options. MCE seemed to be well suited to support decision making process. At this stage, a Geographic visualization approach can be employed; a kind of visual analytics approach, which suggests the combination between visualization tools with specialized analysis tools, which interfaces between cartography and scientific visualization and between technology for mapping and ways in which mapping can facilitate geographic thinking.

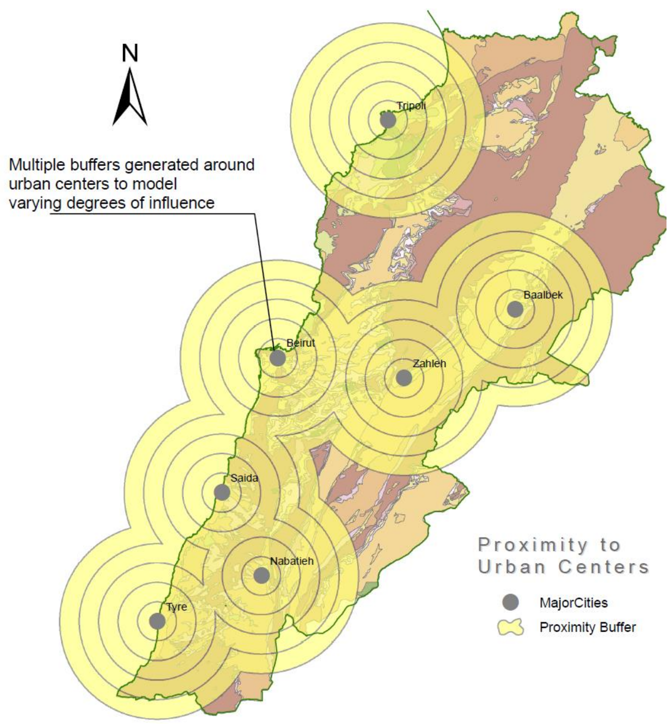
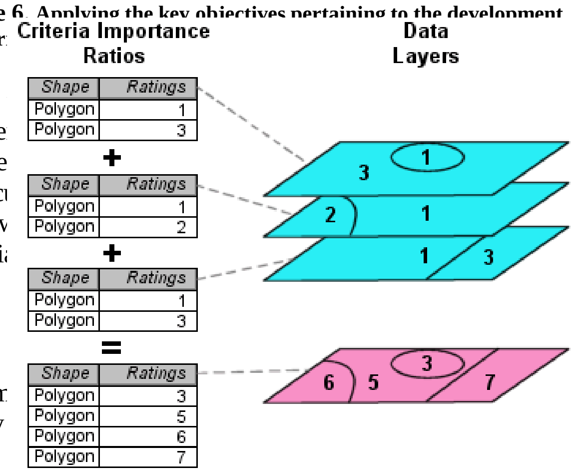


Figure 6.e: Objective five Permit economic development.
Figure 6. Applying the key objectives pertaining to the development of quar

Superimposition - Among the most powerful operations that a modern GIS can perform is the ability to superimpose one set of geographical data on top of another and to combine those characteristics of both into a set of information. In its simplest form, this is the case of visualizing two or more sets of cartographic information simultaneously; a fundamental geographic visualization concept can be done in conjunction with multi-criteria evaluation (MCE) methods. It is a map overlay approach, typically applied to land-use suitability in the form of weighed linear combination (WLC). Data layers represented by constraint and opportunity can be modeled as either a binary or graded surface, so what is left in the site selection process is the optimization of a weighted combination of these opportunities and constraints in order develop a graded development-potential surface of the area of inte Decision tables accompany the final land suitability map outline planning criteria used in formulating the final sitting of a partic land-use or activity (Table 1). This method can be applied at tv different levels for each of the three scenarios: formulating criteria utility measures and applying criteria importance values.



Formulating criteria utility measures involves establishing weights for each planning criteria (also referred to as spatial opportunity and constraints). There are a num weighting methods that we can use to formulate criteria utility

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case, we have used the rating method, which can be easily implemented and applied to vector overlaying of spatial opportunities and constraints within a GIS (Table 1).

The assignment of criteria-importance ratios can be the responsibility of the advocacy groups, criteria importance ratios assigned to each planning criteria can then be summed to formulate a final range of criteria values (Figure 7). Criteria importance ratios, also called suitability scores (figures 8,9,10) are computed using the weighted linear combination. This necessarily involves overlay to obtain disaggregated values at locations and then doing a weighted combination of the criteria scores for each location.

Table 1. Constraints and opportunities are stored as factors.

Figure 7: Criteria importance ratios are computed using the weighted linear combination.

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Condition Statement

Objective	Criteria	Buffer /m	Scenario Rating			Description
			A	B	C	
1	Good quality agricultural land		-5	-2	-3	soft constraint
	Mixed rural areas		-4	1	-3	soft constraint
2	Prospective National and Regional parks		-3	-1	-5	soft constraint
	Protected areas		-999	-999	-999	absolute constraint
	Protected areas buffer	2500	-5	-1	-2	soft constraint
	Remnant vegetation (cedar of Lebanon)		-999	-999	-999	absolute constraint
	Remnant vegetation buffer	2500	-5	-1	-2	soft constraint
	Especial Assets		-5	-1	-2	soft constraint
	Beaches& Natural sites of ecological value		-5	-1	-2	soft constraint
3	Urban Areas		-5	-1	-4	soft constraint
	Large Agglomeration Areas		-4	-1	-3	soft constraint
	Areas of Cultural Heritage	1000	-5	-2	-4	soft constraint
	Protect infrastructure(Roads)		-3	-3	-2	soft constraint
4	Rivers buffer	500	-5	-4	-2	soft constraint
	Springs buffer	1000	-5	-3	-4	soft constraint
	Venerable water Resources		-4	-2	-3	soft constraint
	Landslides		-5	-2	-4	soft constraint
	Flood areas		-3	-1	-2	soft constraint
5	Proximity of quarries to developing areas	5000 10000 15000 20000 25000	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1	opportunity [1]
	Geological distribution		g1=5 g2=4 g3=3 g4=2 g5=1	g1=5 g2=4 g3=3 g4=2 g5=1	g1=5 g2=4 g3=3 g4=2 g5=1	opportunity [2]

Scenarios/ A:Nature conservation; B:Residential expansion; C:Sustainable development

These are soft opportunity values—the land with the highest opportunity is closest to existing quarries location
2- These are soft opportunity values - Scoring of geological distribution was given according to the number of quarries located on a specific geological area with specific aggregate properties.

VISUALIZATION : PRESENTATION

Mapping and presentation of results

The final phase of the land suitability analysis it is a spatial overlay of all of the principle objectives of data layers. This will allow us to construct the final suitability map of the three scenarios (A, B, and C), used to determine the optimal location for quarrying locations in Lebanon. In order to see the area's most suitable or least suitable for locating the proposed quarrying sites, we need to establish a classification system for the potential cost surface. Displaying of the assigned data values within the final data layers requires transforming these values into colors by using a choropleth method.

The values are calculated for the areas, and expressed as a stepped surface, showing a series of discrete values. The starting point will be the absolute values of a specific phenomenon distributed over land zones. Categorizing these values into a number of classes, at this point all areas that fall into a specific category will

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be assigned a color value for this category. Through categorizing, the image will be simplified and the existence of patterns and trends will be better visualized (figures, 8,9,10).

A condition is that the differences within the class are been minimized and differences between classes maximized. Choropleth are the right maps to represent suitability data, because it construction are straight forward, and can be computer-generated easily. The result will be is a final land suitability map that delineates areas most suitable to least suitable for the location. To make the final land suitability map easier to understand is relabeling the classification scheme using relative terms; restricted, most unsuitable, unsuitable, suitable, and most suitable.

The land suitability map, does not tell the decision maker where to locate the structure; rather, the results of the land suitability analysis should be used as a decision aid. The spatial analysis process offers the opportunity for a number of scenarios to be modeled using different input data layers and different importance ratio criteria values.

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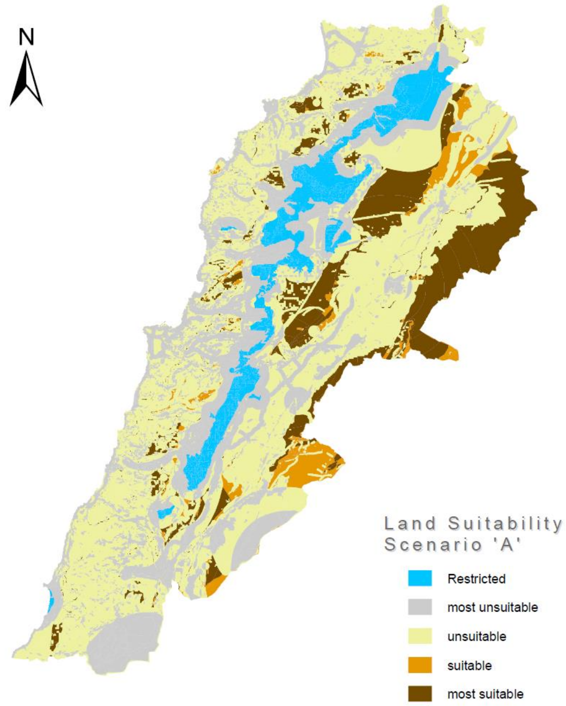

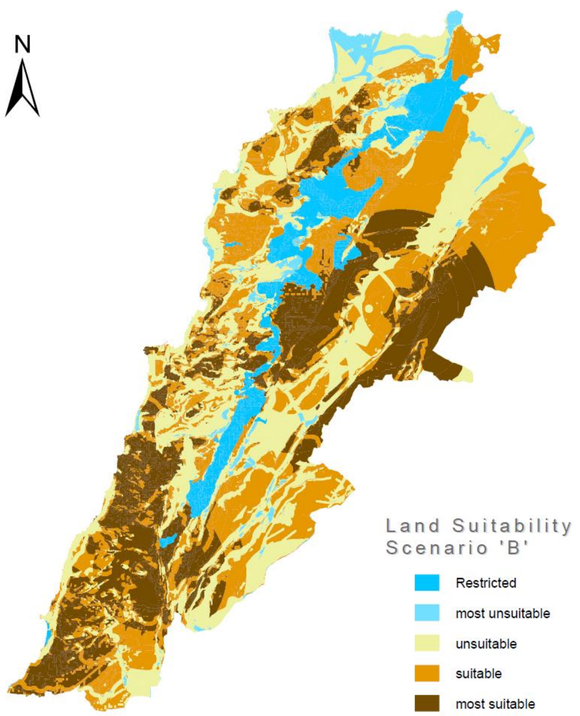

Figure 8: First Scenario: Natural conservation, recreation, and tourism. **Figure 9: Second Scenario: Residential expansion.**

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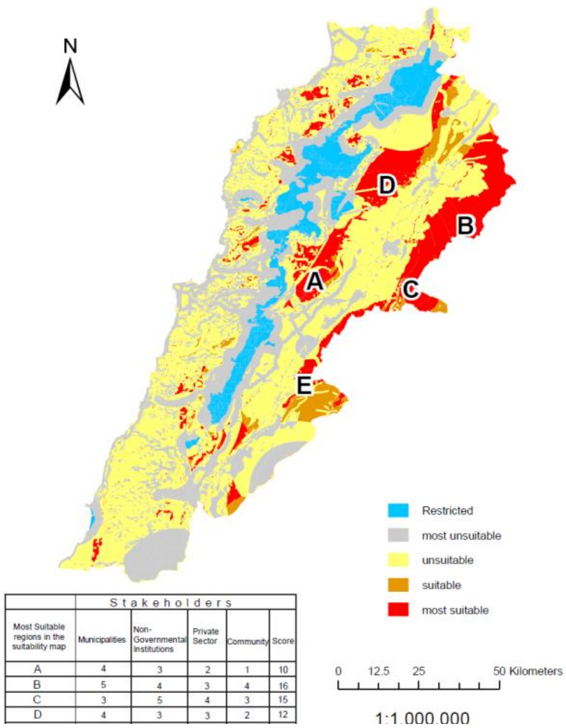

	Stakeholders				
Most Suitable regions in the suitability map	Municipalities	Non-Governmental Institutions	Private Sector	Community	Score
A	4	3	2	1	10
B	5	4	3	4	16
C	3	5	4	3	15
D	4	3	3	2	12

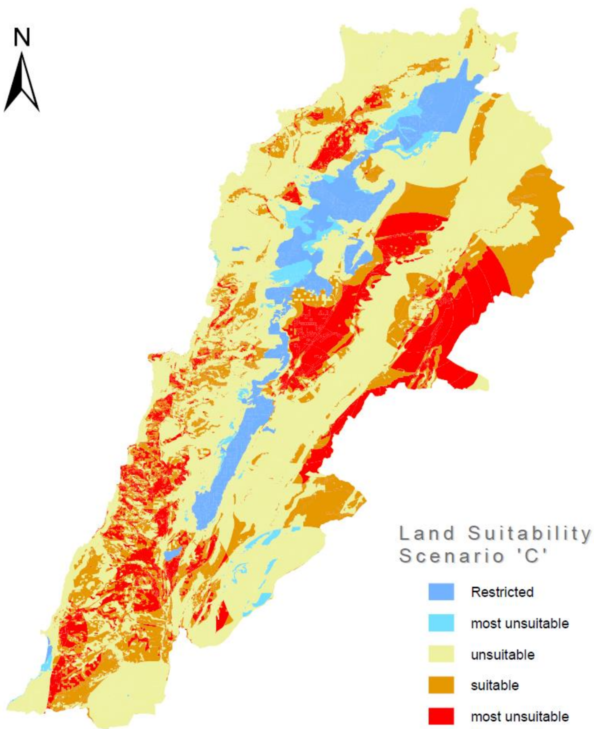

Figure 10: Third Scenario: Sustainable development. map.

Figure 11: Quarries in Lebanon: Final land suitability

Collaboration

Undertaking a comprehensive site selection process, considering the input of each of the individuals and groups as discussed in the previous concept, is important. Using techniques such as Delphi technique, developed by the

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RAND Corporation in the 1960s, could be useful in formulating a number of sitting options. At the case of site selection for quarries in Lebanon; a group of experts could come to some consensus of opinion when the decisive factors were subjective, and not knowledge-based. At this stage suitability becomes preference as it is not used to identify location, but rather to capture community values while assessing locations that have been identified.

In this paper, we nominated a number of locations assigned in the final suitability map. Typically, the evaluation says what the best locations that now satisfy the objectives are. The evaluation can be as simple as finding the best locations with the highest ranked score (Figure 11).

AT this level, Mapping as a visualization technique can be seen as a facilitator for group work with geospatial information. This framework identifies two primary functions for visual representations as a vehicle to support group work; first: visualization as the object of collaboration, and second: visualization is used to support dialogue.

CONCLUSION

Optimizing site selection is a major challenge and puts a great degree of responsibility in the hands of decision-makers. It requires visualization tools integrated within GIS to be used with great capabilities of exploration, analysis, synthesis and presentation of geographic. This paper has developed a transdisciplinary method to perform a kind of suitability analysis. It combines visualization tools with a support of multi criteria evaluation (MCE) methods, integrated with spatial scenario planning approach, and the involvement of different stakeholder and advocacy groups.

The proposed method starts up, by the development of three different scenarios illustrating the possible future state of Lebanon region. Each of these scenarios has direct affects on the land uses functionality, which in its turn influences possible quarrying locations. In evaluating these scenarios, the role playing technique of LUCIS model is used. It simply requires that members of each assigned group concentrate on the optimum suitabilities to accommodate their particular land use without regard for the motivations or preferences of other groups. In this case, role- playing is employed to capture bias. The paper formulated a number of key development objectives, and associated spatial planning criteria. Formulating criteria utility measures is used to assign weights for each planning criteria.

The plans of the three developed scenarios were combined to determine the non conflicting areas. In a further step, one single plane was reached as one that witness consensus among advocacy groups. This final plan was presented to be discussed with different stakeholders in a meeting to designate certain areas with preference. Along this process a number of visualization techniques were depicted according to its role within the land suitability analysis in the fields of exploration, analysis, synthesis and presentation .All of these activities are relevant to the decision activities of identifying criteria, comparing solution and conducting sensitivity analysis, with decision parameters.

Visualization of Scenario combined with participation of stakeholders has proved to be a helpful tool for identification of interests in, and demands on, the future of quarries in Lebanon. The spatial representation of weighted land use as it changes through different scenario powerful and persuasive. They communicate well to the public and to representatives from administration and planning.

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