Application of Spatial Multi Criteria Evaluation for an Agricultural Development Scenario in the Egyptian Deserts

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Abstract

The land use decisions and planning processes deal with large volumes of basic data where technical knowledge must be coordinated with the decision makers' visions of society. This fact makes spatial planning quite a complicated process. This study addresses a regional scale zoning issue through cartographic modeling using Multi Criteria Evaluation in a geographic information environment through a case study. The main objectives of this research are to explore the model potential of providing an answer to the suitability of the desert lands in Egypt for an agricultural development strategy and to provide a decision support tool for land use planners. A geographic database was established at a national scale. Spatial Multiple Criteria Evaluation (SMCE) techniques were used to produce the land suitability index for agriculture development. Lands with constraints were omitted from the study area. Factors needed for land cultivation were identified, ranked, weighted and overlaid in a cartographic model. The product of the model was a suitability index map which was further classified into zones according to the suitability index range of values. A three phase strategy was proposed based on the suitability classes. The resultant map can be used as guidelines providing a base for land reclamation and development. This methodology can be applied on other locations at regional planning levels, and can provide what-if scenarios based on the objectives and relative importance of the selected criteria sets.

Keywords: Land use strategy, Multi Criteria Evaluation, remote sensing, Geographic Information System, cartographic models, geographic database, decision support systems.

1. Introduction

The concept of sustainability is understood for this study in the context of the triple bottom line approach which requires the integrated consideration of environmental, social and economic issues for a sound development. This approach assumes that the development meets the criteria of the three mentioned aspects simultaneously Belka (2005) and Gibson, 2001). Land analysis is commonly done with map overlay and it is used to be done manually. GIS is a computer-based system that is used to store and manipulate geographic information, where the graphical interface is interconnected with a database. The most common relational database allows displaying data as a set of thematic layers. This evolving technology provides better information to support this type of complex decision-making. With the rapid advancements taking place in computer hardware and GIS software, more complex land use models are being developed. These models help researchers and planners to simplify complex systems and to develop theory to understand the process of conducting a Strategic Environmental Assessment (SEA) in a better and easy way (Noble, 2000 and Grzybowski and Associates, 2001).

Cartographic modeling applies map algebra tools together with other basic analysis operations in GIS. Multi-criteria Decision Making (MCDM) is a term including Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM). MADM is applied when a choice out of a set of discrete actions is to be made. It is often referred as Multi-Criteria Analysis (MCA) or Multi-Criteria Evaluation (MCE). Multiple criteria overlay was proposed by (McHarg, 1969) who suggested identifying physical, economic and environmental criteria in order to assure social and economic feasibility of the project. The main objective of MCDM is "to assist the decision-maker in selecting the 'best' alternative from the number of feasible choice-alternatives under the presence of multiple [decision] criteria and diverse criterion priorities". Every MCDM technique has common procedure steps, which are called a general model **(**Janko**wski, 1995).**

Despite the close relationship between the Geographic Information System (GIS) and land-use studies, there has been little constructive dialogue on the relationship between MCDM and land-use analysis and practical applications. Spatial multi criteria decision making refers to the use of multi criteria analysis (MCA) to spatial decision problems (Voogd, 1983). MCA is a family of operations research tools that have experienced very successful applications in different domains since the 1960's. It has been coupled with GIS since the early 1990's for an enhanced decision making. Remotely sensed data together with GIS have been recently used in land use decision analysis. Cartographic modeling and suitability mapping of land in accordance to its potentials and constraints using MCE techniques have been broadly applied. Belka (2005) explains that in order to define the suitability of an area for a specific practice, several criteria need to be evaluated. Multi Criteria Evaluation (MCE) has been developed to improve spatial decision making when a set of alternatives need to be evaluated on the basis of conflicting and incommensurate criteria. MCE is an effective decision-making tool for complex issues that uses both qualitative and quantitative information. It has been utilized around the world for land suitability modeling and is concerned with how to combine the information from several criteria to form a single composite index of evaluation (Sahoo *et al* 2000). A criterion may be a factor providing suitability of phenomenon of continuous measure or may be a constraint to limit the alternatives under consideration The MCE in its Weighted Linear Combination method introduces a soft or "fuzzy" concept of suitability in standardizing criteria. It is scaled to a particular common range where suitable and unsuitable areas are continuous measures. The aggregation method uses weighted linear combination, which retains the variability of continuous criteria and allows criteria to trade off with each other. As the criteria are measured at different scales, they are standardized and transformed such that all factor maps are positively correlated with suitability. The weighted summation allows for evaluation and ordering of all alternatives based on the criteria preferences by decision-makers **(Saaty, 1977).** Examples of raster-based multi-criteria evaluation are given by (Grossardt *et al*, 2001**)** and (Zuccaa *et al*, 2007).

The Study Area:

The geographic location of Egypt lies between latitudes 22° and 32° North and longitudes of 24° and 37° East (Figure 1). The lands cover an area of one million square kilometers in North Africa and Western Asia. Deserts occupy almost 96% of the Egyptian land cover. The vast majority of its 78 million populations for 2006 cesnus, are mainly concentrated in the Nile Valley and the Delta as well as in the coastal zone along the Mediterranean Sea. Inhabited area represents only 4% of the total territory. Rich in unexplored potentials, the vast desert zones are being joined and accessed by development corridors linking the main Egyptian towns. This study attempts to apply the MCE theory and technique in a GIS environment on a national scale for exploring the agricultural potentials of the desert lands surrounding the development corridors in Egypt.

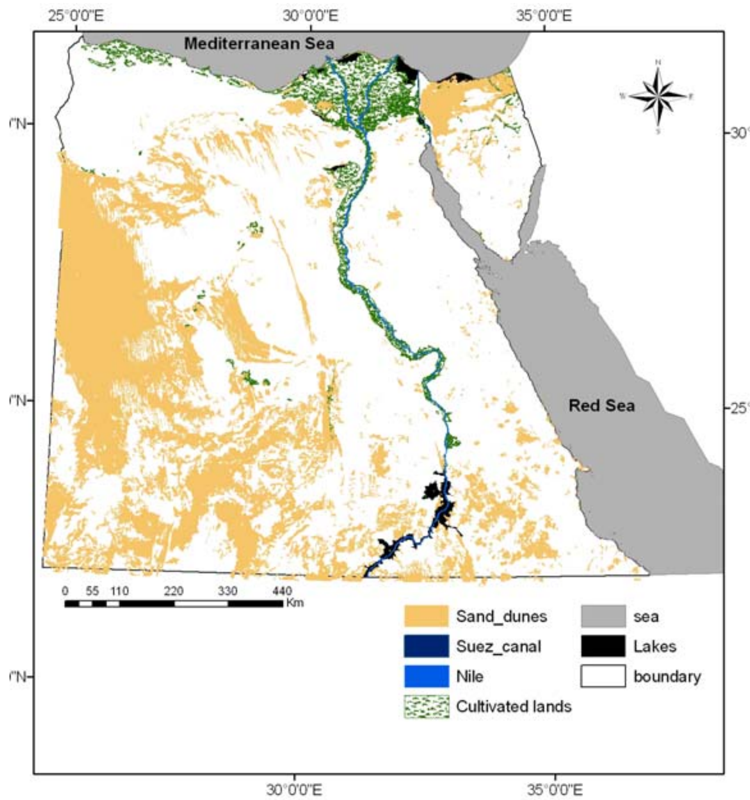

Figure (1): Location and main features of the study area

Objectives of the Study

The main objective of this study is to explore the potentials of remotely sensed data and geographic information system in linking the gap between this geo-science and the land use decisions and applications in the field of regional planning. The study attempts to apply the MCE theory and GIS techniques using maps and remotely sensed data for producing a suitability index map for the Egyptian desert lands for locating new agricultural zones. The study also aims at exploring the land resources, potentials and constraints that need to be considered in sustainable land use plans in Egypt.

Datasets

Several datasets were acquired for this study considering the heterogeneity of the area under investigation, an integrated database was established. The primary data sets used for this study are (Shuttle Radar Topography Mission, SRTM, USG, 2000) with a 90 meters resolution was used to derive the slope, aspect, catchments areas and drainage basins. The derived topographic grids were imported into the database. Hydrogeological maps scale 1:2,000,000 were obtained from the National Water Resources Center Research Institute for Groundwater, (RIGW, 1999). The protectorates maps after the (Egyptian Environmental Affairs Authority, EEAA, 1999**)** Such maps were rectified and digitized, in addition the topographic base map scale 1:1000,000 obtained from the Military Survey Department (1995) as well as the land cover map of Egypt obtained from Food and Agriculture Organization of the United Nations (FAO,2000).

2. Methodology

2.1 Identification of the Suitability Criteria

A criterion is some basis for a decision that can be measured and evaluated. It is the evidence upon which a decision is based. Criteria can be of two kinds: factors and constraints. A factor is a criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration. It is therefore measured on a continuous scale. A constraint serves to limit the alternatives under consideration. In

many cases constraints will be expressed in the form of a Boolean map; 1 or 0/true or false (Durga 2005)

Identification of the essential criteria for agricultural development in the desert was done through literature review and stakeholders participation in defining the general objectives for agricultural development of the land, Figure (2).

2.2 Constructing a Database

Identification of the suitability criteria for agriculture development was started by the data acquisition, rectification and establishment of the database. The acquired maps were rectified, digitized using on-screen digitizing and saved as ESRI format shape files. Such files were imported into feature datasets in a geographic database using ArcGIS9.2 software. The datasets were all projected to the Universal Transverse Mercator UTM, WGS84. Tables from reports were converted to digital and imported into the database. Shuttle Radar Topography Mission (SRTM) was used to derive the slope, aspect, catchment areas and drainage basins. The derived topographic grids were imported into a geographic database.

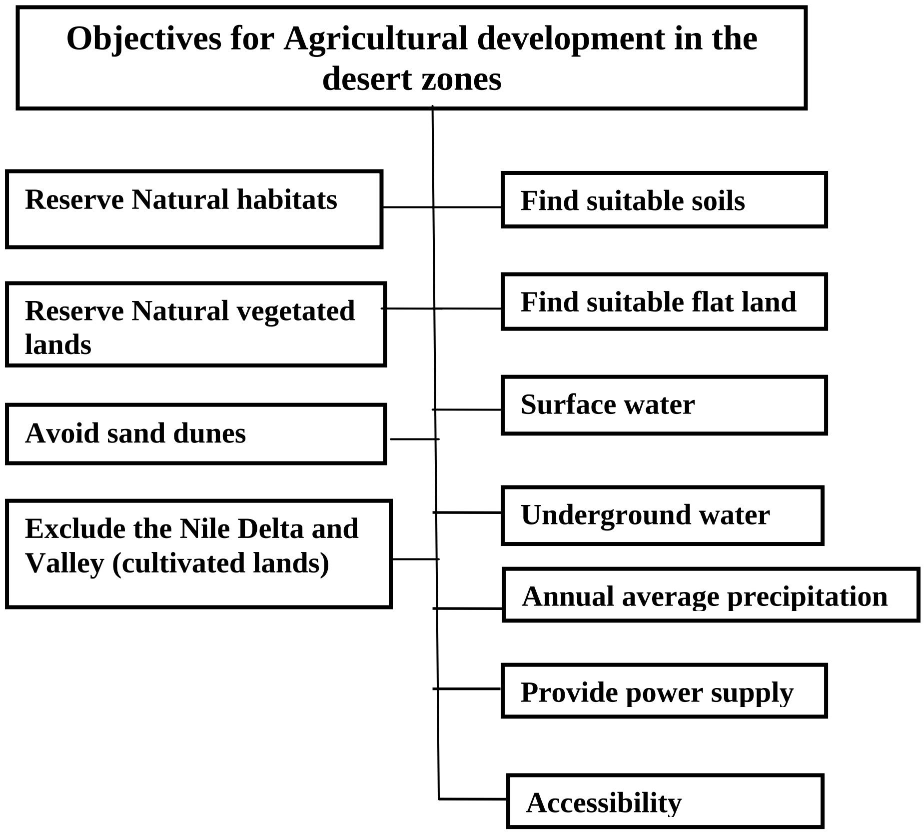

Figure 2: Agricultural development parameters.

Criterion maps are produced as an output of the criteria identification phase. These maps are the input for the MCE cartographic model. The selected criteria sets consisting of constraints and potentials were processed and used as inputs for the multicriteria analysis. A flow chart for the methodology is shown in Figure 3.

Constraints are zones unflavored for a land change. These are either not suitable for the studied activity or protected zones. For this study, it was agreed to consider the cultivated lands in Nile Valley and Delta, the natural vegetation, the sand dunes and the protectorates as constraints to new development decisions. The constraints layers were masked out from the study area resulting in a map of potential sites for zoning as shown in Figure (4). Constraints are described as follows:

Cultivated lands

The cultivated land in Egypt is mainly concentrated in Nile Delta and Valley in addition to some coastal belts and few desert oases. The arable land is legally protected from land use changes. The FAO land covers data for Egypt based on Landsat ETM data and available online in the form of shape files were used. The cultivated lands layer was downloaded, updated using a recent version of Landsat ETM+ and used as a constraint layer.

Natural vegetation

The desert natural vegetation in Egypt has environmental and economic values. Therefore, it was an objective of the study to help preserve natural vegetation zones. FAO landcover was used to extract the natural vegetation layer.

Sand dunes

Sand dunes are one of the obstacles for locating new projects in Egypt. As dunes are affected by wind, sand dunes movement may cause burial of roads, constructions and dwellings. It was considered as one of the constraints to land reclamation zones. FAO dataset was used to extract the sand dunes layer from the land cover. The dunes layer was exported as a feature class in the geo-database and used as a constraint.

Protected Areas

Natural protectorates have environmental values for preservation of tourist and recreational scenic sites, flora and fauna. National parks were considered a constraint to land reclamation. The protected areas map was obtained from the Egyptian Environmental Affairs (EEAA, 1999), converted to a digital form, rectified, projected and exported to the geographic database as a feature class and used as a constraint map.

Factors of the land development are mainly presented by natural and economic resources. Combination of the factors produces sites having the highest suitability for a proposed agricultural development. The selected factors set include the following:

Annual Average Precipitation Map

Data from the climatic atlas of Egypt (Egyptian Meteorological Authority, 1996) covering an average ten years 1986-1996 was used. The annual average precipitation maps were digitized, rectified and projected and used as a factor map.

Surface Water Resources

Surface water is provided by the Nile River, Lake Nasser and some canals. Surface water resources were scanned from the topographic map, digitized, rectified and projected and used as factor maps.

Underground Water

Due to water scarcity, in desert areas, the availability of aquifers and underground water resource is one of the essential factors for new cultivation activities.

Power Supply

The proximity of the site to a power supply such as high electric lines or power stations is an essential economic factor to locating an industrial activity. The high electric lines and power stations were mapped from the topographic map, saved as a feature class and used as factor maps.

Rock type Map

The fact that the study area consist of desert, agriculture activities is given a first priority. The rock type was mapped from the geological map, saved as a feature class and used as a guide in order to identify soils that are favorable to future cultivation and land reclamation.

Proximity to roads

As roads are the main arteries for any development site providing accessibility and linking its remote areas, it is a main factor to agricultural zones selection. The road map was prepared from the topographic map and used to derive the distance from road map and used as a factor map. Since the movement on the land do not happen in all directions but on strictly defined networks (such as roads, railways and utility lines), therefore the use of consecutive buffer zones was applied using the straight distance function in ArcGIS software ,Figure 4.

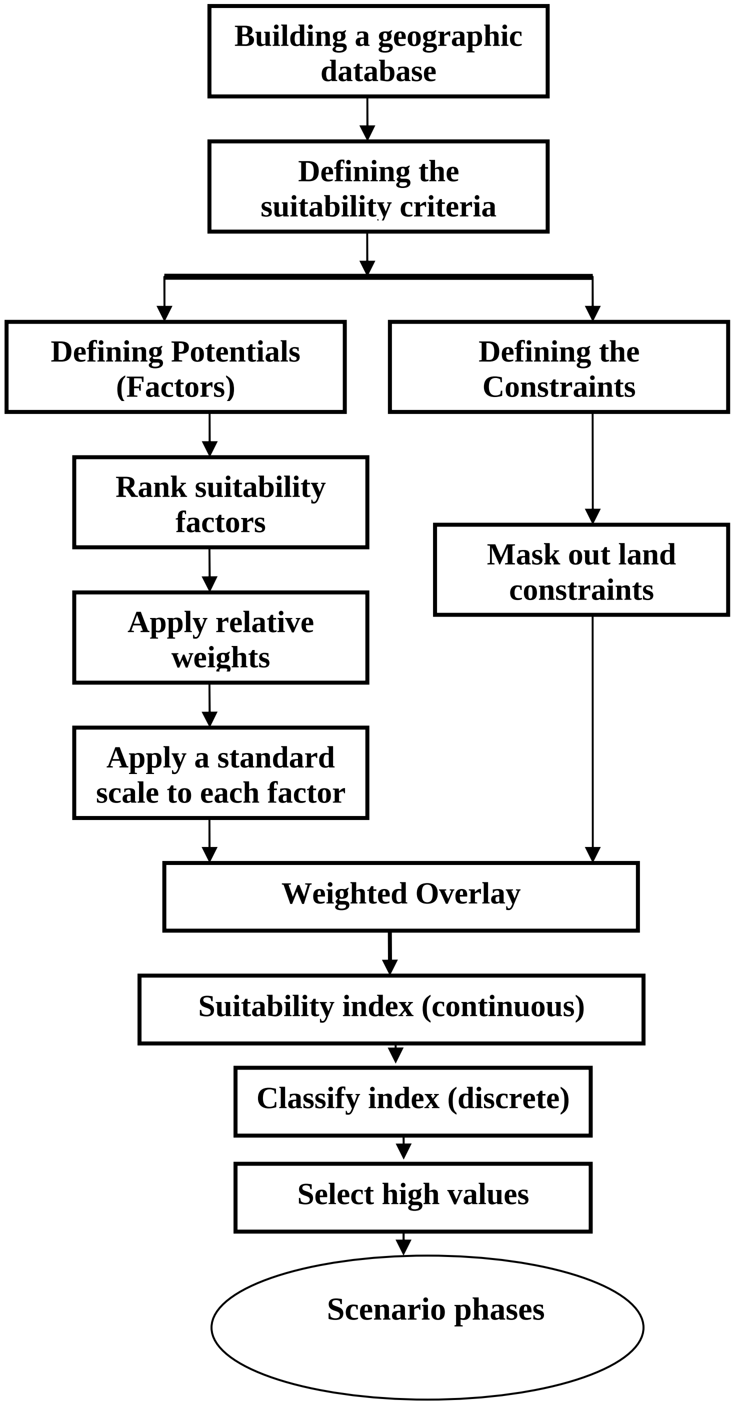

Figure 3: Flow chart for deriving the suitability index for agricultural development

2.3 Ranking and weighting of the Criteria Maps

Ranking of the factor maps is a step prior to applying their relative weighs. The straight rank sum method was selected for this study. The method is one of the simplest criterion weighting techniques though criticized for its lack of theoretical foundations in interpreting the level of importance of a criterion. It is selected here for being a straight forward method that can be used with least confusion to the decision makers. In straight ranking, criteria are ordered from most to least relative important factor in accordance to the decision makers' point of view. After the ranks are established, relative weights are assigned to the factors, using the straight rank-sum method as explained in equation 1 (Belka, 2005):

$$w_j = (n - r_j + 1) / SUM(n - r_k + 1) \quad \ldots\ldots\ldots\ldots\ldots\ldots\textbf{(1)}$$

where **wj** is the normalized weight for j^{th} factor
n is number of factors under consideration
rj is the rank position of the factor.

Several raster layers can constitute a set of criteria where every cell value is assigned a criterion score. Since the criteria attributes differ in evaluation, (example lithology units describe rock types, while the distance maps measure distance) therefore, a common scale had to be applied, namely a suitability scale. Accordingly, each of the attributes was rated to a suitability scale that ranges from zero to nine. The higher the value the more suitable and vice versa. Standardization values of the lithology and aquifer maps are shown in Table (1).

Table 1: Suitability values used for rating of some factors

Standardization of Factors Map Units (suitability scaling)	
(A) Lithology Units	
Rock type	Suitability rate
Basement rock	0
Clay and sand clay	5
Dakhla shale	3
Dolmitic lime stone and clastic	2
Lime stone and marly lime stone	1
Mainly lime stone with intercalations of shale	1
Nile deposit	7
Nubian sandstone	1
Sabkha deposit and gypsum clay	2
Sand sheets and sand dunes	3
Wadi deposits	6
Limestone and chalky limestone	1
Sand gravel and silt stone	3

(B) Aquifers Units	
Extensive and highly productive aquifers continuous	8
Extensive and highly to moderately productive aquifer	7
Extensive and moderately to low productive aquifers with paleo	6
Local and highly to moderately productive aquifers	5
Local and moderately to low productive aquifer insignificant surface	4
Local and very low productive aquifers formed from intercalations	3
Local ground water occurrences in fissured rocks and weathered zones in hard rocks	2
Non aquifers	1
(C) Slope in degrees	
0-10	6
10-20	5
20-30	4
30-40	3
40-50	2
Greater than 40	1

The straight rank sum method was used to obtain a relative importance weight for the suitability factors as shown in Table (2).

Table 2: Relative weights applied for the Agricultural suitability factors

Criteria	Straight Rank (rj)	Weight (n – r j + 1)	Normalized Weight (n – r j + 1) / SUM(n – r k + 1)
Water resource Surface and underground	1	6	25
Lithology	2	5	19
Slope	3	4	15
Precipitation	2	5	18
Power Supply Power Stations High Electric line	3	4	8 7
Road network	4	3	7
Sum	15	27	100

2.4 Cartographic Modeling for Land Suitability Analysis:
The next phase is conducting the land suitability analysis to identify concentrated areas of potentials and limitations to development. The standardized, weighted criteria maps, were then incorporated into the weighted overlay module in ESRI software ArcGIS 9.2. For each location, the average suitability score was calculated equation (2) Caranza, 2006:

$$\overline{S}=\frac{\sum_{i=1}^{n}(W_i\times S_{ij})}{\sum_{i}^{n}W_i} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\textbf{(2)}$$

Where $\bar{S}$ is the weighted average suitability score
Wi is weight for ith map
and Sij is score for jth class of the ith map.

The assigned importance weight Wi depends on the variable significance with respect to the land suitability $\bar{S}$ for a studied activity.

3. Results and Discussion

The constraints of the lands were reflected by the sand dunes spatial distributions, the cultivated lanes in the Nile Delta and Valley, the natural protectorates and the natural vegetation in addition to the river Nile and lakes. The sand dunes propagate in the desert specifically in the Western Desert where the great sand sea exists, figure 3.

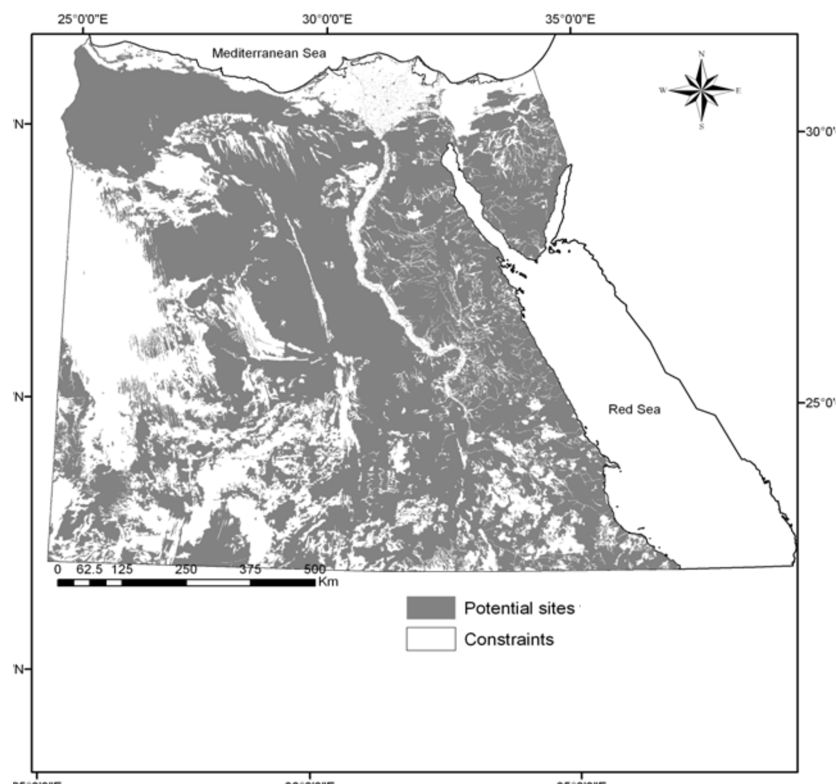

Figure 4: Map showing the land potential and the constraints for selection of new zones for agricultural development.

Results of producing the factor maps and their suitability indices unveiled the distribution patterns of several parameters in the Egyptian deserts. The spatial distributions of the surface water are around the Nile Delta and Valley (Figure 5-a and 5-b.) Power supply and high electric lines extend mainly along the Nile Delta and Valley with extensions in the Eastern Desert, Sinai and the eastern half of the Western Desert, (Figure 5-c). Slope map shows gentle and medium slopes along the Nile Delta and some northern coastal zones while most steep slopes exist in the Eastern Desert, Sinai Peninsula and the Western zones of the Egyptian deserts where the Great Sand Sea exists, (figure 5-d).

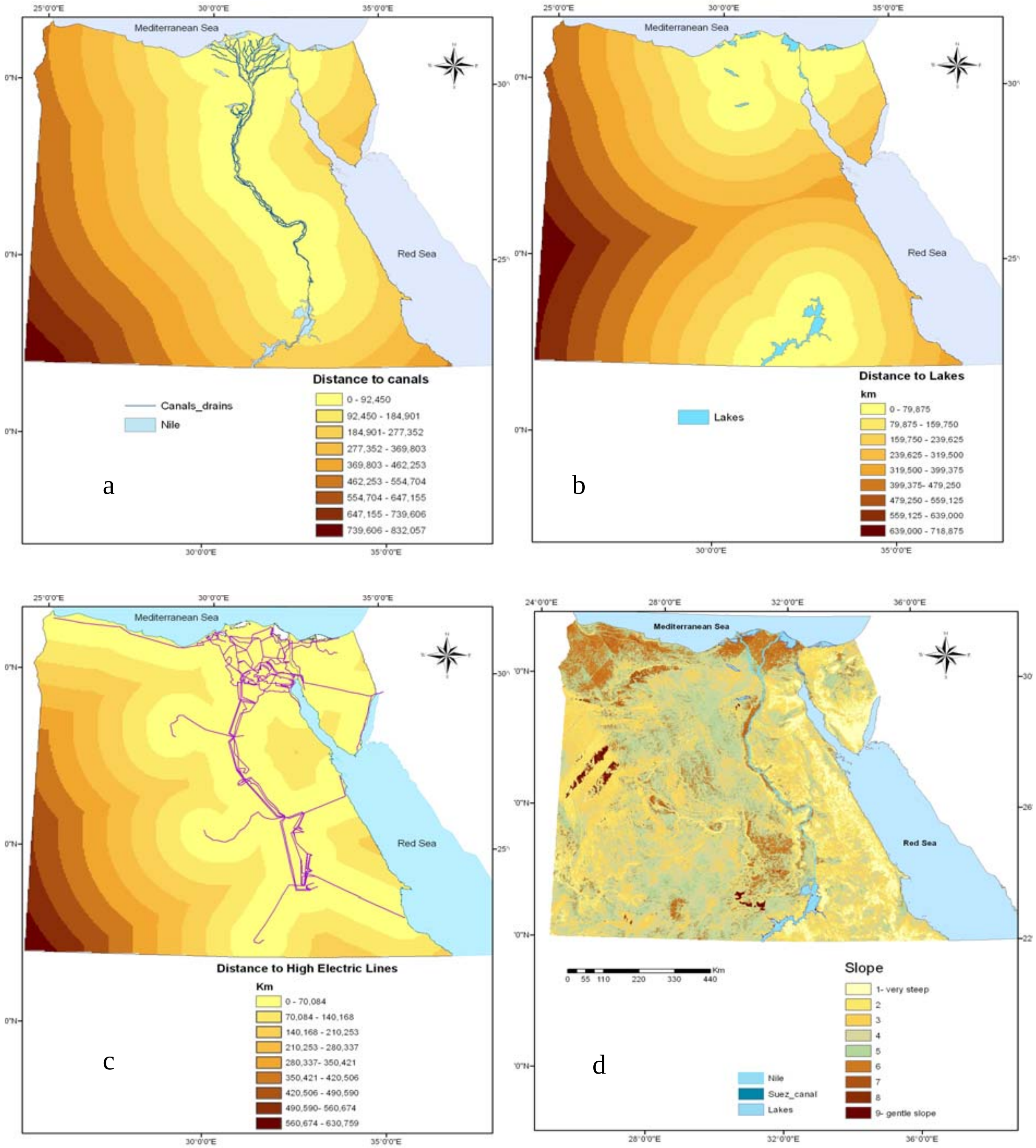

Figure (5): Factor maps: a) Distance to canals. c) Distance to Nile d) Distance to high electric lines. d) Slope angles.

The distribution of the aquifers and underground water aquifers reveal the fact that the Western Desert has extensive and highly productive aquifers zones in addition to the vicinity of the Nile Valley and zones in the middle of Sinai Peninsula (Figure 6-a). Suitable rocks for land reclamation are distributed along the fringes of the Nile Valley and Delta, Sinai and the Mediterranean Coastal zones (Figure 6-b). The precipitation map shows the maximum distributions along the Mediterranean Sea coast decreasing in amount and frequency towards the south (Figure 6-b).

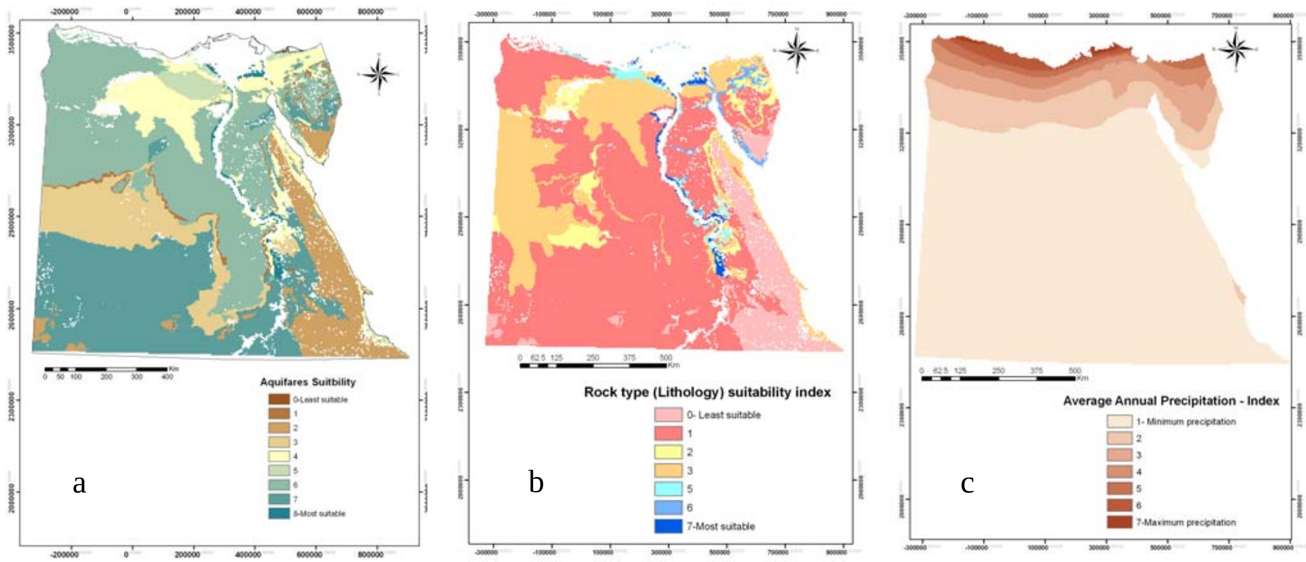

Figure 6: Standardized factor maps; a) aquifers suitability index, b) Rock type suitability index, c) annual average precipitation suitability index

Results of two different scenarios by running the model twice using the same weights but with more constraints, revealed the following:

First Scenario: Coastal Sand dunes reclamation scenario

Masking out all the identified land constraints except for the sand dunes, produced the suitable zones map for agriculture development. These zones vary in their suitability scale according to their realization of the defined set of factors. Some of the coastal sand dunes in Egypt are rain-fed and cultivated by the natives (Bedwians). The Egyptian government has proposed a new canal to extend in Northern Sinai Peninsula in parallel to the Mediterranean shoreline. Such canal is planned to use recycled and treated drainage water. Such plan is expected to consume a considerable area of the coastal sand dunes in land reclamation. Therefore the first scenario is based on such trend, and the suitability map result and potential sites are shown in Figure (7).

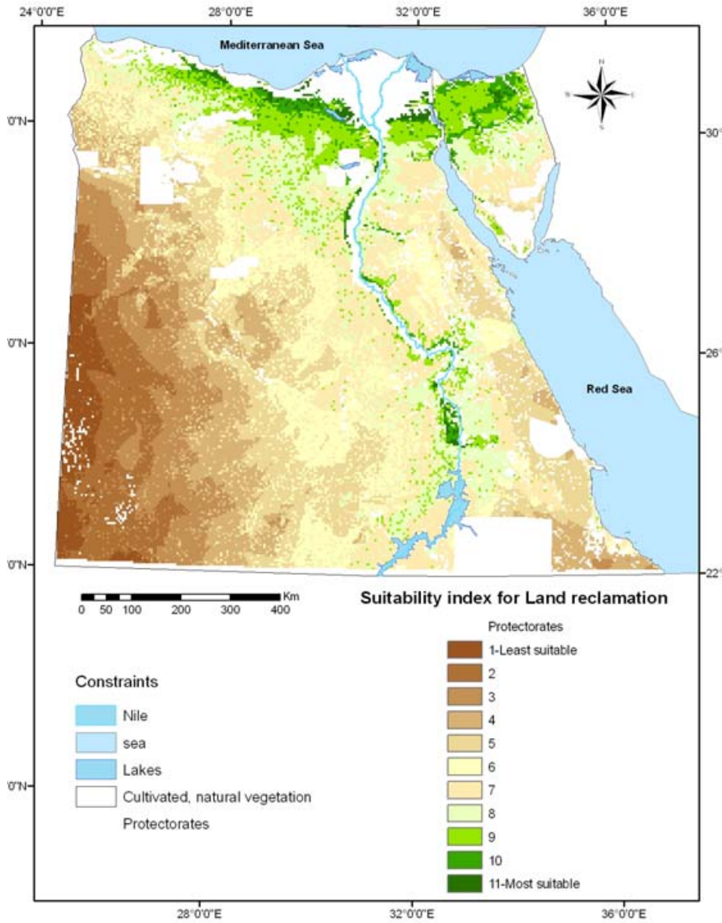

Figure (7): Composite suitability index for agricultural development for the first scenario

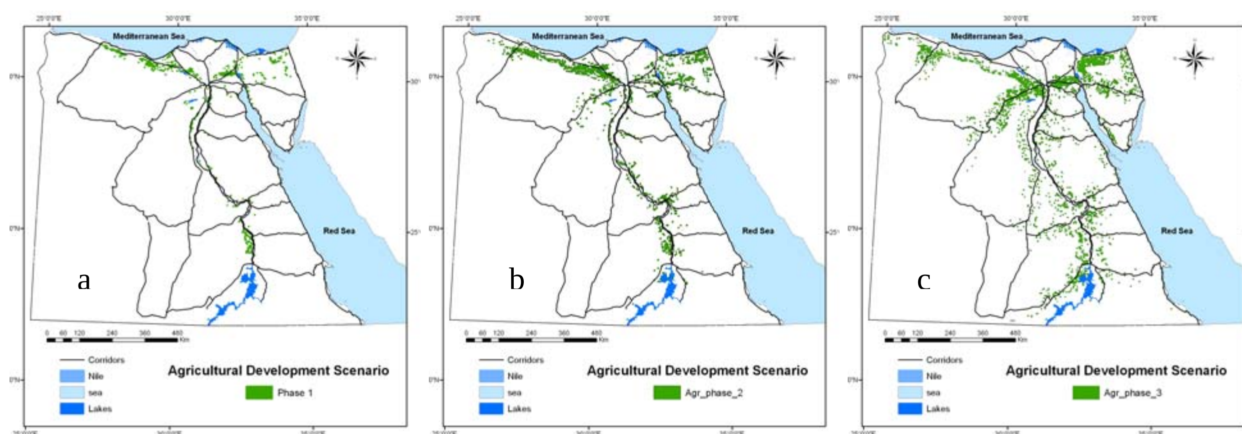

Figure (8): suitability index for agricultural development in a buffer zone 40Km around the development corridors, following the first scenario.

Second Scenario: Avoiding the sand dunes scenario

Masking out all sand dunes in addition to the constraints resulted in a different scenario. A significant zone is northern Sinai sand dunes where coastal sand dunes exist, in addition to a spatial distribution of sand dunes bodies in the Western Desert. Avoiding such feature resulted in a different scenario. Such scenario provided a slightly different vision from the first one. Fewer areas would be suitable to land reclamation and agricultural development. Most suitable zones exist in the middle parts of Sinai Peninsula, and the northern coastal zone in addition to the Nile Delta and Valley vicinity .figure (9).

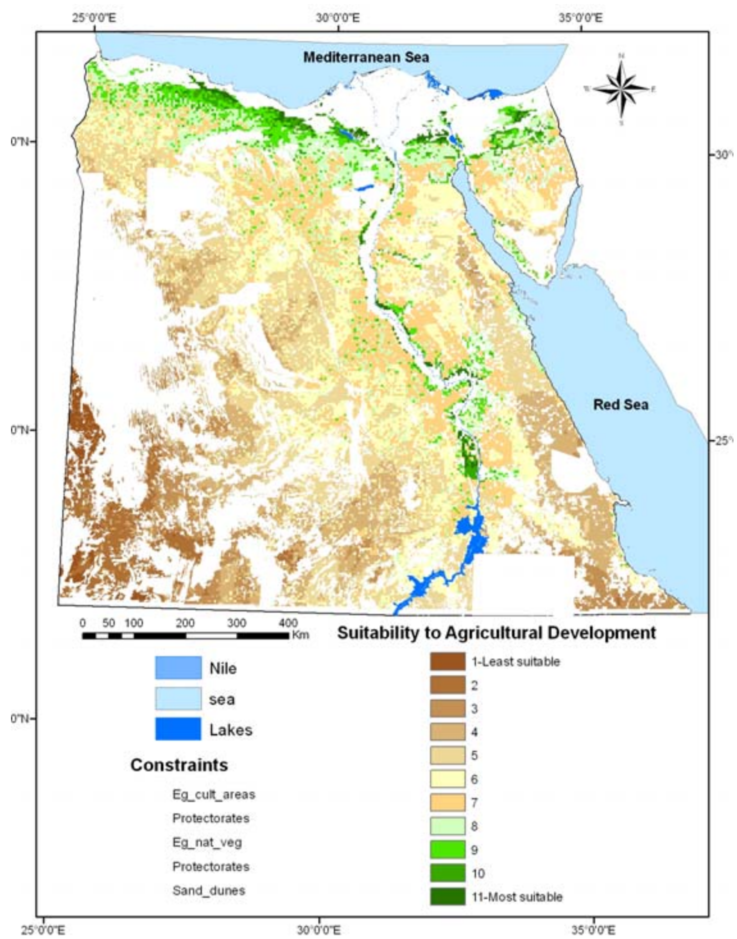

Figure (9): Composite suitability index for agricultural development for the second scenario.

In general, running either of the two model iterations resulted in the suitability index for the most favorable agricultural development zones. Highest suitability scores are found to be spatially distributed among eleven governorates. These governorates are North Sinai, Marsa Matrouh, Aswan, El Giza, El Beheira, South Sinai, El Esamilia, Suez, Beni Suief, El Menia , Qena and El Wadi El Gedid.

The index map shows the spatial distribution of the lands in a graduated scale for its suitability for cultivation. Both scenarios revealed the fact that there exists suitable lands for agricultural development around the Nile Valley and Delta extending in the Northern lands parallel to the Mediterranean Sea. Suitable lands extend in Sinai Peninsula especially in the northern coasts and mid-zones. Lowest suitability scores were found to cover the remote zones in the Western Desert Figures 6 and 7.

The proposed-phases development scenario for the corridors vicinity within a buffer zone of 40 km points out the first priority of land reclamation of the North-Western Coastal zone ,some zones around the River Nile in Aswan Governorate, Ismailia Governorate in addition to several scattered zones in North Sinai Peninsula. For phase two priorities is to be given to North Sinai, Marsa Matrouh, Aswan and Qena Governorates. For phase three Giza, Marsa Matrouh, Aswan and North Sinai Governorates possess potentials to cultivate some zones around their development corridors, areas of suitable zones in the various governorates are presented in Table (3).

Table (3): Results of the proposed three phase development scenario showing the distributions of suitable zones in areas for the various governorates.

Governorate	**Phase 1** Areas in sq km	**Phase 2** Areas in sq km	**Phase 3** Areas in sq km
Marsa Matrouh	1,952.2	3,749.2	4,905.0
El Behiera	141.4		
Ismailia	233.0		
Aswan	887.4	1,443.3	2,642.8
North Sinai	969.7	3,442.6	2,573.8
Qena		923.4	
Giza			2,402.3

4. Conclusion and Recommendation

Spatial Multi-Criteria Evaluation theory (SMCE) applied in this study provided unlimited possibilities to create scenarios based on a selected set of criteria. The methodology proved to be quite flexible and adaptable to the decision maker's alternatives. It can provide what if scenarios according to the objectives and possible alternatives. Prioritizing and emphasizing criteria is done by the assignment of relative weights. This fact makes the technique quite useful for producing several scenarios based on prioritizing certain factors according to the decision makers' objectives and views. This technique can be time and cost saving. Therefore, it is recommended to adopt the Spatial Multi Criteria Evaluation (SMCE) technique by land use decision makers. Such technique can bridge the gap to a multi-disciplinary approach for land use planners on all levels of land use planning. Applying the technique on a national scale provides indicator maps that despite the need for further assessment using detailed local analysis, it can be used as a guide for the local scale zoning plans and land use strategies. It is also recommended to conduct further detailed studies for applying this technique on the different land use planning levels.

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References:

Belka, K.M., 2005. Multicriteria Analysis and GIS application in the Selection of sustainable motorway corridor. Master's thesis submitted to Linköpings universitet Institutionen för datavetenskap. ISRN-LIU-IDA-D20--05/019—SE, 2005

Buckley, R.C., 2000. Strategic environmental assessment of policies and plans: legislation and implementation. Impact Assessment and Project Appraisal, vol. 18, No. 3, pp.183-189.

National Strategy and Action Plan for Biodiversity Conservation, 1998. *Department of Nature Conservation, National Biodiversity Unit.* **Egyptian Environmental Affairs Authority (EEAA).**

Climate Atlas of Egypt. **Egyptian Meteorological Authority**, 1996.

ESRI, ArcGIS9 Desktop Software , 2001. Help References. Working with ArcGIS Spatial Analyst. *ESRI.*

Egypt Multipurpose Land Cover Database (Africover). **Food and Agriculture Organization of the United Nations, FAO, 2000.** cited http://africover.org

Gibson, R. B., 2001. Specification of sustainability-based environmental assessment decision criteria and implications for determining "significance" in environmental assessment. Available on: http://www.sustreport.org/downloads/sustainability,EA.doc (August 8, 2005).

Grossardt, T., Bailey, K., and Brumm, J., 2001. Analytic Minimum Impedance

Surface: Geographic Information System-Based Corridor Planning Methodology. Transportation Research Record. No. 1768, pp. 224–232.

Grzybowski and Associates, 2001. Regional environmental effects assessment and strategic landuse planning in British Columbia. Report prepared for the Canadian Environmental Assessment Agency CEAA Research and Development Program. Hull, Quebec.

Jankowski, P., 1995. Integrating geographical information systems and multiple criteria decision-making methods, International Journal of Geographical Information Systems. Vol. 9, pp. 251-273.

Malczewski, G, 1999. GIS and Multicriteria Decision Analysis: John Wiley and Sons, Inc., New York.

McHarg, I. L., **1969**. Design with nature, John Wiley & Sons, London.

Noble, B.F., 2000. Strategic environmental assessment: what is it and what makes it strategic, Journal of Environmental Assessment Policy and Management, vol. 2, pp.203-224.

Research Institute for Groundwater (RIGW), 1999 National Water Research Center (NWRC). The Hydro-geological Map of Egypt. Scale 1:200,000

Sahoo, N. R., Jothimani, P. and Tripathy, G. K., 2000. Multi-criteria analysis in GIS environment for Natural Resource Development - A Case Study on Gold Exploration. Online publications cited from GIS development.net
http://www.gisdevelopment.net/magazine/gisdev/2000/may/gise.shtml

Saaty, T.L., **1977**. A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology, vol. 15, pp. 243-281

Shuttle Radar Topography Mission, (SRTM) 2000. United States Geological Survey (USGS) online free download http://seamless.usgs.gov

Voogd, H., **1983**. Multicriteria Evaluation for Urban and Regional Planning. Pion, London.

Zucca,A., Sharifi,A.M and Fabbria, A.G.,2007. Application of Spatial multicriteria analysis to site selection for a local park: a case study in the Bergamo Province, Italy. Journal of Environmental Management, doi:10.1016/j.jenvman.2007.04.026

Military Survey Department, 1995, The topographic map of Egypt, scale 1:1000,000.

Rao D., 2005. Multicriteria spatial decision analysis for forecasting urban water requirements: a case study of Dehradun city, India K.H.V. Landscape and Urban Planning 71, 163-174.