Resource and Vulnerability Assessment of Suez Governorate, Egypt for New Industrial Settlements

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Abstract. Creating new attraction poles for settlement and investment in a desert environment is quite a complex issue. Such new poles have to satisfy two main factors; the environmental safety of the location and the economic base for living. Little information is revealed about the potentials of desert zones and their environmental hazards. Therefore, the main objective of this study is to provide a decision support methodology for exploring the potentials, constraints and suitability of part of the Egyptian desert for economic development. Land suitability was studied using Multi Criteria Evaluation and Geographic Information System. Data from Shuttle Radar Topography Mission (SRTM), SPOT 4, topographic and hydro-geological maps were used to create the criterion maps. Applying three models using MCE and geographic information system resulted in identifying the most suitable zones for a potential development scenario in the study area. Vulnerability of the Governorate for possible land collapse risk was modeled resulting in a constraint map. The second model identifies zones suitable for investment in industry and future related settlements. The zoning map was overlaid with the existing development corridors and the administrative boundaries to provide guidelines for the development axis in the governorate. The model provides a suitability index for future investments in a desert environment based on its potential resources. The applied methodology can be adapted to any desert location considering the spatial distribution of its land resources and constraints. It can be an asset to urban planners and decision makers for providing the basic foundations for a zoning plan.

Keywords: environmental hazards- land suitability- Multi criteria evaluation- criterion maps- suitability index

1 Introduction

1.1 Cartographic Modeling of Land Suitability

Broadly defined, land-use suitability analysis aims to identify the most appropriate spatial pattern for future land uses according to specified requirements or preferences *(Malczewski, 2004)*. GIS-based land-use suitability analyses have been applied in a wide variety of situations, including ecological and geological approaches, suitability for agricultural activities, environmental impact assessment, site selection for facilities, and regional planning *(Malczewski, 2004; Sharifi and Retsios, 2004; Marinoni and Hoppe, 2006; Lamelas et al 2009)*. Despite the existence of a diverse range of methodologies, spatial multicriteria decision-making methods have certain aspects in common. The alternatives represent the different choices of action available to the decision maker, and multiple attributes represent the lowest level of decision criteria. Firstly, spatial constraints, which represent areas under usage restrictions, have to be identified. These restrictions are usually caused by the presence of other uses or by high value natural areas that are under protection or vulnerable lands that are subjected to a certain hazard. Such vulnerable and/or protected lands identified as constraints are not to be considered potential lands and thus, have to be excluded. Decision weights are assigned to such attributes (criterion maps), with the weights usually being normalized to add up to one *(Gilliams et al., 2005).* Criteria weights reflect the importance of each particular criterion *(Lamelas, 2007).* Normally, the criteria maps are classified into qualitative and quantitative criteria maps. Before combining the criterion maps using multi-criteria methods, the criteria maps have to be standardized to make them comparable *(Belka, 2005; Sharifi et al , 2008 and Van Herwijnen ,1999).* Finally, The standardized criteria maps are combined using a weighted arithmetic overlay function *(Carranza,2006).* Cartographic modeling was applied to the Suez Governorate case using spatial multi criteria evaluation for exploring both vulnerability and suitability of the lands to industrial development.

1.2. Description of the Study Area

The Suez Governorate is one of the governorates located in the northeastern part of Egypt between 30º 48º 20º E , 32º 49º 20 ºE and 28º 57º 00º N , 30º 18º 20º N. The governorate covers an area of 9002.21 km². The governorate is located in the Suez Canal Region and is bordered in the north by Ismailia, in the east north by north Sinai governorate, in the east by Suez gulf, and in the west by Cairo and Giza governorates with a sector of the e Suez Canal passing through its lands fig.1. It represents 0.9% of the total area of Egypt. According to the preliminary results of the 2006 census, population is 511,000 with a population growth rate amounting to 19.9 per thousand capita. The governorate is well known for its industrial potentials and resources, rich in Limestone, Dolomite, Coal and Petroleum. The main industries include petroleum exploration, cement industry, glass industry, and chemical and fabrics industry in addition to port-based activities.

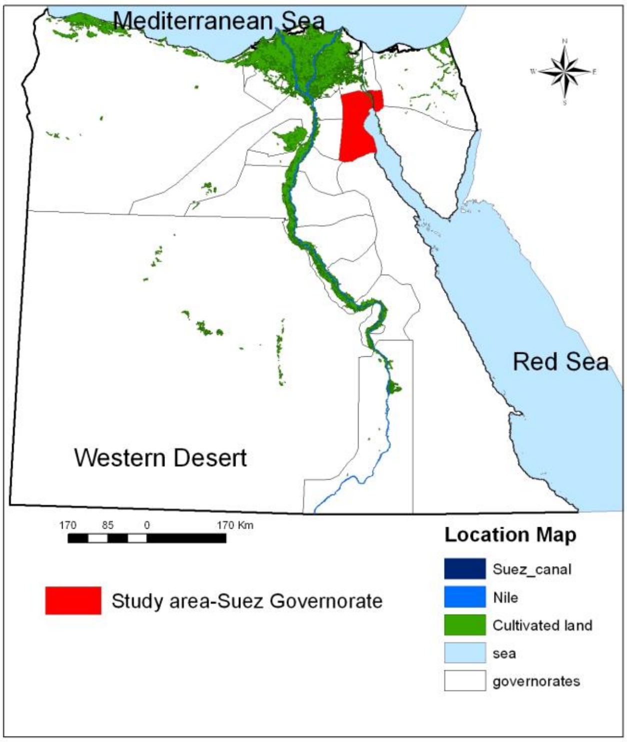

Fig.1. Location map of the study area.

2. Materials and Methods

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) 90 meters resolution was used to derive the slope, aspect, catchments areas and drainage basins. The FAO Africover land cover map produced by the FAO organization from Landsat ETM+ data was used. Geological maps *(CONOCO, 1987)* scale 1:500,000 were used for the rock type and identification. The topographic base map scale 1:50,000 Egyptian Survey Authority (ESA) was used. The datasets were all projected to the Universal Transverse Marketer UTM, WGS84.

2.1. Defining the Objectives, Indicators and decision rules

The objectives are the elements a decision maker wants to achieve. Each multi-objective decision problem has a set of objectives to achieve. To what degree an objective is achieved can be measured with a criterion. The objectives are translated into a set of criteria which is presented by a criterion maps. Objectives for selecting future industrial zones are diagramed in fig.2 and explained as follows:

- The geological safety of the location.
- The environmental protection of the agricultural, archaeological, ecological and tourism sites.
- Feasibility of the sites; in other words, the sites should have an economic resource as a base for development.

2.2. Criteria Maps for Industrial Development

Criteria are used to evaluate the alternatives by measuring the effects or impacts of the alternatives. A criterion gives an indication of how well an alternative reaches the objective. A criterion is called spatial if it needs information about locations to measure the effects of an alternative. Hence, it is possible for these effects to be visualized in map form. These criteria can be represented in the form of digital maps and stored in a GIS database as map layers. Criterion maps form an output of evaluation criteria identification phase. This follows after input of data into GIS (acquisition, reformatting, georeferencing, compiling and documenting relevant data) stored in graphical and tabular form, manipulated and analyzed to obtain desired information. *(Belka, 2005)* These map layers, the criterion maps, are the input data for spatial multi-criteria decision analysis *(Sharifi et al, 2004).* Defining the objectives was followed by identifying the set of criteria consisting of constraints and factors as shown in fig.2

2.2. Constraints

In GIS practice, constraints are defined as lands being unsuitable for changing to a specific land use and are therefore to be eliminated from the potential lands. For this study the constraints were considered for the protection of the site against land collapse, sites having environment, economic and social values. The set of constraints were identified as follows:

Vulnerable Lands (Geological Hazards Potential Sites)

The study area bordering the Red Sea is characterized by faults and potential seismic zones. Thus the geological hazards potential sites are vulnerable sites that need to be masked out from the potential sites for urban development. A land collapse vulnerability index was modeled using spatial multi criteria evaluation. The model inputs included SRTM digital elevation model, slope, streams, geological map, faults density and seismic intensity zones map (*Hegazy and Effat, 2009).* Such map was used as a land constraint.

Archaeological and Ecological Sites

Archaeological and ecological sites are potential resources for tourism development. Such sites should be protected against other land use development decisions**.** The suitability index for tourism was modeled in a Multi Criteria Evaluation. High suitability values were discriminated and excluded from the suitability index for industrial zones.

Land Cover and Land Use

Sabkha and wetlands were considered as vulnerable land cover classes and therefore as constraints to be eliminated from the site selection. Cultivated lands are legally protected. Thus the agricultural lands are considered another constraint to locating a new city.

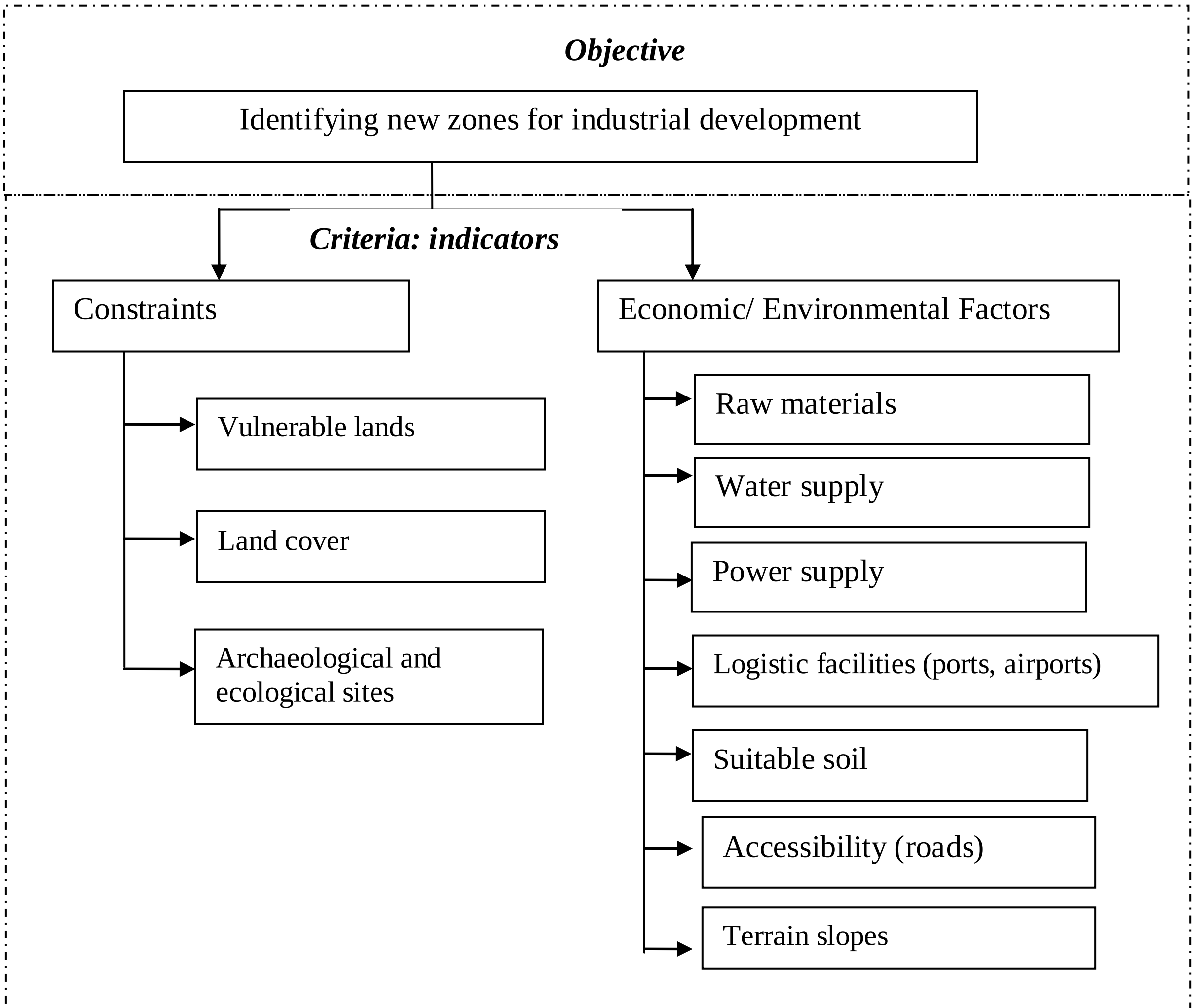

Fig.2. Objective and Criteria for identifying new industrial zones in the Suez Governorate

Factors are the potential criteria that promote a required or specific land use development and/or activities. The factors for suitability to locating new industrial zones were based on the provision of resources to provide an economic base to sustain new settlements in the desert zones. Normally, the factor maps are classified into qualitative and quantitative criteria maps. Qualitative criteria maps are, for example, soil types or vegetation types. Quantitative criteria maps are, for example, distance maps or slope maps. Before combining the factor maps using multi-criteria methods, the performance values of the criteria factor maps have to be standardized to make them comparable. Various methods to standardize the scores are available *(Belka, 2005; Sharifi et al, 2008 and Van Herwijnen ,1999).* The method to use depends on the character of the problem and the character of the attributes *(Voogd, 1983).* Thus each of the factor maps was standardized using a suitability evaluation scale ranging from 1 to 5 using ESRI ArcGIS 9.2 software**.** Attributes with least suitability get a low value in the suitability evaluation scale. The factor maps are created and standardized as follows:

Distance to Mines and Quarry Sites

Mining and quarrying are basic resources for many industrial activities. The Suez desert has some mining as well as quarry resources. A buffer zone of five kilometers was created around each mine site and a buffer zone of two kilometers was created around each quarry site. A distance map was created which divided the study area it into five distance zones. Zones in proximity to the mines and quarries were assigned the maximum suitability value of 5 while the values decrease as the distance increases to reach 1 in the farthest zones.

Surface Water Resources

The studied governorate is characterized by a desert environment. Water resources are limited except for Ismailia Canal which is a branch from River Nile. A buffer zone of 500 km was used to protect the canal from possible industrial pollution. Distance from the canal was divided into five zones with maximum suitability value of 5 in proximity to the canal buffer zone and values decreases as distance increased to reach a value of 1.

Ground Water Resources

The groundwater aquifers classes were considered a factor where extensive aquifers are favored therefore assigned a value of 5 while local and non extensive aquifers were assigned lowest suitability values of 1.

Distance to Power Supply

Distance to a power supply is an economic factor that has impacts on the allocation decisions. A distance map was created from main power supply which divided it into five distance zones. Zones in proximity to the power supply were assigned the maximum suitability value of 5 while the values decrease as the distance increases to reach 1 in the farthest zones.

Wind Energy Potential Zones

The Suez Governorate has promising potentials for wind energy. The wind speed reaches 12 knots in certain zones along the Red Sea shoreline. The wind speed map was reclassified into five wind zones where highest speed values were assigned a value of 5 which in turn decreases as wind speed decreases where it reaches 1 in zones of wind speed less than 2.5 knots.

Distance to Ports and Airports

Ports and airports are main facilities to industrial activities where raw materials and finished products can be exchanged. A distance map was created around existing airports and ports where highest suitability values of 5 are assigned to zones in proximity to such facilities with values decreasing to reach 1 in remote zones**.**

Distance to Road Network

Accessibility to a new city is a main factor to its functionality and polarization. Therefore, the proximity to main road network was considered as a factor. The study area was divided into five distance zones with highest value of 5 close to the roads buffer and lowest value of 1 as distance to roads increased.

Slope

Building and construction costs are much less on flat lands, therefore flat and gentle slopes are preferable to location of new urban areas. The slope angles was derived from SRTM digital elevation model and reclassified into a five classes where the gentle slopes assigned a maximum value of 5 and the values decrease as the slope angles increase reaching a value of 1 in steepest slopes.

Soil /Lithology

Soil classes map is considered a crucial factor when developing desert zones. For this study such factor was not available due to lack of data. It was substituted by the lithology units in order to preserve silt, clay and Wadi deposits for agricultural activities.

2.4. Applying Relative Weights to the Factor Maps

Since Objectives are not always equally important to a decision maker, different priorities have to be given to the various criteria. These priorities are indicated as the relative weights. Criterion weights are usually determined in the consultation process with decision makers (DM) which result in ratio value assigned to each criterion map. They reflect the relative preference of one criterion over another. Several methods for applying relative weights exist such as the Ranking Method; the Rating Methods and the Analytical Hierarchy Method *(Jankowski, 1995; Rapaport and Snickars, 1998; Belka, 2005 and Sharifi et al 2008).* The rank-sum method is used for this study; equation (1), due to its simplicity and transparency to the decision makers *(Malczewski, 1999; Belka, 2004).*

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

where $\mathbf{w_j}$ is the normalized weight of the criteria

n is number of criteria under consideration (k=1,2,….n)

r_j is the rank position of the criteria.

r_k is the criterion number

Table 1. Criteria and weight calculation using the rank sum method

Criteria (n)	Straight Rank (r_j)	Weight ($n - r_j + 1$)	Normalized Weight W_j (%) ($n - r_j + 1$) / SUM($n - r_k + 1$)
Mines and quarries	1	8	0.222
Surface water supply	2	7	0.194
Ground water supply	3	6	0.166
Power supply	4	5	0.138
Logistics	5	4	0.111
Lithology	6	3	0.083
Slope	7	2	0.055
Accessibility	8	1	0.027
Sum		36	1.000

2.5. Combining the Criteria Maps for suitability model

For each of the suitability model, the standardized criteria maps were combined using a weighted linear combination as shown in equation (2) **(Carranza,2006)**

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

where S¯ is the weighted average suitability score,
Wi is weight for i-th map,
and *Sij* is score for j-th class of the i-th map.
The assigned importance weight *Wi* depends on the variable significance with respect to the land suitability S¯¯ for a studied activity.
n is the number of criteria under consideration.

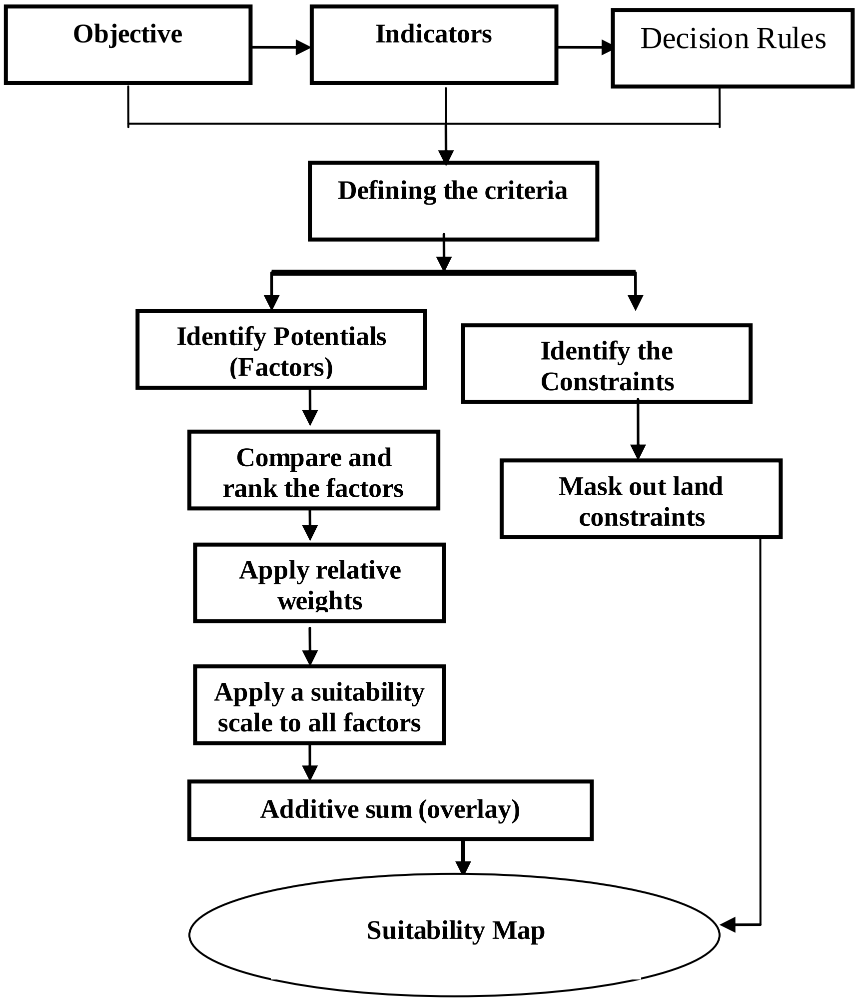

Fig.3. Conceptual flow chart for Spatial Multi Criteria Evaluation producing the suitability index

3. Results and Discussion

3.1. Vulnerability Index

The vulnerability index was produced by map overlay. Classification of the vulnerability index revealed the highest values presenting the most vulnerable zones which were extracted in a separate map. Total vulnerable areas amounted to 1,433.7 square kilometers. Such zones were found to be spatially distributed between two administrative districts namely, Ataqa and Feisal. Total vulnerable zones falling within Attaqa districts amounted to 1,172.3 square kilometers distributed among nine zones while total vulnerable zones falling in Faisal district amounted to 261.3 square kilometers. The most vulnerable zones are depicted in fig.5

3.2 Suitability index for Industrial Development

The criteria maps revealed several interesting information about the spatial distribution of potential resources in the investigated governorate. The aquifer map reveals that most of the lands have a moderately to low productivity aquifers. Such areas extend from north where in the northern lands are local and moderately to low productive aquifers while in the middle the lands are extensive and moderately to low productive aquifers. In the eastern south zone the lands are extensive and high to moderately productive aquifers fig. (4-a). Few mines exist in the Suez Governorate; such mines exist in the southern zones fig. (4-b). An extensive quarry sites exist in the investigated governorate fig. (4-c). Spatial distribution of vulnerable zones show a concentration in Fayssal and Attaqa districts. Fig. (4-d).

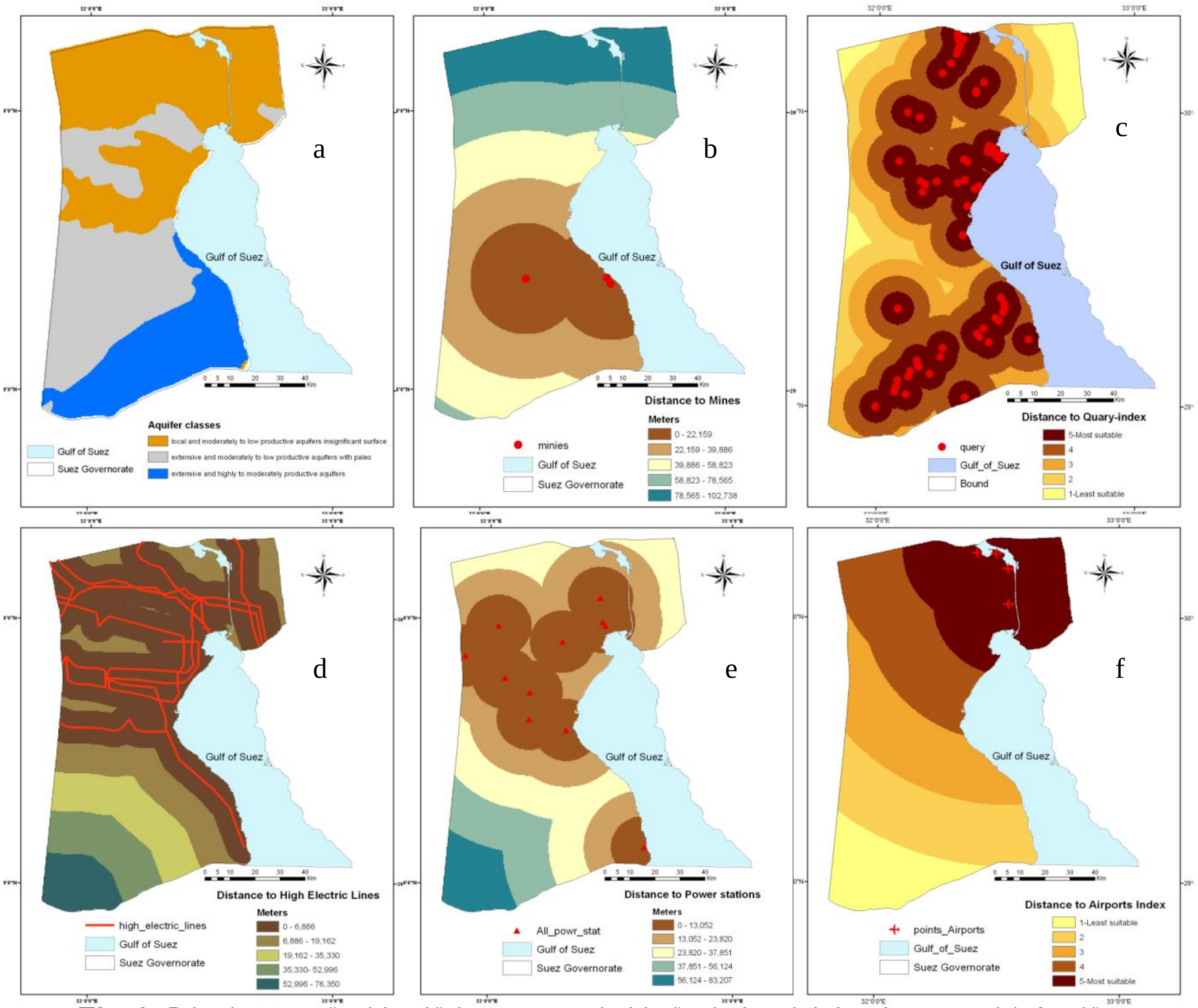

Fig. 4. Criteria maps for identifying zones suitable for industrial development. (a) Aquifer classes. (b) Distance to mines. (c) Distance to Quarries. (d) Distance to high electric lines. (e) Distance to power stations. (f) Distance to Airports.

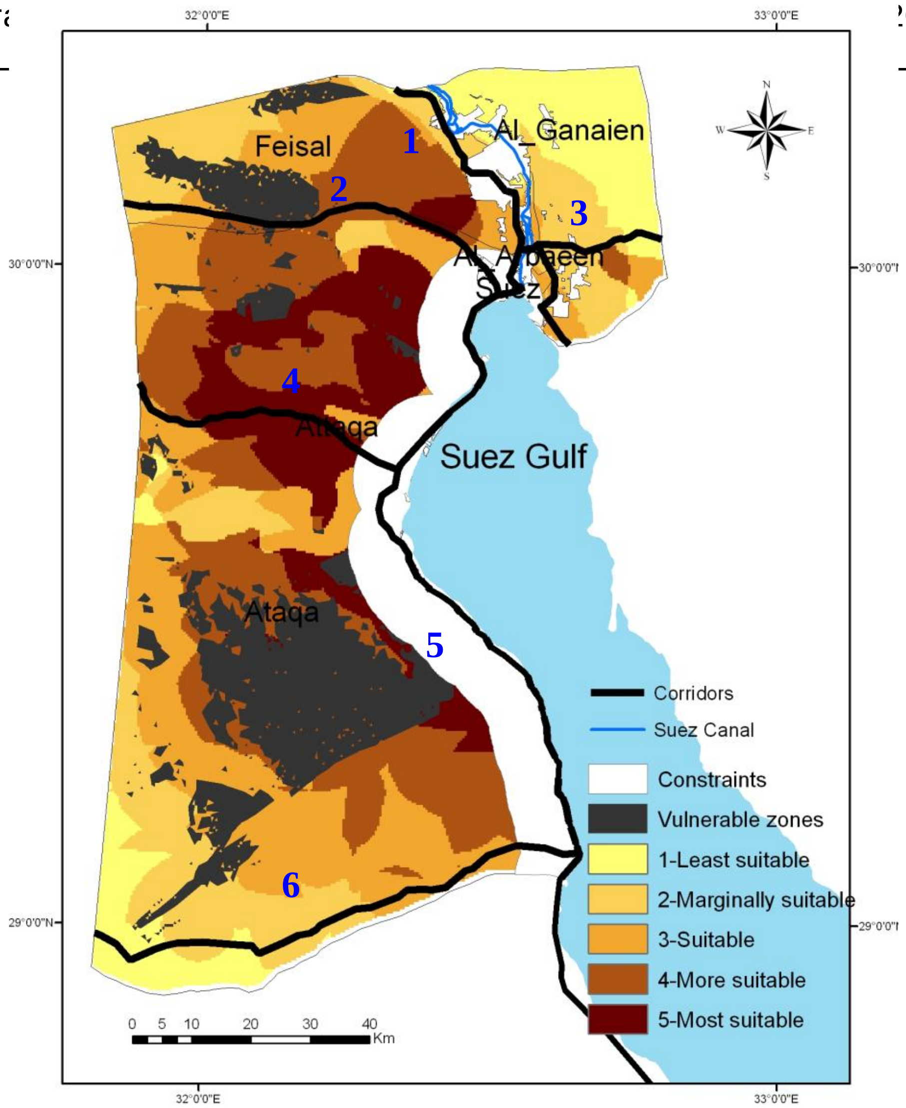

Fig.5. Most vulnerable zones and most suitable zones for industrial development overlaid with the development corridors in Suez Governorate.

1-Port Saied-Suez
2-Cairo-Suez
3-Taba-Suez
4-Giza- ElAin El Sokhna
5-Suez-Halayeb
6-Rass Zafarana-Koraymat

4. Conclusion

The highest suitability values for industrial development were found to exist in Attaqa division amounting to 1179.7 square kilometers. Such high suitability values were divided among three zones a coastal and two desert zones. Such zones are recommended for locating new settlements that are based on industrial activities fig.5 Comparing the suitability index for industrial zoning with the development corridors in Suez Governorate revealed that most zones were found to be distributed in the lands lying between Cairo-Suez and Ain Sokhna-El Giza development corridors. Such zones are considered suitable for locating industrial activities such as mining and quarrying and related industry.

5. 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, Linköping, 2005. ISRN-LIU-IDA-D20--05/019—SE.

Carranza, J. (2006). Knowledge-driven Predictive Modelling of Geo-objects: Index Overlay Method. *NUFFIC Researcher course,2006* : Innovative application of RS and GIS for female Professionals in the Earth Sciences, NARSS, Cairo, Egypt, 03/10 –16/11 2006.

Egyptian Survey Authority (ESA). *The topographic Map of Egypt, 12 scale 1:25,000*

Egyptian General Petroleum Corporation (EGPC) and CONOCO, (1987). *Geological Map Egypt. Scale 1:500000.*

Gilliams, S., Raymaekers, D., Muys, B., van Orshoven, J. (2005). Comparing multiple criteria decision methods to extend a geographical information system on afforestation. *Computers and Electronics in Agriculture 49, pp.142–158.*

Effat, H.A. and Hegazy, M.N. (2009). *Land Use Suitability Modeling for Integrated Development in Suez Governorate Using RS and GIS*. National Authority for Remote Sensing and Space Sciences, Egypt. Research 166 p.

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

Lamelas, M.T. (2007). Geo-resources and Geo-hazards in the Context of a Sustainable Development in the Periphery of Urban Areas, Exemplary of a Part of the Ebro Basin in the Surroundings of Zaragoza (Spain). PhD, *Technische Universität Darmstadt, Darmstadt. 211 p.*
http://elib.tu-darmstadt.de/diss/000794, last accessed June, 2008

Lamelas,M.T.; Hoppe, A.; De La Riva; J. Marinoni,O. (2009). Modeling environmental variables for geohazards and georesources assessment to support sustainable land-use decisions in Zaragoza (Spain). *Geomorphology (article in press). GEOMOR-02945; 16 p.*

Malczewski, J. (2004). *GIS-based land-use suitability analysis: a critical overview. Progress in Planning* , 62, 3-65.

Marinoni, O.; Hoppe, A. (2006). Using the analytic hierarchy process to support the sustainable use of geo-resources in metropolitan areas. *Journal of Systems Science and Systems Engineering 15, pp154–164.*

Rapaport, E. ; Snickars, F. (1998). Integration of environmental risk into the road location analysis: A GIS based case study to minimize environmental impacts,building costs, and travelling time.
http://stratema.sgis.net/cupum/pdf/E8.pdf , accessed in May 20, 2005.

Sharifi,A.; Retsios, V. (2004). Site selection for waste disposal through spatial multiple criteria decision analysis. *Journal of Telecommunications and Information Technology pp. 3, 11.*

Sharifi, A. ; Van Hrewijnen,M. and Van den Toorn,W. (2004). Distance Learning Course: Spatial Decision Support Systems. *International Institute for Geo-information Science and Earth Observation (ITC), The Netherlands.*

Sharifi, A.; Boerboom ,L. and Zucc,A. Distance Education Course on Spatial Decision Support Systems. *International Institute for Geo-information Science and Earth Observation (ITC), The Netherlands, accessed in 2008.*

Shuttle Radar Topography Mission (2000).*Unites States Geographical Survey 3, USGS* http://seamless.usgs.gov

Van Herwijnen M. (1999). Spatial Decision Support for Environmental Management. *Institute for Environmental Studies in Amsterdam (IVM*). *Elinkwijk bv, ISBN: 90-9012449-7*

Voogd, H. (1983). *Multicriteria evaluation for urban and regional planning, Pion, London.*