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Suitability Assessment for New Minia City, Egypt: A GIS Approach to Engineering Geology

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ABSTRACT

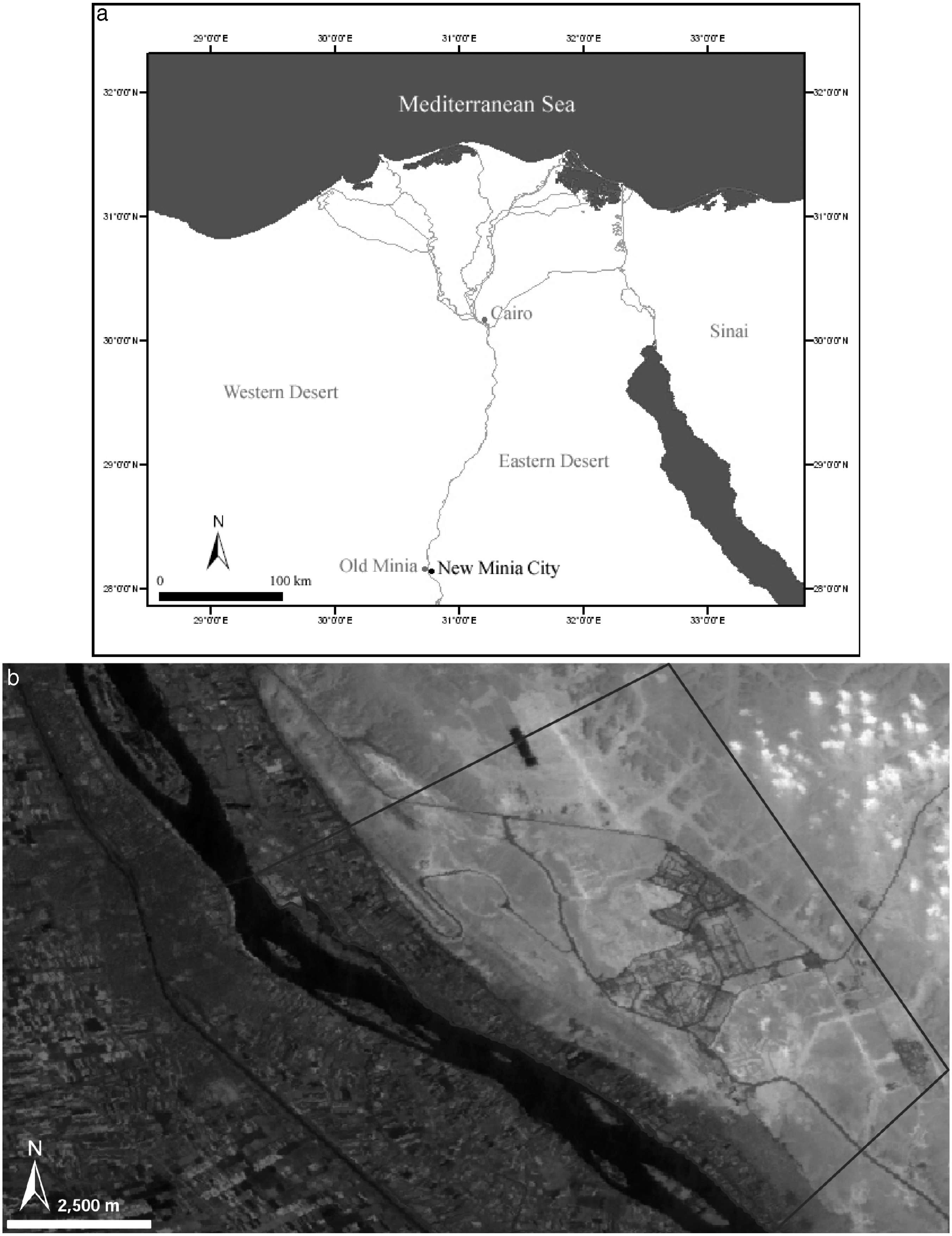
Urban development is a high priority in Egypt. New Minia City, located on the eastern bank of the Nile River, approximately 250 km south of Cairo, is one of 16 new development communities. Urban development in New Minia City may encounter several geo-environmental problems. Karst conditions and structural features in the local heterogeneous bedrock limit its suitability for constructional purposes. In this research, suitability of the area for urban development was assessed using a geographic information systems (GIS)-based approach. A weighted GIS model that incorporated land use/cover, types of soil, karst feature distribution, fracture densities, slopes, distances to major faults and streams, road network, and city boundaries was established to create a map of site suitability for the city. Model weights were developed using the analytical hierarchy process (AHP) approach. Current urban land use within New Minia City falls into four classes of suitability. Approximately 7 percent of the area built by 2002 is in the low suitability class, which suggests that the map of site suitability can serve as a reliable base for planning sustainable development in New Minia City. The developed map of site suitability is effective for assessing and revealing ratings of suitability for urban development. Furthermore, the map of suitability provides the foundation for informed decision making in the development of New Minia City.

INTRODUCTION

For the past 20 years, the Government of Egypt has encouraged the construction of new cities in the desert areas outside the Nile River Valley and its delta. The Nile River Valley has been the focus of the majority of the population concentration of Egypt over millennia. Currently, this region is home to 96 percent of the population of Egypt (Aly, 1997). New cities are being constructed to relieve population pressure on the environment and natural resources of the Nile River Valley and its delta. The original planning concept called for these new communities to be strategically situated and established to accommodate a housing shortage, which is approaching one million units, and also to curtail building construction in the Nile River Valley area (Aly, 1997; Aly et al., 2002). Additionally, locations of these cities were intended to minimize the impact of urban development on current agricultural reclamation in the desert. Whereas the consideration given to the social and infrastructure planning is noteworthy, little consideration was given to the geologic environment and potential geologic hazards.

In some of these new cities in Egypt, potential problems in engineering geology related to the bedrock suitability for urbanization were not thoroughly investigated before construction. Because of various structural problems that have developed, remedial investigations and repairs to mitigate the problems have been necessary in several cases. This study provides useful information that can be used to minimize the effects of geologic hazards threatening urban development in New Minia City.

New Minia City is one of 16 new cities in a program of community development that has been initiated over the last 20 years. New Minia City (Figure 1a and b) is located in close proximity to Old Minia City, but outside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the Nile River Valley. The location allows the physical and social infrastructure of Old Minia City to be used. The city location maximizes the availability of potable water and other necessities, but minimizes the occupation of fertile agricultural land. The bedrock underlying New Minia City is a heterogeneous karstified limestone with weakened bearing capacity caused by the presence of a large number of faults, joints, and fractures (Aly, 1997). Urban development and expansion of New Minia City, however, face several potential engineering geology problems. More specifically, properties of the heterogeneous bedrock make some areas of the city unsuitable for common urban development. Structural setting and karst features significantly reduce the bearing capacity of the bedrock in some areas. Consequently, construction on these areas can result in uncontrollable subsidence with concomitant cracking and collapsing of the engineered structures.

The geologic hazard presented by the bedrock in New Minia City creates a multi-criteria problem. A geographic information system (GIS) has the capacity to model and analyze various types of spatial data and provide options to assess site suitability of multi-criteria nature for developmental purposes. Vitek and Giardino (1993) provide a good overview and perspective of the evolution of hazard mapping and future directions with GIS, artificial intelligence, modeling, and immersive technology.

There are two common approaches for multi-criteria evaluation: the concordance–discordance analysis and the weighted linear combination (Voogd, 1983; Carver, 1991; and Eastman et al., 1995). In the concordance–discordance approach, each pair of alternatives is analyzed for the degree that one outranks the other on specific criteria. However, this is computationally impractical in cases of a massive raster dataset, where every pixel is an alternative. In the weighted linear combination approach, each selected factor is multiplied by a designated weight and then summed to arrive at a final suitability index. The later approach is suitable for solving multi-criteria problems using a raster geodatabase. Several approaches can be used for deriving the factor weights. The analytical hierarchy process (AHP) approach has been used in this study because it has been found to be the most appropriate method for the derivation of the factor weights, which is the major concern within the context of multi-criteria decision support systems.

PROBLEM STATEMENT AND STUDY APPROACH

The identification of areas within a city that may be hazardous is fundamental to any planning project. Because the suitability assessment for the location of New Minia City was not done properly and because the city is still in the early stages of development, a site suitability assessment for urban development in the city is a pressing need. The results of this study can assist in identifying areas most suitable for urban expansion and, thus, can minimize risks and costs associated with construction on areas with potential problems.

This paper presents an approach using a GIS in integration with the AHP to accomplish a site suitability assessment for urban expansion in New Minia City. This assessment will delineate areas with characteristics that indicate bedrock instabilities that are susceptible to foundation failure.

STUDY AREA

New Minia City, located approximately 250 km south of Cairo, has an incorporated area of approximately 35 km^2 (Figure 1a and b). It is situated 10 km east of Old Minia City and is outside the Nile River Valley and its agricultural fields. The city is constructed on a plateau, 100–160 m above sea level and approximately 20 m above the level of the Nile River. Access to New Minia City is provided by a wide bridge over the Nile River.

The predominant land use/cover types within New Minia City include urbanized areas in the center of the city, barren land, and a narrow strip of agricultural land parallel to the Nile River. Soil types include argillaceous sands, calcareous sands, and alluvium deposits, with thicknesses ranging from a few centimeters to a few meters in some locations (Aly, 1997).

The geology, primarily Middle Eocene rocks, mainly consists of carbonates and is structurally controlled by normal faults with a NW-SE major trend. The surface expression of some of these faults, typically trending N35°W direction, can be traced for approximately 10 km. In addition to major faults, a large number of minor faults and joints are present. The majority of these minor structural features are NW-SE oriented; however, some faults have a NE-SW trend. These faults have not been active during the Holocene (Aly, 1997).

The morphology of the area includes flood plains, scarp faces, a limestone plateau, stream valleys, and karst landforms. Chemical weathering of the carbonate bedrock in post–Middle Eocene time resulted in various karst features. Sinkholes are the most predominant karst feature occurring in the foundation bedrock of New Minia City. Caves and underground drainage systems also underlie the city. The sinkholes have diameters ranging from 0.5–10 m, and most of the sinkholes are

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Figure 1. (a) Location map of New Minia City; (b) New Minia City as seen by ASTER (04/30/2002). Bands 7, 3, and 2 are assigned to red, green, and blue, respectively.

Table 1. *Standardized potential scores (the higher the score, the better the suitability).*

	Potential Ratings				
Factors	0	1	2	3	4
Karst distributions	Large caves and/or sinkholes	High karstification zone	Moderate karstification zone	Low karstification zone	No karst features
Distances to major faults (m)	<100	100–300	300–400	400–500	>500
Distances to major streams (m)	<100	100–200	200–300	300–500	>500
Fracture densities (no./km^2)	>30	20–30	15–20	10–15	<10
Slopes (%)	>20	15–20	10–15	5–10	<5
Soil types	Argillaceous sands	—	Calcareous sands and alluvium deposits	—	Compact bedrock (carbonate rocks)

filled with Egyptian alabaster and clay (Aly, 1997). The arid environment minimizes dissolution and, thus, processes associated with karst development are not active at the present. However, the addition of weight in the form of foundations may affect the stability of the bedrock and may cause building collapses.

The climate of the study area is arid. Temperatures range from approximately 5°C in the winter months to approximately 40°C during the summer. In Southern Egypt, where New Minia City is located, several years may pass without any significant rain. Precipitation is minimal, with the majority of precipitation occurring in the winter for short periods of brief but heavy rainfall. The mean annual rainfall is approximately 15 mm/year (Aly, 1997).

Depth to the saturated zone is not considered a major hazard affecting urban development in the city. Borehole observations give no indication of a saturated zone lying within 40 m from Earth's surface (Aly, 1997). There is a small chance that a fluctuating level of saturation may cause new karst features to be formed or inactive faults to be rejuvenated in the shallow subsurface.

INTEGRATION OF GIS AND AHP FOR SUITABILITY ASSESSMENT

In GIS modeling, multiple analytical approaches can be established to evaluate various scenarios of site suitability. These approaches enable alternative developmental strategies to be examined and compared before making final decisions or commitments (Albrecht, 1996).

GIS has been widely used in assessing geologic hazards and site selection as well as geo-environmental evaluation. Carrara and others (1991) used GIS techniques and statistical models in evaluating landslide hazards; Wang and Unwin (1992) modeled landslide distribution on loess soils in China; Gunawan and others (1992) developed a method to combine geomorphic mapping and engineering properties using a GIS to evaluate natural hazards; Atkinson and Massari (1998) developed a generalized linear model of susceptibility to landsliding in the Central Apennines, Italy; Guzman and others (1995) mapped Environmental Units (EU) using a GIS; and Mejia-Navarro and Garcia (1996) assessed natural hazard and risk using decision support systems. Zhang and Giardino (1992) combined GIS and artificial intelligence to create a system to automate the evaluation of sites and the selection process; Carver (1991) integrated multi-criteria evaluation with GIS; Irigaray and others (1994) assessed the site selection for urban waste disposal in the Granada District, Spain, using a combined GIS geotechnical and environmental approach; and Dai and others (2001) evaluated geo-environmental problems for urban land use planning using GIS.

To assess site suitability for New Minia City, a GIS-based approach was developed to model the geologic hazards affecting urban development. The GIS model incorporates thematic information derived from existing maps and satellite images as well as detailed geologic and geomorphologic field maps. Maps depicting land use/cover types, types of soil, karst feature distribution, fracture densities, slope angles, and distances to major faults and major streams were combined using a multi-criteria analysis to produce a hierarchical rating of site suitability for urban development in New Minia City. The resulting map categorizes the city into different levels of suitability for urban development.

A GIS and an AHP are integrated in this study to establish a weighted GIS model for the assessment of site suitability for New Minia City. The effects of the selected factors (Table 1) on site suitability differ greatly. For this research, we define a factor as some property of the surface or subsurface in New Minia City that enhances or detracts from the suitability for urban development (Eastman et al., 1995). In constructing a site map of weighted suitability, a set of relative weights for

Table 2. *Scale for comparisons.*

1	Equal importance
3	Moderate prevalence of one over another
5	Strong or essential prevalence
7	Very strong or demonstrated prevalence
9	Extremely high prevalence
2, 4, 6, 8	Intermediate values
Reciprocals	For inverse comparison

From Saaty and Vargas, 1991.

influential factors was established. The AHP approach is used in this study for establishing the factor weights.

AHP is a multi-objective, multi-criteria, decision-making approach introduced by Saaty (1977). In AHP, a series of pairwise comparisons between each of the factors used in the modeling is developed to create a scaled set of preferences that describe the importance of each factor relative to every other factor (Saaty and Vargas, 1991; Saaty, 2003). AHP has gained a wide usage in regional planning (e.g., Jankowski, 1989), in site selection and suitability assessment (e.g., Banai-Kashani, 1989; Carver, 1991; and Bantayan and Bishop, 1998), and in the evaluation of geographical hazards (e.g., Dai et al., 2001).

AHP attempts to solve complex and unstructured problems by breaking the problem down into a set of component factors. Once the relevant factors are identified, in the current case surface and subsurface properties, hierarchical relationships based on the respective importance are identified and quantified through the assignment of numerical scores. These values are based on subjective determination by the investigator of the relative importance of each factor (Saaty and Vargas, 1991; Saaty, 2003).

The relative ranking of the importance of each factor is accomplished through the construction of a pairwise comparison matrix. Each cell of the matrix represents the rating of one factor against another. Because the matrix is symmetric, one-half of the matrix contains all possible pairwise comparisons, and the remaining cells are simply the reciprocals of these comparisons. If the row factor is relatively more important than the column factor, the matrix cell value varies between 1 and 9, depending on how much more relatively important the row factor is perceived to be. Conversely, if the column factor is perceived to be relatively more important, a reciprocal value ranging between 1/2 and 1/9 is considered. The comparison scale, developed by Saaty and Vargas (1991), is shown in Table 2. The main diagonal of the matrix is always equal to unity. Table 3 shows the constructed pairwise comparison matrix of the selected six factors considered to affect urban development in New Minia City.

The principal eigenvector of the pairwise comparison matrix is then computed to produce a best-fit set of weights. The eigenvector corresponding to the largest eigenvalue of the AHP matrix has been demonstrated to provide the correct relative priorities of the selected factors, i.e., if a factor is preferred to another, then its eigenvector component is larger than that of the other (Saaty and Vargas, 1991; Saaty, 2003). Because the components of the eigenvector sum to unity, the developed weights reflect the relative importance of the various factors involved in the pairwise comparison matrix, and they are used to create the final map of site suitability. In creating the required inputs for AHP, GIS modeling techniques were used that included a set of interacting, systematic, and ordered analytical operations on raw data and derived intermediate datasets (Figure 2).

METHODOLOGY

Factor Selection and Creation of the Factor Maps

Multiple cartographic themes, representing the pertinent geologic, geomorphic, physiographic, and cultural characteristics of the landscape of New Minia City that affect site suitability for urbanization, were created from existing maps and remotely sensed images as well as from field studies. Six geologic/geomorphologic factors were considered the most important in assessing suitability of the study site for construction and, thus, were selected for the analysis. These factors include karst feature distribution, distances to major faults, distances to major streams, fracture densities, slope angles, and types of soil. The selection of factors and values of relative importance that are assigned to each factor are de-

Table 3. *Relative weighting of factors.*

	Karst Distributions	Distances to Major Faults	Distances to Major Streams	Fracture Densities	Slopes	Soil Types	Weights
Karst distributions	1	—	—	—	—	—	0.4243
Distances to major faults	1/5	1	—	—	—	—	0.1399
Distances to major streams	1/5	1/2	1	—	—	—	0.1175
Fracture densities	1/2	3	2	1	—	—	0.2548
Slopes	1/9	1/7	1/7	1/9	1	—	0.0223
Types of soil	1/8	1/5	1/5	1/8	1/4	1	0.0412
Consistency ratio: 0.08							

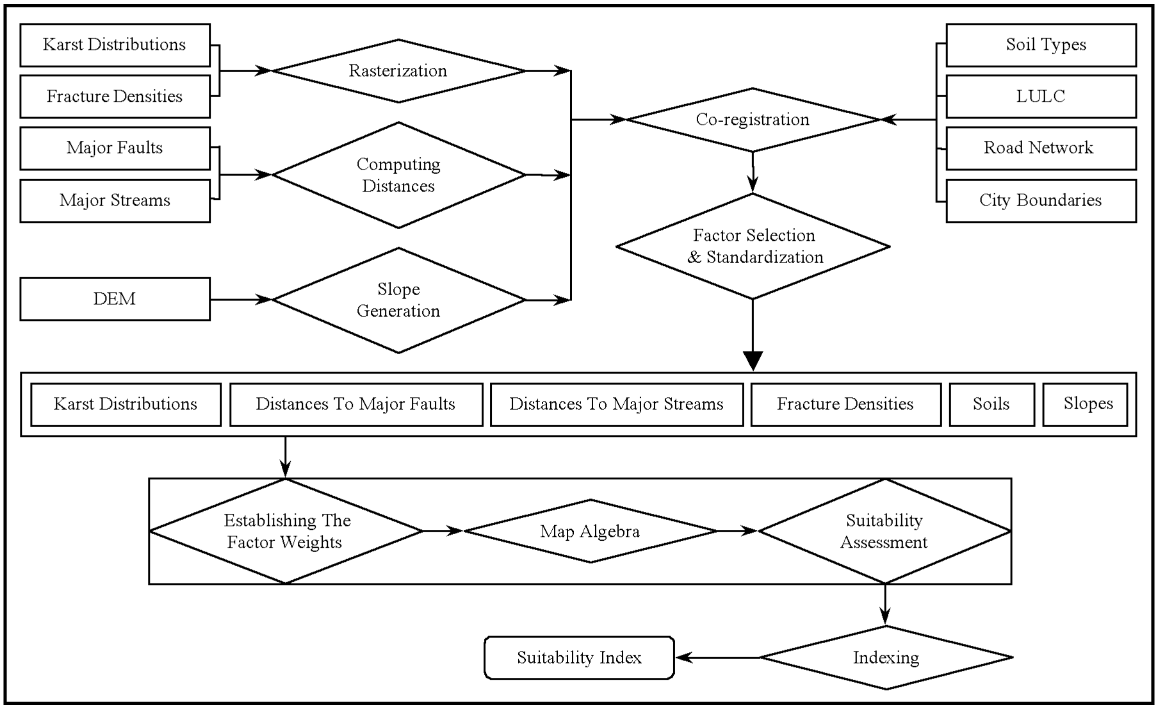

Figure 2. Modeling methodology developed for the assessment of site suitability.

termined based on *a priori* knowledge of the local geology and geomorphology.

Maps, showing the karst feature distribution, fracture densities, and stream orders, were scanned and added to the database as raster-based GIS themes. Surface and subsurface distribution of karst phenomena were obtained from previous studies conducted by the Egyptian Nuclear Materials Authority (1990). Fracture densities and stream orders in the city were mapped by Aly (1997) from a 1:50,000 aerial photographic mosaic. Whereas larger scale maps would have been better for the analysis, 1:50,000 scale maps were the best available scale for the study area.

Digital maps of major faults and streams as well as the road network of New Minia City were created through screen digitizing using an enhanced ASTER (advanced spaceborne thermal emission and reflection radiometer) image of 15-m spatial resolution as a base map. The distances to major faults and streams were then computed. Safety was a major concern in selection of the various factors. Therefore, the distances to major faults were considered because the bearing capacity and compressibility characteristics of the bedrock close to the major faults may not meet the safety demands for supporting various types of construction. The distances to major streams are also considered an important factor in ensuring safety during and after constructions.

Layers for city boundaries and slopes were also used in the spatial analysis. The administrative boundaries of New Minia City were derived from a 1:50,000 topographic map prepared by the Egyptian General Survey Authority (1991). A digital elevation model of 15-m spatial resolution was constructed from the acquired ASTER scene (04/30/2002), and a slope map was generated from the developed digital elevation model.

In Egypt, preservation of agricultural land has the highest priority in planning scenarios. Therefore, in a study of urban site suitability, agricultural areas need to be identified and excluded from the final suitability map of urban development. For this reason, a land use/cover map that was generated by Aly (1997) from a supervised classification of a Landsat Thematic Mapper image (08/02/1995) of 30-m spatial resolution was used to exclude the agricultural areas. The supervised classification results were verified through field observations by Aly (1997). The supervised classification technique was also used to generate a map of soils from the Landsat Thematic Mapper image.

All thematic maps were then co-registered to a common coordinate system (UTM [universal transverse mercator] Zone: 36N; Datum: WGS1984) to enable the subsequent spatial analysis. These efforts resulted in the creation of a set of co-registered raster layers with a common spatial resolution of 15 m that served as inputs to the GIS model.

Factor Standardization and Development of the Factor Weights

To ensure that the created factor maps retained the range of values of the original scores of suitability, the scores for all inputs had to be standardized to uniform ratings of suitability. The assigned values of suitability acted as thresholds for each factor in the decision rule process. For consistency and ease in modeling, a positive correlation between the value awarded and suitability was used in this research. Integer numbers, ranging from 0 to 4, were assigned to very low, low, medium, high, and very high suitability classes, respectively (Table 1) to standardize all selected factors.

Various statistical and empirical guidelines from the related national codes for urbanization in Egypt and field observations were used to determine the boundary values for the various factor maps concerning the site suitability for urban expansion in New Minia City. The determination of class boundary values for karst feature distributions, fracture densities, slopes, and soils takes into account the suitability ratings for urban development and the effect of each class on the safety demands for the engineered structures as defined by the national codes. The distances to major faults and streams account for potential runoff and instability consequences.

Once the raster GIS themes of the six selected factors were standardized, factor weights for determining the suitability of urban development were created. The cumulative effect of the factors determines the suitability ratings. After assigning suitability classes to the six selected factors, an AHP pairwise comparison matrix was constructed based on *a priori* knowledge of local geological and environmental conditions in the study area. The weights for the six standardized factors from the constructed pairwise comparison matrix are shown in Table 3.

Assessment of the Pairwise Comparison Consistency

Because the pairwise comparison matrix was established through subjective assignments of relative weights, a need existed to assess the degree of consistency with which the weights were assigned. Saaty (1977) introduced a procedure by which an index of consistency, known as a consistency ratio (CR), can be produced (Table 3). The *CR* indicates the probability that the matrix judgments were randomly generated (Saaty, 1977). As was demonstrated by Saaty and Vargas (1991), it can be expressed as the following:

$$CR = CI/RI, \tag{1}$$

where *RI* is the average of the resulting consistency index depending on the order of the matrix given by Saaty (1977), and *CI* is the consistency index and can be expressed as follows:

$$CI = (\lambda_{\max} - n)/(n - 1), \tag{2}$$

where $\lambda_{\max}$ is the largest or principal eigenvalue of the matrix and is calculated from the matrix, and n is the order of the matrix.

A consistency ratio of the order of 0.10 or less is considered a reasonable level of consistency. Matrices with a $CR > 0.10$ should be reevaluated (Saaty, 1977). In this study, the *CR* of the matrix of paired comparisons between the six influential factors in the suitability assessment is 0.08 (Table 3). The pairwise matrix, thus, appears to have sufficient internal consistency to be considered acceptable.

Assessment of Site Suitability

The most relevant procedure for multi-criteria evaluation is the weighted linear combination (Voogd, 1983). In a weighted linear combination, factors are combined by applying a weight to each, followed by a summation of the results to yield a map of suitability (Eastman et al., 1995) as the following:

$$S = \sum W_i X_i, \tag{3}$$

where S is the suitability, W_i is the weight of factor i, and X_i is the potential rating of factor i.

An underlying assumption in this study has been that agricultural land must be preserved; thus, agricultural areas were excluded from the analysis. This step was accomplished by creating a Boolean map with agricultural areas coded as zero and non-agricultural areas coded as one. In cases where Boolean constraints apply, the previous procedure is modified by multiplying the suitability calculated from the factors by the product of the constraints (Eastman et al., 1995) as the following:

$$S = \sum W_i X_i * \prod C_j, \tag{4}$$

where C_j is the potential score of constraint j, and $\prod$ is the product operator.

Once the factor maps were developed and relative weights were computed, each factor map (each raster cell within each map) was multiplied by its weight as determined from the principal eigenvector. The site suitability map was produced as the sum of these weighted factor maps using Eq. 3. Because the factor weights sum to unity, the range of values in the site suitability map matches those in the standardized input factor maps. The agricultural Boolean map generated from the land use/cover map acted as a constraint for the site suitability; consequently, the produced suitability map had to be multiplied by the constraint map according to Eq. 4 to eliminate agricultural areas.

For the final map of suitability, an equal interval classification was used in which site suitability was assigned to one of five categories (very low, low,

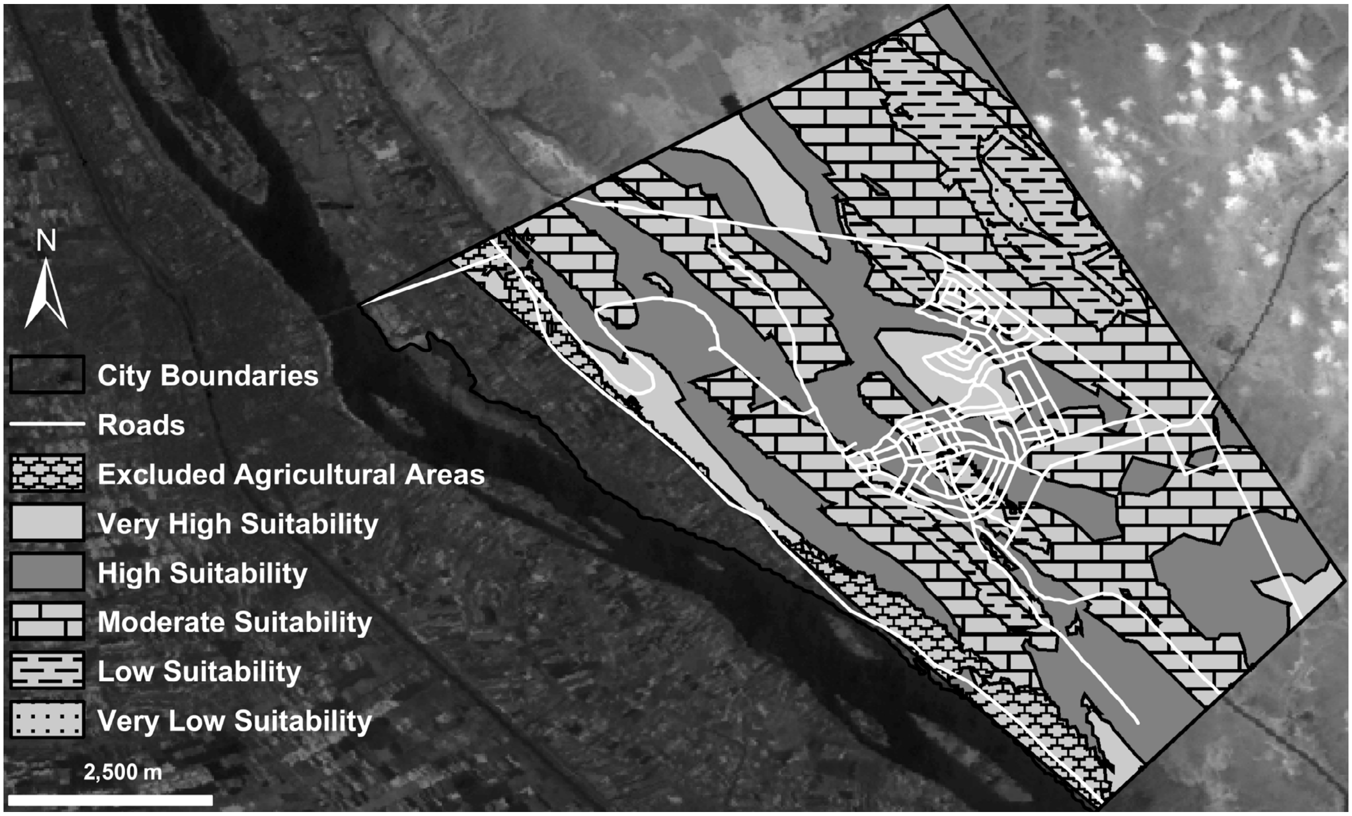

Figure 3. Ratings of site suitability for New Minia City.

moderate, high, and very high suitability) using the same range of suitability values used in the input maps (Figure 3). The resulting ratings of suitability were indexed with the road network and city boundaries to produce the final map of suitability.

RESULTS AND DISCUSSIONS

The map of site suitability for New Minia City (Figure 3) reveals differences in suitability range across the city. In general, areas of similar suitability tend to be elongate and to have the same trend (N35°W) as of the dominant karst and structural features present in the city. The suitability ratings appear to be primarily controlled by the factors of karst feature distribution and fracture densities. These two major factors were assigned the two highest importance ratings, as explained in the methodology section.

Analysis of the map of site suitability suggests that most of the land designated for New Minia City is suitable for urban development. As can be seen in Figures 3 and 4, approximately 45 percent of the area of the city is highly suitable for urban development. If one extends the boundary to moderately suitable areas, the total area of the city suitable for urban development increases the fraction to >87 percent of the total area. Thus, it appears that the New Minia City location is suitable for urban development. Areas of very low and low suitability are concentrated in the northeastern and southwestern portions of the city. These areas represent approximately 12 percent of the total area of the city. Approximately 42 percent of the area is identified as moderately suitable. These areas are discontinuously distributed in the central part and are concentrated in the eastern and western portions of the city. Areas of high and very high suitability are primarily concentrated in the central part and in northwestern and southeastern portions of the study area. These areas represent approximately 36 percent and approximately 9 percent, respectively, of the total area of the city. Based on examination of the map of suitability, we suggest that the central, northwestern, and southeastern parts of the region should be given the first priority for urban development in New Minia City.

Although the development of New Minia City is already underway, the developed areas were also investigated. If this investigation identifies urban development over unsuitable areas, the obtained maps from this study can raise awareness of potential hazards in such areas. Thus, we restate the question: is urban development occurring over suitable areas? To address this question, an urban land use map was created from

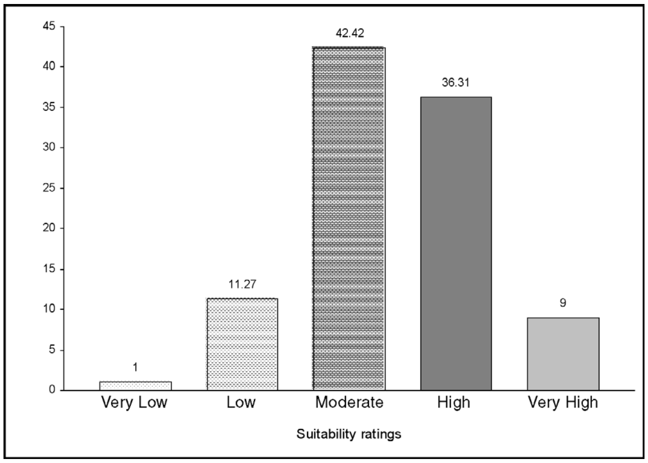

Figure 4. Site suitability ratings in New Minia City shown as percentages.

a supervised classification of the ASTER image acquired on April 30, 2002, using Band2 VNIR (visible/near-infrared) (0.66 µm, 15 m), Band3N VNIR (0.81 µm, 15 m), Band3B VNIR (0.80 µm, 15 m), and Band4 SWIR (shortwave infrared) (1.66 µm, 30 m). Current urban land use (Figure 5) within New Minia City falls in four suitability classes. Approximately 7 percent of all areas urbanized by 2002 are in the low class of suitability, which suggests that the map of site suitability can serve as a good base for planning sustainable development in New Minia City.

Integration of GIS and AHP allowed us to develop a weighted GIS model to assess site suitability for New Minia City. The GIS modeling procedure incorporated field investigations, information derived from photographic mosaics, and satellite digital data, including Landsat Thematic Mapper and ASTER scenes. Surface and subsurface information obtained from previous studies were also analyzed and used in this assessment of suitability. The AHP approach is effectively used in this study to develop rational weights for factors that affect suitability according to the respective importance for suitability of the site for urban development. Using AHP, high weights were assigned to factors of karst feature distribution and fractures densities because they are considered the major problems in New Minia City; however, a low weight was assigned to the slope factor because New Minia City is built on a relatively flat surface.

This research demonstrates the potential of GIS-based assessment for site suitability in an urban area. The reliability of the assessment depends on a multitude of factors ranging from the quality of the established database to the potential errors that may be associated

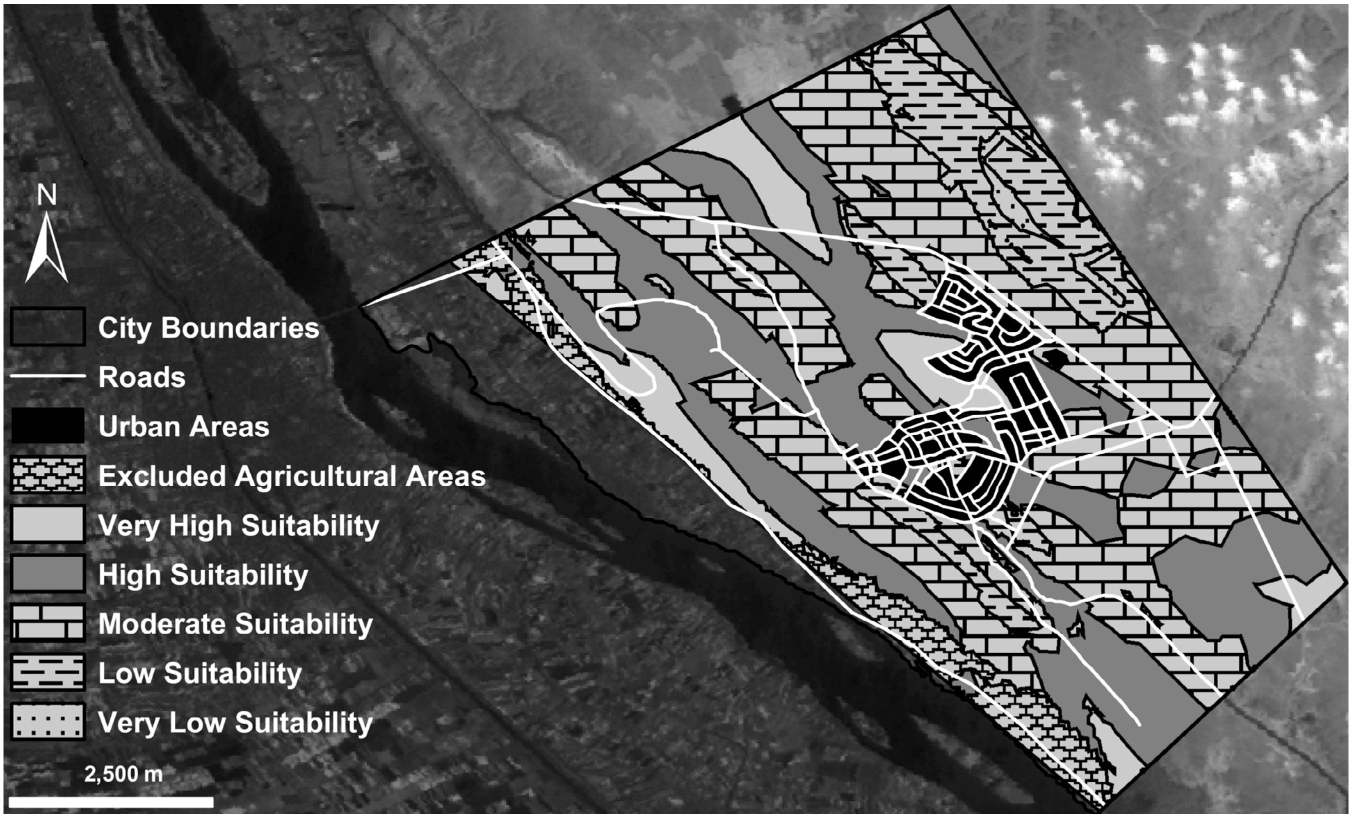

Figure 5. Ratings of site suitability overlain by urban land use generated from a supervised classification of the ASTER image (04/30).

with data input and analysis. Thus, the resulting database included only reliable information related to specifically selected factors that were considered most important in determining site suitability within New Minia City. In addition, input data, analysis procedures, and outputs were checked for potential errors at various stages of the GIS modeling. The modeling results are highly sensitive to the weights applied and altering the weights assigned to the various factors will have significant effects on the final results. Therefore, *a priori* knowledge of the local geology and geomorphology of the study area was effectively used to rationalize and justify the weights that were applied.

CONCLUSIONS

Accurate information and perfect data are rarely available, leading to a kind of uncertainty in building a geodatabase. This, in turn, affects the accuracy of the criteria assessment. To accommodate the propagation of uncertainty through the established geodatabase, input data should be of suitable spatial resolution for the analysis, factors should be selected carefully, and the manner in which the selected factors are combined and analyzed should be suitable for the desired objectives.

A GIS-based assessment of site suitability can help identify optimal areas for development and promoting preservation of environmentally sensitive or hazardous areas. The map of site suitability obtained from this study can provide decision makers with useful information to determine the general trends and spatial distribution of classes of suitability for urban development in New Minia City. For assessment of site suitability, GIS can manage a large number of spatially related data and integrate multiple layers of surface and subsurface information to extract new, useful information.

The AHP approach was used to create appropriate weights for the different factors affecting the suitability of the site for urban development. The technique enables detailed field observations and *a priori* knowledge to be systematically considered when assigning the relative importance of the factors in the model.

The established GIS model provides a basis for informed decision making to support integrated sustainable development in New Minia City. The GIS model was applied locally to assess site suitability for urban development in New Minia City; however, the developed approach integrating GIS and AHP can be adapted and used to assess suitability of any other site wherever multi-criteria decision making is needed.

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