Developing a GIS to Assess the Ecological Characteristics of El-Daba'a Region, Egypt

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Abstract

Egypt faces formidable population and environment-related challenges. Its population accounts for one-third of the population in the Arab region (324 million at 2006). It is a country of high population growth. It almost tripled between 1952 and 2006, from 25 million to more than 74.9 million in 2006. This population - with 1.87% natural increase rates - expected to be 170 million inhabitants at 2050. Egyptian decision makers will face tremendous problems related to satisfying the people needs especially in water and energy sectors.

The most important problem is the shortage of energy resources. To treat this problem, Egyptian Government plans to establish a series of nuclear power stations. El-Daba'a region – in the western north coast of Egypt - is a top list candidate to be the site of the first Egyptian nuclear power station.

This paper illustrates the methodology and results of studying the ecological characteristics of El-Daba'a region using different spatial data including maps and Landsat remote sensing data. These data were used to create a series of GIS maps that describe the ecological spatial characteristics (the spatial ecological characteristics) of the study area. These GIS maps are composed of superimposed layers of geographic data embedded in a geographic information system (GIS). This GIS allows decision makers to handle large amounts of information simultaneously such as geological, geomorphologic, land cover, wild life and many other different information layers.

This GIS was designed to help the decision makers to organize, relate, analyze, and visualize the ecological data and information in the study area. It might be used to determine the probable effects of building a nuclear unit on ecosystem.

Key Words: GIS – Ecological Spatial Characteristics – Sustainable Development - El Daba'a

1 Introduction

Egypt is the most populated country in Arabian League, with approximately 74.9 million inhabitants which is about one-third Arabian League total population. This population - with 1.87% natural increase rates is expected to be 170 million inhabitants in the next four decades. More than 80% of Egypt land is classified as deserted area occupied by less than 5% of population, where 20% are occupied by 95% of population (CAPMAS, 2006).

Since the first economic reform in the end of 1970, Egypt attempts to redraw the population distribution map by establishing many new settlements and support the industrial development. This trend has kept through the second economic reform in the mid 1990s. By the eve of the new millennium, the urbanization has extended to include different Egyptian frontiers such as Toshka region and Northwestern Coast. This wide development creates new demands for power energy.

For decades the power energy system in Egypt depended on the High Dam energy and the energy generated by a large network of thermal power stations. Different alternatives are proposed to extend the capabilities of the power energy system. These alternatives are designed to be sustainable, economic and eco-friendly. Alternatives like wind power, tide power, nuclear power and sun power are studied. Based on these studies the nuclear power is chosen as a best alternative (SCE, 2000).

Egyptian Nuclear Power Research Program is the oldest peaceful nuclear research program in the Middle East. It was established in 1959 to create national experience in the field of nuclear power generation. Since 1970, the program researchers identify the site of El Daba'a as the most feasible site for establishing a nuclear power station to generate power and supply Alexandria Metropolitan and the Northwestern coast by energy. This reason has kept El Daba'a Area out of the urbanization that waved the Northwestern coast since 1990th which has kept El Daba'a area as a complete model for the Northwestern coast ecosystems which have destructed - or at least deteriorated - in Northwestern coast as a result for the wild urbanization.

The problem that this paper attempts to handle is double faces. The first face is the national demands for the power that assure the establishing a nuclear power station in El Daba’a area; the second face is the national demand to keep a model ecosystem like El Daba’a area for the next generations. ***Simple paradox, how to develop and to conserve in the same time, that is the problem what it handled here***.

Ecological assessment based upon spatial data analysis can provide an efficient and cost-effective approach for acquiring up to date and accurate habitat level information (Prato, 2005), (Gontier et. al, 2006) and (Gontier, 2007) for use by resource planners, researchers, and conservationists. Spatial tools like GIS and remote sensing have been used to map ecological characteristics in various sites and objectives (Zandbergen, 1998), (Geneletti, 2004), (Roy, et al., 2005), (Stefanov & Netzband, 2005), (Yue, et al., 2006), (Bertazzon, et al., 2006), (Barbour, et al., 2007), (Wimberly & Reilly, 2007), and (Williams, 2007) including the Northwestern coast of Egypt (Mohammed, et al., 2000), (Raey, et al., 2005), and (Raey & Mohammed, 2006).

GIS merges topographic maps, thematic maps, remote sensing data, field survey data, and census to provide a comprehensive geospatial database that managed by a set of powerful analytical tools to identify the spatial and quantitative relations between ecological elements and socioeconomic circumstances.

This paper aims to assess the ecological characteristics using GIS of El Daba’a in a framework of research efforts to create an environmental management plan for this area, attempts to represent a framework to keep the development and ecological conservation together in the same way. The assessment objectives intended for (1) identifying the local species geographic distribution, (2) mapping the natural habitats of these species, and (3) identifying (recognize) the spatial properties of these habitats.

2 Study Area

The study area; El Daba'a area as shown in **Figure (1)** is located in Matrouh Governorate in the Northwestern coast region of Egypt, approximately far from Alexandria Metropolitan 160 km and from Marsa Matrouh city the capital of Matrouh Governorate. It extends from 28^{o} 21´33´E to 28^{o} 35´11´E and from 30^{o} 58´50´N to 31^{o} 5´22 N, about 21.5 km length and 11.8 km width occupying an area approximately 254 km^2.

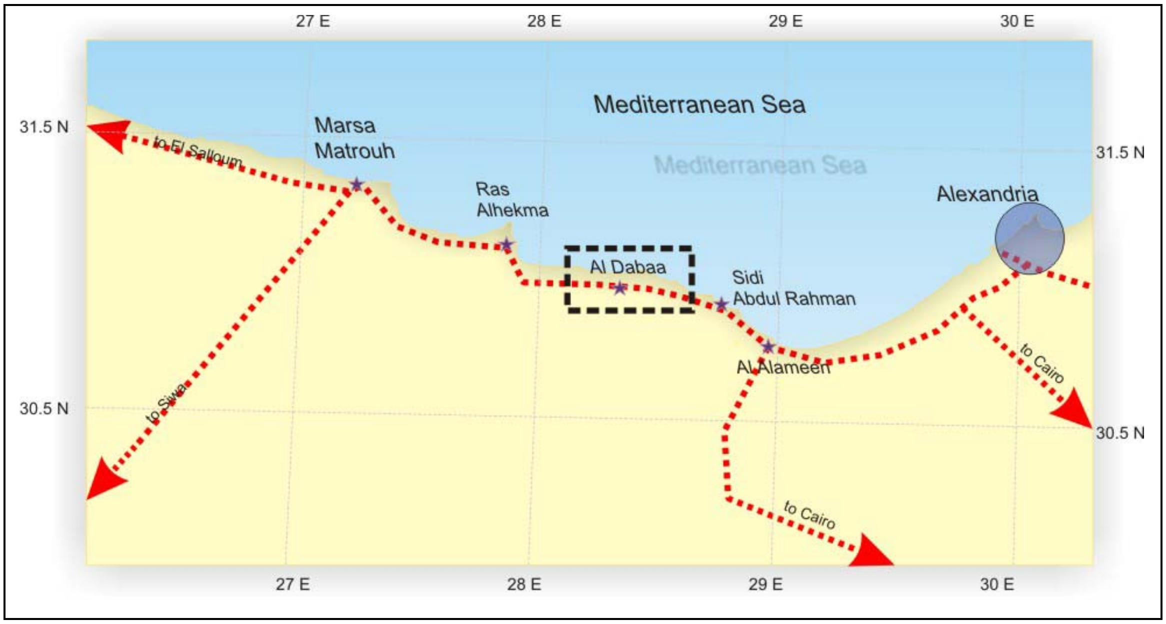

Figure (1): Location map of the study area

Mediterranean Sea is the northern border of the study area while the southern border is Matrouh Plateau. Figure (2) displays the map of the study area. The basic man made features in the study area is the "International Coastal Highway" and the "railway". The International Coastal highway divides the area into two divisions. The first division in the northward of the highway where the basic land use is the agriculture, and the second division southward of the highway where the main land uses are the urban, agriculture and grazing respectively. El Daba'a Town is the main settlement in the study area and it was in the southward of the highway. Different tiny villages are scattered in the area in between the International Coastal Highway and the railway. These scattered settlements belong to "El Daba'a Town Municipality". Population of El Daba'a Municipality is approximately 12000 inhabitants at 2006 (IDSC, 2007). Most of this population is resident in El Daba'a Town, while the little scattered villages are resident by the Bedouin.

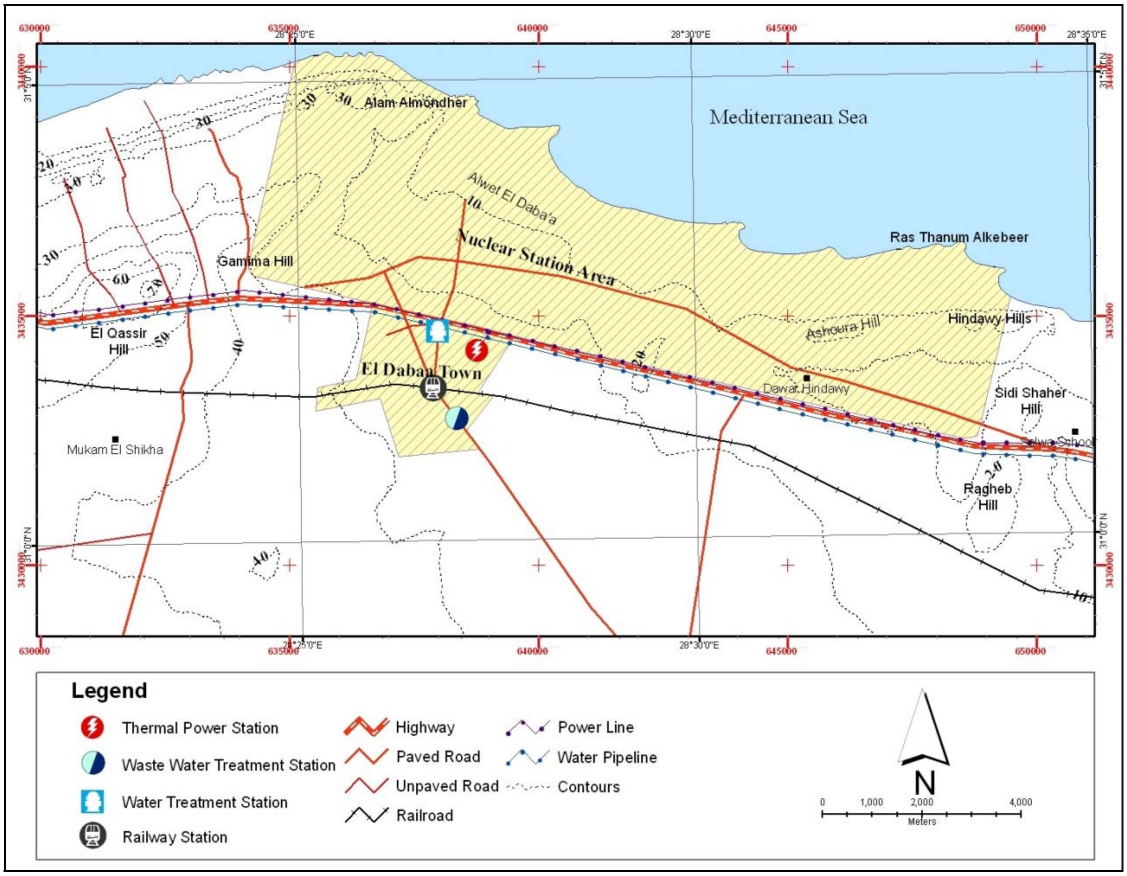

Figure (2): Study area map

El Daba'a has a climate that is hot-dry in summer and rainy-warm in winter. It is affected with the contrary wind from the Mediterranean Sea in winter, and the northern wind coming from Europe in summer. Dust storms arise periodically in spring and autumn from the south west. The yearly average temperature is 21°C, the precipitation is almost 138 mm and the humidity is 67% (NRC, 1987).

Exactly four ecological habitats are noticed in the study area. These habitats are wadies, gravel plains, sand dunes and wetland (Kassas, 1993). These habitats are dominated by *Thymelaea hirsute* (Zahran & Willis, 1992). These habitats support a wide range of animal life. Distinctive birds include the Barbary Partridge *Alectoris barbara*, Dupont's Lark *Eremophila bilopha*, and Red-rumped Wheatear *Oenanth moesta* (Goodman *et. al.*, 1989). Characteristic mammals include the Long-eard Hedgehog *Hemiechinus auritus*, Cape Hare *Lepus capensis*, Anderson's Gerbil *Gerbillus andersoni*, Shaw's Jird *Meriones shawi*, Fat Sand Rat *Psammomys absus*, Lesser Molerat *Spalax leucdon*, Middle Eastern Dormouse *Eliomys melanurus*, Greater Egyptian Jerboa *Jaculus orientalis*, and Four-toed Jerboa *Allactaga tetradactyla* (Hoath, 2003). Reptiles include Moorish Gecko *Tarentola mauritanica*, Northern Elegant Gecko *Stenodactylus mauritanica*, Changeable Agama *Trapelus mutabilis*, and Small-spotted Lizard *Mesalina guttulata* (Baha El Din, 2006).

3 Data Available

3.1 Species Data

The data about species sighting sites are collected by Matrouh Resource Facility administrated by Environmental Affairs Authority. These data describes 28 sites for 10 species sighting. These species are five mammals (*Gerbillus andersoni, Lepus capensis, Psammomys absus, Jaculus orientalis,* and *Hemiechinus auritus*), two birds (*Alectoris Barbar* and *Eremophila bilopha*), and three reptiles (*Tarentola mauritanica, Stenodactylus mauritanica,* and *Mesalina guttulata*). Each site is identified by its geographic location where this location is accompanied by the species classification, English common name, scientific name, and local Arabic name.

3.2 Spatial Data

Spatial data include the maps and satellite images that are used to develop the geodatabase. Actually two topographic maps are used to create most of base map features such as power line, railroads, and roads. These two maps are titled El Daba'a and Ras Abu Kharouf, produced by Military Survey Unit at 1996. Both are scaled to 1:50000 and projected to Universal Transverse Mercator *UTM* – Zone No. 35N with World Geodetic System *WGS* datum for 1984.

Satellite image produced by Landsat 7 Enhanced Thematic Mapper *ETM* Sensor located in path No. 178 and row No. 39 on Worldwide Reference System *WRF* is used in this study. The image dated 4 September 2002. The image is rectified to UTM 35N / WGS 84 by provider. The image includes six bands of 28.5 m spatial resolution and single panchromatic band of 14.25 m spatial resolution. Two bands – which are the thermal bands 61 and 62 - are removed from the image, whatever these two bands are not important for the analysis scheme used in this study.

3.3 Field Survey

Three expeditions through the period of December 2004 to July 2006 were made to the study area. The objectives of these three expeditions are to collect the ground truth data for satellite image processing and to collect data to develop map for natural habitats.

4 Methodology

The methodology used in this paper attempts to combine the pervious data into one geodatabase to get the aforementioned objective of the study. In this context, work of this study can present in two phases: (i) geodatabase development and (ii) GIS analysis.

Phase I includes different activities which are producing of base map shows the principal features such as roads by digitizing the topographic maps. These features are updated using the panchromatic Landsat 7 ETM band data. The contour lines and highs spots in the topographic maps used to produce Digital Elevation Model (DEM) which is used to create another terrain features maps like slope and aspect. The species data are drawn with its attributes. Also, the image processing activities are used to produce land cover map from Landsat 7 ETM multispectral bands. These products are stored in ArcGIS/ArcInfo personal geodatabase format, where spatial relationships are established to understand the relation between species and habitats.

Phase II includes analysis of the spatial data using proximity analysis to conclude the counter-area for the different species and zonal statistics to identify the spatial properties for habitats and counter-areas.

4.1 Geodatabase Schema

ArcGIS/ArcInfo 9.x Personal Geodatabase Schema is used to store the data produced in the phase I. the schema of this geodatabase is shown in **Table (1)**.

Table (1): Geodatabase Schema

Dataset	**Data Class**	**Geometry**	**Attributes**
Base	Basemap	Polygon	Type – Area – Length
	LandOwnership	Polygon	Title– Area - Length
	Mask	Polygon	MaskID– Area - Length
	Landmark	Point	Title
Ecology	Fauna	Point	Species – SightingDate
	Natural_ Habitats	Polygon	Title – Area - Length
Facilities	Facilities	Point	Title
	Waterwell	Point	Title – Type
	Powerline	Line	Title – Length
	Waterpipeline	Line	Title – Length
Topography	ElevationPoints	Point	Elevation
	Contours	Line	Elevation
Transportation	RailStation	Point	Title
	Roads	Line	Title – Type – Length
Hypsography	DEM	Raster	Elevation
	ASPECT	Raster	Aspect in Degree
	SLOPE	Raster	Slope in percentage
	HLSHD	Raster	Hill shade
	EnhancETM	Raster	Enhanced satellite image.

As shown in this table, the geodatabase includes six feature datasets. The first feature dataset is BASE feature dataset which includes the principal feature classes that defined the study area. These feature classes are: BASEMAP feature class which is polygon geometry define the terrestrial and marine areas, LANDMARK feature class which is point geometry identify the location of main land marks, LANDOWNERSHIP feature class which is polygon feature to map the authority of El Daba'a Town and El Daba'a Nuclear Power Station, and MASK feature class which is a polygon geometry identify the area of interest for raster analysis processes.

The second feature dataset is ECOLOGY. This feature dataset include two feature classes FAUNA and NATURAL_HABITAT. FAUNA is point geometry to describe the sighting sites of species. NATURAL_HABITAT is polygon geometry feature class identifies the natural habitats area. There is also a spatial relationship which named FAUNA_HABITAT. This spatial relationship defines N-M relationship between FAUNA feature class and NATURAL_HABITAT feature class to show what is the habitat of an identified species sighting site and *vice versa*.

The third feature dataset is FACILITIES dataset which includes four feature classes: FACILITIES feature class is point geometry shows some main facilities such as water stations and waste water treatment stations, POWERLINE and WATERPIPELINE are line geometry shows the main power line and water pipe line in the study area respectively, and

WATERWELL which is point geometry for artesian and non-artesian water wells in the study area.

The fourth feature dataset is Topography dataset which include a line geometry feature class called CONTOURS to represent the contour lines from the topographic maps and point geometry feature class called ELEVATIONPOINTS to store the height spots in the study area.

The fifth feature dataset is transportation feature dataset which is include two feature classes; point geometry feature class called RAILSTATION to show the rail stations in the study area and ROADS feature class which is line feature store the roads and railroad data in the study area.

Adding to these feature datasets; there are four raster dataset to represent the hypsographical features which are the digital elevation model DEM, aspects ASPECTS, slope in percentage SLOPE_P, the hill shades HLSHAD, and the final enhancement Landsat 7 image. Also, an annotation feature class is stored in the geodatabase to present the map label.

5 Geodatabase Development

Geodatabase development for ecological assessment of the study includes different activities. These activities are described here after.

5.1 Data Vectorization

The topographic maps described before were used to extract different features. To conduct this activity, these maps are scanned and vectorized using ArcScan extension for ArcGIS/ArcInfo 9.x software. The products of vectorization are edited to remove scanning and vectorization error then stored in the geodatabase. This stored data is updated by comparing it to the satellite data in field.

Data vectorization includes also converting the descriptive data for species sighting sites to point geometry feature class and producing habitat map from field survey.

5.2 Terrain Feature Mapping

The contour lines which is vectorized before, is converted to point geometry and merged to height spots to produce one feature class. This feature class is fed to Inverse Distance Weight (IDW*)* interpolation algorithm to produce digital elevation model (DEM) for the study area. This DEM is used to conclude the other terrain features like aspect, slope and hill shades. The digital elevation model is shown in **Figure (3**).

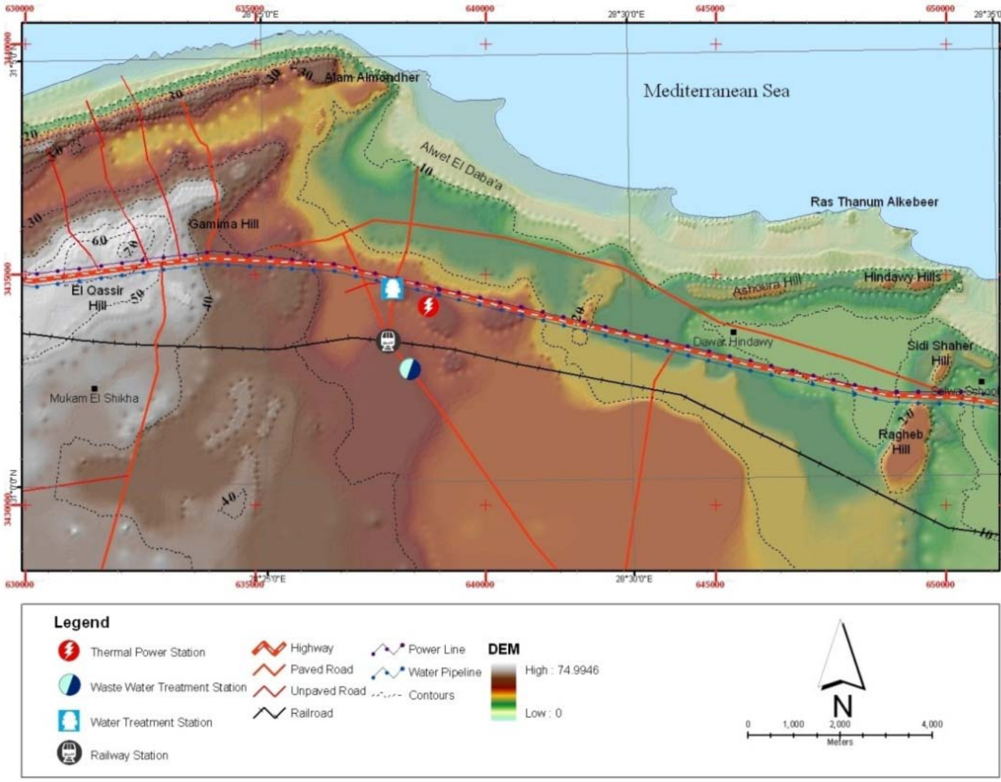

Figure (3): Digital Elevation Model for the Study Area

5.3 Land Cover Mapping

Image processing of Landsat 7 ETM data produced the land cover map in two sub-activities. The first activity is data enrichment and the second activity is data classification. Image processing was achieved using Erdas Imagine 9.0 software.

5.3.1 Data Enrichment

Data enrichment is a technique to enhance the spatial resolution of satellite imagery by merging it to high resolution imagery. Landsat 7 ETM+ dataset include 28.5 m spatial resolution multispectral data and 14.25 m spatial resolution panchromatic band. Merging multispectral data to panchromatic data produces new multispectral dataset with 14.25 m spatial resolution. The result of this task is shown in **Figure (4)**.

5.3.2 Image Classification

The data used for this task include Landsat ETM+ image and field observation in the same period of image acquisition. Through field visits, six land cover classes are identified in the study area. These classes are defined based on the Classification scheme for Northwestern Coastal Area (Mohammed et al., 2000). These classes are urban, shrubs, sandstone, sand, orchards and dense vegetation.

Both of the enriched image and field observation are used to generate a group of signatures. These signatures are designed to be completely representative for the land cover classes in the study area. The processes of signature development include assigning locations of training samples of the required signatures, creating statistical parameters of the signatures, and testing both separability and contingency of these signatures to be accepted and activated.

The accepted signatures used through maximum likelihood classifier were used to classify the subset image. The product is a primary land cover thematic map. To create the final land cover thematic map, the primary land cover map accuracy is calculated, which is equal to 92.6%. Therefore, the primary land cover map is considered to be final map and is presented in **Figure (5)**.

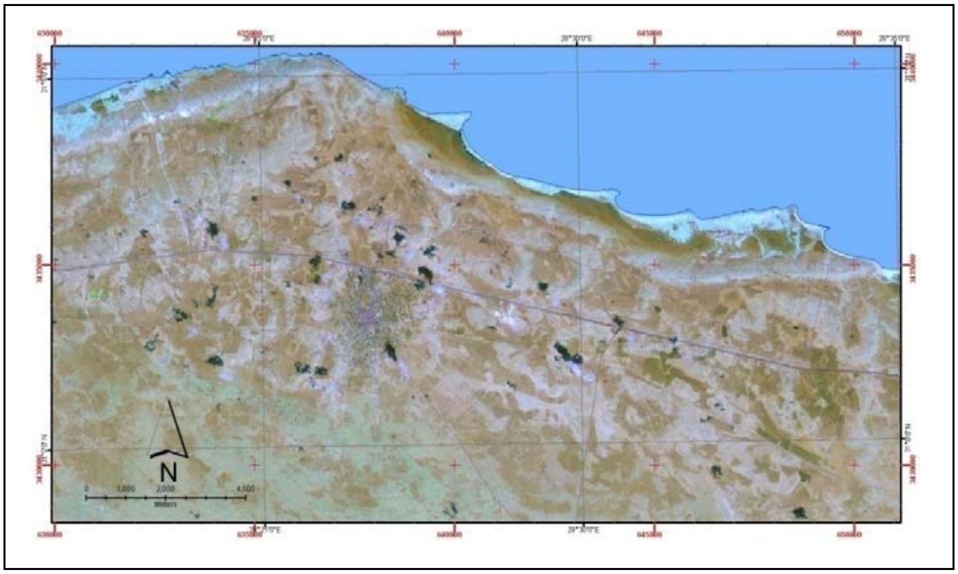

Figure (4): False Color Composite (RGB:742) for Spatial Enriched Landsat 7 ETM Multispectral Dataset

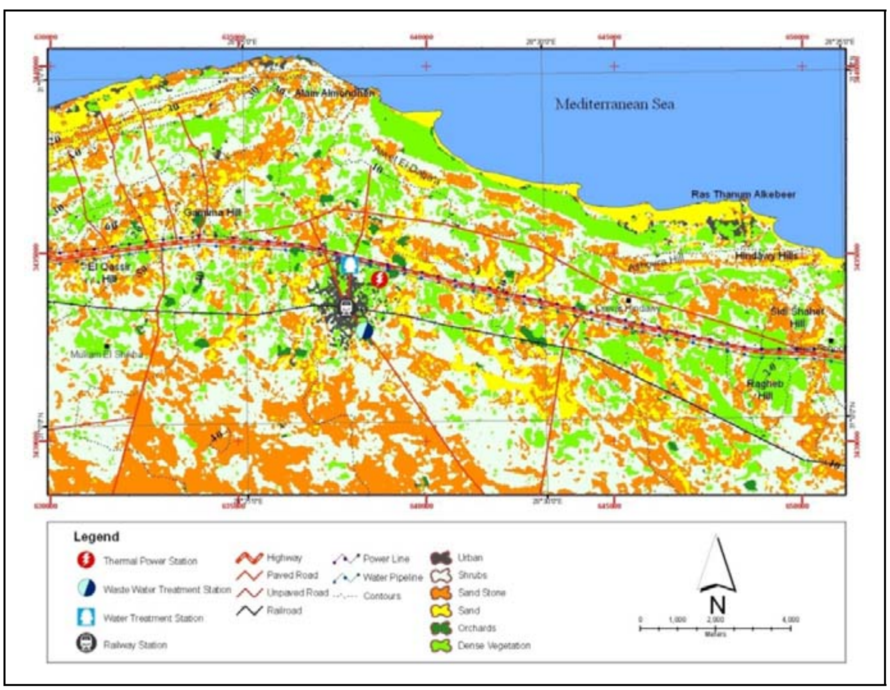

Figure (5): Land Cover Map of the Study Area.

6 Spatial Ecological Properties Analysis

Ecological properties in the context of this paper are defined by two factors; the natural habitat map and the counter area map. Natural habitat map was drawn by field survey. To draw counter-area map, simple procedure was used. This procedure is based on proximity analysis. Using species sighting sites – FAUNA feature class - as a source input data for Euclidean distance analysis procedure, new polygon feature class is produced. Each class in this feature class is identified as a counter area for a specific species. To understand the concept of counter area, consider two sighting sites A and B located in limited and defined area, using Euclidean distance analysis algorithm, let this area be divided into two polygons, sites in polygon labeled A is close to sighting site A more than sighing site B and *vice versa*. Counter area is an area dominant by a specific species.

Spatial ecological properties assessment means identification of the dominant spatial properties in each natural habitat area and in each counter-area. To identify this feature a set of zonal statistics were achieved where natural habitat polygon feature class and counter-area polygon feature class are used as a zonal map and the variables are LANDCOVER, DEM, SLOPE_P, ASPECT raster datasets.

Merging species sighting sites, counter-area and natural habitats produces the ecological map for the study area which is shown in **Figure (6)**, where the spatial properties of species counter-area and natural habitats are presented in **Table (2)** and **Table (3)** respectively.

Figure (6): Ecological Map for the Study Are

Table (2): Spatial Properties for Species Counter-Area

Species	Dominant Land Cover	Mean Elevation	Mean Slope	Mean Aspect
Alectoris barbara	Shrubs	12.60	1.52	149.16
Eremophila bilopha	Shrubs	12.58	0.55	107.90
Gerbillus andersoni	Sand Stone	28.86	0.21	77.57
Hemiechinus auritus	Sand Stone	38.87	0.34	164.62
Jaculus orientalis	Shrubs	33.14	0.47	110.75
Lepus capensis	Shrubs	25.66	0.63	126.66
Mesalina guttulata	Shrubs	12.75	1.53	152.99
Psammomys obesus	Shrubs	21.47	0.98	153.53
Stenodactylus mauritanica	Dense Vegetation	1.57	0.36	45.98
Tarentola mauritanica	Shrubs	21.24	0.52	105.74

Table (3): Spatial Properties for Natural Habitats in the Study Area.

Habitat	Dominant Land Cover	Mean Elevation	Mean Slope	Mean Aspect
Gravel Plains	Shrubs	38.24	0.66	145.01
Sand Dunes	Sand	3.80	1.10	146.75
Desert	Shrubs	18.17	0.70	110.30
Wetlands	Dense Vegetation	3.20	0.43	103.69

7 Results

It is obvious from **Table (2**) and **Table (3**) that the most important land cover for the biodiversity in the study area are sand, dense vegetation, sand stone and shrubs respectively. This order is based on the area covered by these classes. So, these land cover classes are the dominant land cover classes in the natural habitats and counter-areas for species, and then the importance of land cover class is defined by scarcity of the simple ecosystem composed of this land cover and the species that occupied.

Using these tables and the ecological map for the study area shows that the coastal area which has elevation less than 25 m above sea level and average slope less than or equal to one percent are rich with five species from ten considered species. The spatial characteristics for this area let it described as coastal plain.

Based on this information, simple spatial ecological sensitivity index *SESI* was designed to illustrate the ecological sensitivity in the study area and to aid management planning. This SESI illustrates the sensitivity based on a set of rules. The main rule is that all the area less than or equal 25 m above sea level and slope less than or equal 1 percent is sensitive area. This sensitive area was classified according to the land cover class occupied. The area occupied by the sand is the most sensitive area because the sand is the least area among the dominant land cover classes. The second sensitive area is that area occupied by dense vegetation. The third is the area occupied by sand stone. The less sensitive area is that area occupied by shrubs. These four areas are ranked from 1 to 4 where 1 means the most sensitive area and 4 means the least sensitive area. Figure (7) shows the spatial ecological sensitivity index for the study area as produced by the pervious rules.

To identify the SESI inside both of El Daba'a town and the nuclear power station area, the land ownership map and SESI map are superimposed and the attribute data summarized to illustrate the area of each sensitive area in the nuclear power station area and in El Daba'a Town. **Table (4** shows the summarization results.

8 Conclusion

The sensitive area in the area allocated for the nuclear power station are large than that in El Daba'a Town. So, it is important to take into consideration preparation for environmental management plan to conserve the ecological characteristics for El Daba'a region, specially, if the project of the nuclear power station will begin.

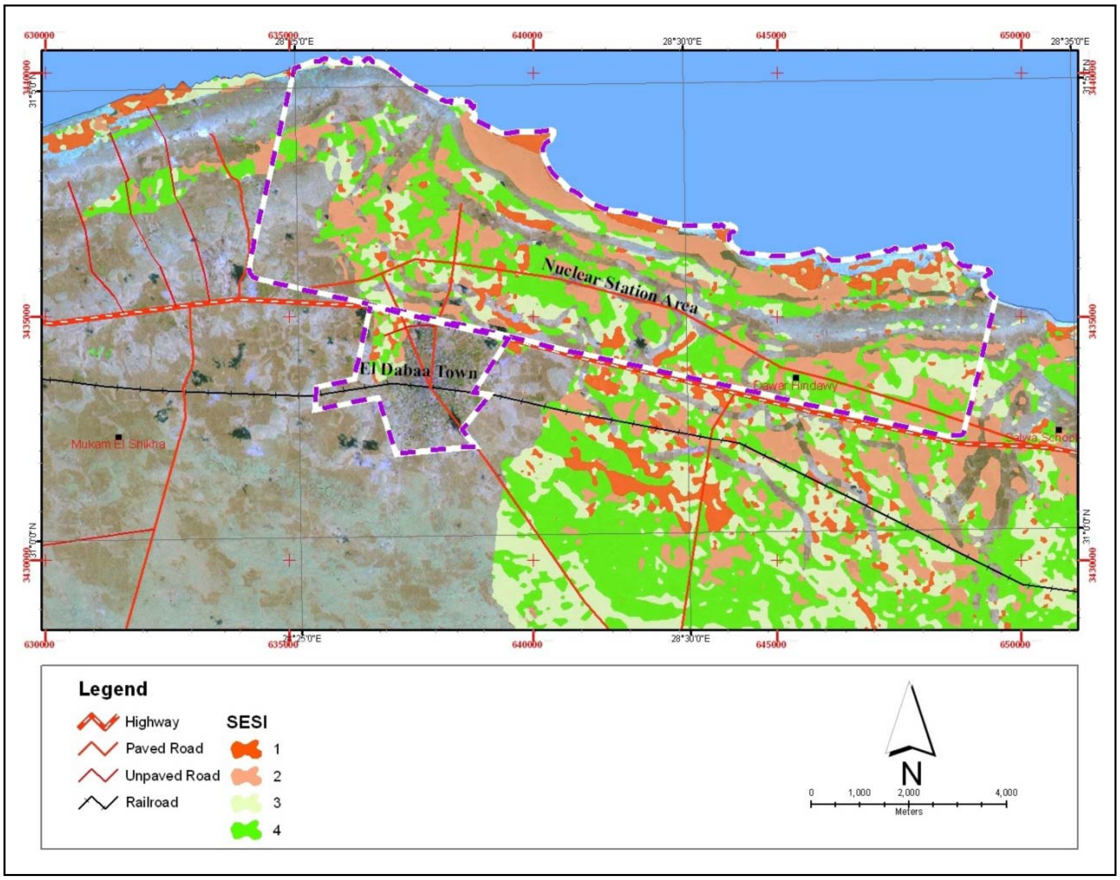

Figure (7): Spatial Ecologic Sensitivity Index SESI map

Table (4): Area of Each Sensitive Area in the Power Station Area and El Daba'a Town

SESI	Power Station Area (m^2)	El Daba'a Town (m^2)
1	3763172.47	165628.08
2	11655132.60	145565.92
3	7105038.79	371665.41
4	11975257.75	278709.25

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