Spatial Analysis for Sustainable Development of El Fayoum and Wadi El Natrun Desert Depressions, Egypt with the Aid of Remote Sensing and GIS

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Authors’ contributions

This work was carried out in collaboration between authors AAG and AEZ. Both authors participated equally in the study idea, literature review, data collection and analyses, methodology, statistical analyses, tabulating the data, results validation, writing and revising the whole manuscript.

ABSTRACT

El Fayoum and Wadi El Natrun are typical examples of desert depressions, differ in nature; El Fayoum is connected with the Nile Valley by a major irrigation network, while Wadi El Natrun is inserted in the Eolian desert landscape. Remote sensing and GIS spatial analysis were employed to assess the magnitude and geographical distribution of land resource and environmental hazard susceptibility, in addition to create and develop different thematic layers to evaluate potentiality for sustainable development in the studied depressions. The land resources database shows that the soils associated with recent alluvial terraces dominate the depressions. Multi-temporal satellite images revealed that urbanization mainly occurred on the account of most fertile soils of El Fayoum depression, hence shrinking the high and moderate capable soils. Wadi El Natrun depression and its expansion are potential areas for agricultural purposes. Land use/ cover maps clearly show that the El Natrun depression does not undergo significant hazards, as the expansion of urban and agricultural areas occur on the count of bare land. It could be concluded that desert
Depressions represent promising areas for sustainable development. The depressions connected to active river systems, such as El Fayoum, may support integrated sustainable development. The establishment of basic infrastructure in isolated depression areas, such as Wadi El Natroun, encourages sustainability in areas located at the open deserts.

**Keywords:** Remote sensing; GIS; sustainable development; desert depressions; Egypt.

### 1. INTRODUCTION

Sustainable development is defined by the Brundtland Commission, as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. The FAO, 1995 refers that sustainable development is ‘the management and conservation of natural resource base and orientation, in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations’. Sustainable development would conserve land, water, plant and animal resources.

Sustainable development, however, has increased the requirement for systemic and thorough assessments, and reporting that takes into account the links among environmental, socio-economic and policy issues [2]. Global economic growth and industrialization, under the influence of the forces of globalization, are increasing natural resource consumption, drawing down non-renewable resources, stressing ecosystem processes, and generating unprecedented amounts of wastes [3].

Modern concept of sustainability underlines the importance of inserting environmental criteria in regional development choices, rather than supporting specific protection policies [4]. The economic efficiency criterion in resources exploitation, as well as the social dimension of sustainability, becomes relevant issues at the same time [5,6]. The potential utility of remote sensing data has been well recognized in mapping and assessing land attributes such as physiography, soils, and land use/land cover [7]. Remote sensing, integrated with GIS, plays a major role in providing the information on land use/land cover, DEM, Soil types, infrastructures, NDVI and detection of the changes through years, to maintain and achieve the concepts of sustainable development [8].

The present study aims to assess the potentiality for sustainable development in two different Egyptian desert depressions (i.e. El Fayoum and Wadi El Natrun), in order to maintain and improve the situation. Remote sensing integrated with GIS and archival data were employed to obtain the necessary information used as indicators for evaluating sustainability in the studied depressions.

Particular objectives of the present research are; 1) Studying the natural, environmental and anthropogenic characteristics of the studied depressions, 2) Monitoring the changes occurred in land use/cover maps during the period 2003-2011, 3) Assessing socio-economic and environmental factors affecting the depressions and their extensions, 4) Evaluating the potentials of sustainable developments in the two studied areas and 5) Addressing the barriers of sustainable development in the region.

### 2. ENVIRONMENTAL SETTING OF STUDY AREA

#### 2.1 El Fayoum Depression

The depression is located southwest of Cairo, where the distance to the Fayoum town is 90 Km (Fig. 1). It is connected to the Nile Valley by the Hawara canal, through which Bahr Yousef is transporting the Nile water. The total area of El Fayoum depression is 2025.5 km². The depression area is distinguished by its temperate climate along the year, in addition to its long history extending back millions of years.

The climatic data of El Fayoum district indicate that the total rainfalls does not exceed 7.2 mm/year and the mean minimum and maximum annual temperatures are 14.5 and 31.0°C respectively. According to the aridity index [9], the depression is located under arid climatic condition class. El Fayoum depression is excavated in the Middle Eocene rocks, which form the oldest exposed beds in the area and are composed essentially of gyps-ferrous shale, white marls, limestone, and sand [10].

The agricultural land in the depression amounts to 1350.7 km², classified into five grades
according to their production capability. The first and second capability classes do not exceed 20.2% of the total cultivated land, whereas about 70.2% are accommodating the third and fourth classes [11]. According to the Egyptian Meteorological Authority [12] and Key to Soil Taxonomy [13], the soil temperature regime of the depression could be defined as thermic and soil moisture regime as Torric. The depression has a particular nature, contrasting, in its geographical, topographical and environment features, with both the Nile Delta and the desert oases.

2.2 Wadi El Natrun

Wadi El Natrun, is a narrow depression located in the west of the Nile Delta, approximately 110 km northwest of Cairo between longitudes, 30º 02´ and 30º 40´ E and latitudes, 30º 10´ and 30º 40´ N (Fig. 2). The total area of Wadi El Natrun depression is about 2960.5 Km², extending in a NW-SE direction and 23 m below sea level. Underground water in Wadi El-Natroun is originated from Nile stream seepage [14].

Wadi El Natrun area is considered as an extremely arid region where the mean annual rainfall, evaporation and temperature are 41.4 mm, 114.3 mm and 21ºC respectively [15]. Inland saline lakes and salt crusts occupy the area surrounded by contour zero [16]. The geology of Wadi El Natrun indicates that it is covered by Quaternary lake deposits and old alluvial deposits of sand and gravel laid when the sea encroached the area and the Nile flowed through it [16,17].

A number of small shallow lakes extend along the deepest parts of the Wadi in an axial position near the eastern edge of the depression. Since the evaporation rate is high and the lakes lie in closed basins without outlet, the water in the lakes has a high salt concentration and is susceptible to marked fluctuations in level and salinity [18,19].
3. MATERIALS AND METHODS

3.1 Satellite Images Analyses

Landsat satellite images dated 2003 and 2011 were used in this study to point out the changes in date land use/land cover. ENVI 4.8 image processing system was used for the geometric correction of the used images to the UTM grid system (Zone: 36N, datum: WGS84). Radiometric correction was applied to remove atmospheric noises and additives. The images were cropped to the study area to be ready for any further analysis. The integration of image processing and Geographic Information System (ArcGIS version 10) systems were employed to overcome stripping phenomena found in LANDSAT images.

The Destripe module of ENVI system was applied on the image of 2011, in order to be compatible with the one of 2003. This step was followed by the pre-processes of layer stacking, mosaicking and geometric correction.

The images were supervised classified using the Maximum Likelihood classifier. A comparison of classified unit areas was insinuated to detect changes in land use/land cover related to sustainability parameters. Fig. 3 summarizes the elaborated procedures of satellite image analyses and detecting changes.

The Normalized Difference of Vegetation Index (NDVI) was estimated, from the two images of 2003 and 2011, as the following formula: $NDVI = (NIR - RED) / (NIR + RED)$.

Where: NIR is the near infrared band, RED is the red band [20].

Reclassification of the obtained NDVI values (-1 to 1) was elaborated to define areas for different vegetation densities. Categorization of vegetation density resulted in defining a number of four density classes (i.e. sparse, medium, dense and very dense). Negative values are indicative of non-vegetated areas or non-reflective surfaces, while positive values denote vegetated or reflective surfaces [21]. Shuttle Radar Topography Mission (SRTM) images were used to develop the digital elevation model (DEM) of the study areas.
3.2 Creation of Geo-environmental Database

The ArcGIS software ver. 10 was used for the creation of spatial database linked with its particular attributes. It was employed in the analysis, integration, and generation of various thematic maps [22]. Soil maps of the study areas, produced by NARSS, in the context of Egyptian digital land resources database [11] were considered as main layer in the current geo-environmental database. Moreover, other thematic layers (i.e. roads, irrigation/drainage network, utilities, land use/land cover, altitude over sea level and vegetation density) were created on bases of General Egyptian Survey Authority maps produced 1991.

4. RESULTS AND DISCUSSION

Three main issues were followed (i.e. environmental, Economic and social) to realize and achieve the potential sustainable development in the current study. It was possible to choose particular indicators for each issue that could be investigated through remote sensing and GIS. Fig. 4 demonstrates the concept, chosen indicators and tools used to investigate each of studied issues. Remote sensing integrated with GIS in addition to archival data were basically used to produce different layers representing DEM, NDVI, Land use/cover, soil and infrastructure. The research activities resulted in the following findings;
4.1 Environmental Issues

4.1.1 Digital elevation model (DEM)

Fig. 5 shows the DEM of the studied areas based on the processing of SRTM images. It is clear that El Fayoum Depression area (Fig. 5A) attains an elevation ranging between -60 and 140 m asl. Most of the depression is characterized by an altitude ranging between -0.29 to 20 m asl. The low altitudes (i.e. -60 to -0.3 m asl) exhibit the northern El Fayoum area around Lake Qarun, while the western region is characterized by high altitude (59 to 140 m asl) scarps. The sustainability is favored in the low altitude area in the majority of the depression. Fig. 5B shows that the higher altitudes (69 – 180 m asl) of Wadi El Natrun depression are observed at the southern west region. However, the majority of the depression area is characterized by medium elevation (24 – 46 m asl) which is relatively lower than the surrounding region. The low elevation areas (-46 – 0 m asl) exist as a stripe starting from the west of Wadi El Natrun depression and extends southeastwards.

4.1.2 Land use / cover

4.1.2.1 El Fayoum depression

Supervised classification (Maximum Likelihood Classifier) has been utilized to produce land use/cover maps for El Fayoum depression at the two years of study (2003 & 2011). The overall accuracies obtained were 88.50% and 85.92% for 2003 and 2011, respectively. Four different classes were identified in El Fayoum depression; urban, vegetation, lake and bare land. Irrigation and drainage canals, roads networks and utilities are well distributed in the whole study area. The settlements are extensively inserted in the depression, connected by a dense road network (Fig. 6).

Lake Qaroun is a distinctive landform located north of the depression, along which cultivation and urban areas are distributed. It was found that most of El Fayoum depression is exhibited by cultivated land. Fig. 7 and Table 1 show the changes in land use/cover of El Fayoum depression during the period 2003 and 2011. A remarkable increase is observed in the urban area from 165.3 Km$^2$ (8.2%) in 2003 to 219.2 Km$^2$ (10.8%) in 2011. In the other hand, the vegetation area decreased from 1399.8 Km$^2$ (69.1%) in 2003 to 1350.7 Km$^2$ (66.7%) in 2011. It is worthwhile to refer that the bare land and the lake do not practice a significant change.

4.1.2.2 Wadi El Natrun depression

Likewise, maximum Likelihood Classifier has been utilized to produce land use/cover maps for Wadi El Natrun depression at the two years of study (2003 & 2011). The overall accuracies obtained were 92.38% and 89.84% for 2003 and 2011, respectively. Four different classes were identified in the depression; urban, vegetation, lake and bare land. Irrigation and drainage canals, roads networks and utilities are well
distributed in the north eastern parts of Wadi El Natrun depression. Wadi El Natrun is a newly reclaimed promising area for agricultural purposes. Settlements mostly exist along the main roads and surface water bodies (Fig. 8). The infrastructure map (Fig. 9) reveals that these areas are served by a fair irrigation and drainage network, which may encourage more sustainable development.

Fig. 9 and Table 2 show the changes in land use/cover of Wadi El Natrun depression during the period 2003 and 2011. A notable increase is remarked in vegetation area from 530.4 Km² (17.9%) in 2003 to 1474.6 Km² (49.8%) in 2011, as well as the urban area which increases similarly from 24.1 Km² (0.8%) in 2003 to 90.5 Km² (3.1%) in 2011. Expanding vegetation and urban areas occurred on the account of bare land, which significantly decreased from 2386.8 Km² (80.6%) in 2003 to 1376.4 Km² (46.5%) in 2011. On the other hand, water does not undergo any changes during the study period.

4.1.3 Soil conditions

4.1.3.1 El Fayoum depression

Soil layer (Fig. 10) indicates that the sub great group *Vertic Torrifuvents* dominates the depression, covering an area of 684.3 Km², representing 33.8% of the total mapped soils. *Typic Calciorthids* is found along the eastern and western boundaries of the depression covering an area of 361.7 Km² (17.9%). Consolidated rocky ridge exists in the bare land of the depression as along stripe parallel to the lake, representing an area of 212.9 Km² (10.5%). On the other hand, *Typic Torrifuvents* are located in the middle part of the depression covering an area of 134.0 Km² (6.6%).

### Table 1. Changes in land use/cover of El Fayoum depression

<table>
<thead>
<tr>
<th>Classes</th>
<th>Year 2003</th>
<th>%</th>
<th>Year 2011</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>165.3</td>
<td>8.2</td>
<td>219.2</td>
<td>10.8</td>
</tr>
<tr>
<td>Vegetation</td>
<td>1399.8</td>
<td>69.1</td>
<td>1350.7</td>
<td>66.7</td>
</tr>
<tr>
<td>Lake</td>
<td>244.8</td>
<td>12.1</td>
<td>241.3</td>
<td>11.9</td>
</tr>
<tr>
<td>Bare land</td>
<td>215.5</td>
<td>10.6</td>
<td>214.3</td>
<td>10.6</td>
</tr>
<tr>
<td>Sum</td>
<td>2025.5</td>
<td>100</td>
<td>2025.5</td>
<td>100</td>
</tr>
</tbody>
</table>
Fig. 5. Digital Elevation Model (DEM) of the studied areas, based on SRTM satellite images (A: El Fayoum; B: Wadi El Natrun)

Fig. 6. Infrastructure of El Fayoum depression
Fig. 7. Land use/cover of the El Fayoum depression (A: 2003; B: 2011)
Fig. 8. Infrastructure of Wadi El Natrun depression
The northeast of the depression is occupied by *Typic Gypsiorthids* having an area of 75.7 km$^2$ (3.7%). Rocky land is located in the northwestern corner of the depression, covering an area of 37.1 km$^2$ (1.8%). *Typic Quartizipsamments* extends as a stripe between *Typic Calciorthids* and Consolidated rocky ridge in southwest part of the depression, covering an area of 20.0 km$^2$ (1%). Finally, *Typic Salorthids*, which are found as a patch elongated south of the depression between *Typic Calciorthids* and *Vertic Torrifluvents*, representing the smallest area of the mapped soils in the depression, estimated to be 3.5 km$^2$ (0.2%).

4.1.3.2 Wadi El Natrun depression

Soil layer of Wadi El Natrun depression is presented in Fig. 11. The dominant sub great group in Wadi El Natrun, in contrast to El Fayoum depression, is *Typic Quartizipsamments*, covering an area of 1155.7 km$^2$ (39%), extending from northeasterward to southwestward of the depression. *Typic Torriorthents* exist in a triangular shape, whose base located to the east of the depression, covering an area of 458.0 km$^2$ (15.5%), while *Typic Gypsiorthids* extends southwestwards, covering an area of 450.6 km$^2$ (15.2%). *Calcic Torripsamments* represents 8.1% of the mapped soils, covering an area of 238.5 km$^2$, extending from southeast to mid of the depression, while Rock escarpment is found in the north of the depression, with an area of 183.1 km$^2$ (6.2%).

### Table 2. Changes in land use / cover of Wadi El Natrun depression

<table>
<thead>
<tr>
<th>Classes</th>
<th>Year 2003</th>
<th></th>
<th>Year 2011</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Km$^2$</td>
<td>%</td>
<td>Km$^2$</td>
<td>%</td>
</tr>
<tr>
<td>Urban</td>
<td>24.1</td>
<td>0.8</td>
<td>90.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Vegetation</td>
<td>530.4</td>
<td>17.9</td>
<td>1474.6</td>
<td>49.8</td>
</tr>
<tr>
<td>Water</td>
<td>19.1</td>
<td>0.6</td>
<td>19.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Bare land</td>
<td>2386.8</td>
<td>80.6</td>
<td>1376.4</td>
<td>46.5</td>
</tr>
<tr>
<td>Sum</td>
<td>2960.5</td>
<td>100.0</td>
<td>2960.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Fig. 10. Soil of El Fayoum depression

Fig. 11. Soil of Wadi El Natrun depression
4.1.4 Normalized difference vegetation index (NDVI)

The obtained NDVI values were re-categorized to express the vegetation cover percent as reflected in the satellite images. Multi temporal analysis, in the two studied areas, reveals the following results;

4.1.4.1 El Fayoum depression

Fig. 12 and Table 3 demonstrate areas exhibited by different categories of vegetation cover. It is obvious that the cultivable land is characterized by moderate vegetation cover density, which is dominating the depression. The area of this class has increased from 1062.8 km$^2$ to 1145.6 km$^2$, representing 52.5 and 56.6%, respectively. However, the surrounding desert area, characterized by sparse vegetation, does not show a significant change from 2003 to 2011. This class indicates favorable conditions to expose land surface for different erosion agents (i.e. wind and water).

4.1.4.2 Wadi El Natrun depression

Fig. 13 and Table 4 show the situation of vegetation cover density in Wadi El Natrun Depression. The area of sparse vegetation has decreased from 2521.9 to 1964.9 km$^2$ during the period 2003-2011. That change has shifted to the higher vegetation density classes. The images show the development of pivot irrigated land at different locations in 2011. It can be pointed out that sustainable development is well expressed in the recent years.

Table 3. NDVI for El Fayoum depression (2003 & 2011)

<table>
<thead>
<tr>
<th>Categories of vegetation cover (%)</th>
<th>Area, Year 2003 km$^2$</th>
<th>Area, Year 2003 %</th>
<th>Area, Year 2011 km$^2$</th>
<th>Area, Year 2011 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sparse (&lt;5%)</td>
<td>835.7</td>
<td>41.3</td>
<td>803.2</td>
<td>39.7</td>
</tr>
<tr>
<td>Moderate (5-30%)</td>
<td>1062.8</td>
<td>52.5</td>
<td>1145.6</td>
<td>56.6</td>
</tr>
<tr>
<td>Dense (30-60%)</td>
<td>126.9</td>
<td>6.3</td>
<td>76.7</td>
<td>3.8</td>
</tr>
<tr>
<td>Sum</td>
<td>2025.5</td>
<td>100.0</td>
<td>2025.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Fig. 12. NDVI of El Fayoum depression (A: 2003; B: 2011)

Table 4. NDVI for Wadi El Natrun depression (2003 & 2011)

<table>
<thead>
<tr>
<th>Categories of vegetation cover (%)</th>
<th>Area, Year 2003</th>
<th>Area, Year 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km²</td>
<td>%</td>
</tr>
<tr>
<td>Sparse (&lt;5%)</td>
<td>2521.9</td>
<td>85.2</td>
</tr>
<tr>
<td>Moderate (5-30%)</td>
<td>390.4</td>
<td>13.2</td>
</tr>
<tr>
<td>Dense (30-60%)</td>
<td>45.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Very dense (&gt; 60%)</td>
<td>2.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Sum</td>
<td>2960.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>
4.2 Socio-economic Issues

4.2.1 El Fayoum depression

It is obvious that El Fayoum Depression is equipped by satisfactory infrastructure facilities needed for sustainable development (i.e. Roads, irrigation and drainage channels and power lines). GIS ready thematic maps (Fig. 6) refer that variable road categories connect different inhabited areas. Dual and main paved roads (Total length of 114.8 km) link the depression with different towns in the Nile valley. The Nile water is transported to the depression through major irrigation canals (i.e. Bahr Youssef). Moreover, the depression is served by irrigation and drainage networks having total lengths of 1295 and 853.2 km, respectively.

4.2.2 Wadi El Natrun depression

Fig. 8 point out the infrastructure facilities needed for sustainable development. The depression is well connected with different towns in the Nile Delta by a dual carriage and paved roads. Tracks roads are serving the settlements and agricultural projects in the depression. It is worthwhile to refer that the main water resources are located in the underground. The irrigation networks (300.0 Km length) control the distribution of the pumped groundwater, while the drainage ones (7.6 km length) support the soil protection against salinization and water logging. The limited distribution of drainage system is related to the dominance of sandy soils which mostly does not require surface drainage. The basic utilities, including power lines, oil and gas and water pipelines, are installed in the depression and might be upgraded with more sustainable development.

4.3 Potential of Sustainable Development

All collected data in the two study areas were analyzed in order to determine the level of sustainable development potentiality. Indicators related to environmental, economic and social factors were selected on bases of the available data. Table 5 demonstrates a matrix developed to come out with determination of potential sustainability. Terms of promising, suitable and critical were proposed to reflect the evaluation. It was found that each of the two studied depressions may be subdivided into the old areas and extended ones. The old El Fayoum land is characterized by a flat landscape, allowing an easy workability, irrigation practices and transportation. It is also exhibited mainly by fertile alluvial soils, supporting sustainable agriculture. Dense vegetation protects land surface from susceptibility to erosion agents. The basic infrastructure encourages more progress.
and support for sustainable development. The dense population provides labor power and marketability. The overall environmental and socio-economic issues bring the potentiality for sustainable development at the High level. On the other hand, sustainability indicators at the extension of El Fayoum depression, refers mostly to a critical levels, which brings the potentiality for sustainability at low level. The infertile soils, rugged landscape, low vegetation cover and infrastructure networks are not favoring sustainable development.

The situation in Wadi El Natrun shows a promising landscape and vegetation density in both old land and extensions, in addition to the promising infrastructure at the first one. This situation brings the potential sustainability in the depression to moderately high. However, the critical levels of the socio-economic indicators, at the extension areas, leads to a moderate potentiality for sustainable development.

### 4.4 Barriers of Sustainable Development

It is obvious that El Fayoum depression is subjected to expanding of urban areas on the account of the vegetated ones. Such conditions adversely influence the potentiality for sustainable development in the depression. Loss of vegetated areas may lead to unbalance in the land use/cover at the depression. It is noticed also that bare land, which may hold expansion of new urban areas, is nearly unchanged. It is worthwhile to point out that Wadi El Natrun depression is a promising area for agricultural purposes. Land use/cover maps, on bases of both 2003 and 2011 images, clearly show that the depression does not undergo any hazards, as the expansion of urban and agricultural areas occur on the count of bare land. On the other hand, the geographic locations, of Wadi El Natrun depression, and the potentiality of groundwater, are the main key factors which enhance sustainability.

### Table 5. Evaluation of sustainability of both El Fayoum and Wadi El Natrun depressions

<table>
<thead>
<tr>
<th>Issues</th>
<th>El Fayoum Depression</th>
<th>El Fayoum Extension</th>
<th>Wadi El Natrun Depression</th>
<th>Wadi El Natrun Extension</th>
</tr>
</thead>
<tbody>
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<td>Environmental</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscape</td>
<td>Promising</td>
<td>Critical</td>
<td>Promising</td>
<td>Promising</td>
</tr>
<tr>
<td>Soil</td>
<td>Promising</td>
<td>Critical</td>
<td>Suitable</td>
<td>Suitable</td>
</tr>
<tr>
<td>Vegetation density</td>
<td>Promising</td>
<td>Critical</td>
<td>Promising</td>
<td>Promising</td>
</tr>
<tr>
<td>Economic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land use/cover</td>
<td>Promising</td>
<td>Critical</td>
<td>Promising</td>
<td>Suitable</td>
</tr>
<tr>
<td>Roads</td>
<td>Promising</td>
<td>Suitable</td>
<td>Suitable</td>
<td>Suitable</td>
</tr>
<tr>
<td>Irrigation/Drainage</td>
<td>Promising</td>
<td>Critical</td>
<td>Suitable</td>
<td>Critical</td>
</tr>
<tr>
<td>Utilities</td>
<td>Promising</td>
<td>Critical</td>
<td>Promising</td>
<td>Critical</td>
</tr>
<tr>
<td>Social</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Roads</td>
<td>Promising</td>
<td>Suitable</td>
<td>Promising</td>
<td>Critical</td>
</tr>
<tr>
<td>Urban areas</td>
<td>Promising</td>
<td>Critical</td>
<td>Critical</td>
<td>Critical</td>
</tr>
<tr>
<td>Inhabitants</td>
<td>Promising</td>
<td>Critical</td>
<td>Critical</td>
<td>Critical</td>
</tr>
<tr>
<td>Potentiality for sustainable development</td>
<td>High</td>
<td>Low</td>
<td>Moderately high</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Fig. 14. Changes in land use/cover in the studied depressions during the study period  
(A: El Fayoum, B: Wadi El Natrun)
5. CONCLUSION

Desert depressions represent promising areas for sustainable development; they often attain fertile soils, vegetation cover density and sufficient population to maintain sustainable development. The depressions connected by active river streams (i.e. El Fayoum) may support integrated sustainable development. The establishment of basic infrastructure in the Wadi El Natrun depression area encourages the expansion of sustainability to areas located in open deserts. The critical status of sustainability issues should be considered in order to maintain sustainable development. Remote sensing and GIS proved to be satisfactory tools to collect information for assessing the potentiality for sustainable development items and hazards.

DISCLAIMER

This manuscript was previously presented in the following conference.
Conference name: 8th National GIS symposium.
Dates: 15-17 April 2013.
Location: Dammam - Eastern Province, Saudia Arabia.
Web Link of the proceeding: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.691.925&rep=rep1&type=pdf

ACKNOWLEDGEMENTS

The authors express their deep appreciations to the United States Geological Survey for supporting Landsat image data and to the ASRT funded project “Establishment of Egyptian Land Resources Database” for supporting soil data to this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

17. Philip G, Barakat M, Abu Khadrah A. Stratigraphy and mechanical analysis of Neogene sediments in Wadi El Natrun area, Egypt, Bulletin. Faculty of Science, Cairo University, No. 48; 1975.