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Assessing and Monitoring Sustainable Land Management for Land Degradation Neutrality in Wadi El Farigh

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ABSTRACT

This study aimed to understand the new management challenges related to the impact of climate change on biodiversity, deterioration of agricultural productivity, food security, and increasing rates of desertification. This constitutes an important indicator for studying Land Degradation Neutrality (SDGs Target 15.3), which is considered a significant target in achieving the Sustainable Development Goals 2030. The present study is concerned with assessing and monitoring land management and land degradation in Wadi El Farigh from 2000 to 2019. Soil quality is a major part of the chain that leads to understanding sustainable land management of natural resources (land, groundwater, and natural vegetation). A geopedological approach produced the studied area's physiographic and soil map. The study of changes in land degradation level in Wadi El Farigh over 20 years with a period of every five years shows a very high improvement in the study area from the year 2000 up to 2014. From 2015 to 2019, this class was reduced due to the effects of land degradation reflected by the use of saline water for irrigating crops. Using remote sensing and geostatistical analyses within the GIS environment illustrated that the soils were classified as *Entisols*, representing 79.45 of the total studied area, and *Aridisols* representing 20.55% of the total studied area.

Keywords: remote sensing, geostatistical analysis, GIS, land degradation changes.

INTRODUCTION

One of the main challenges facing us is the increase in climate changes and extreme weather phenomena (such as droughts, floods, torrential rains, and dust storms), as these changes lead to irregular water supplies, a decline in agricultural land areas, and the migration of rural residents to urban areas, affecting the stability of life in rural communities.

The sustainable use of the land comes within the goals and objectives of Goal 15 (SDG15) of the Sustainable Development Goals, which the world ratified in New York in September 2015. Its component revolves around protecting, restoring, and promoting the sustainable use of terrestrial ecosystems, sustainably managing forests, combating desertification, halting land degradation, and restoring and halting biodiversity loss stated in the United Nations Convention to Combat Desertification (UNCCD, 1996), desertification is defined, as "the degradation of lands in arid, semi-arid and dry semi-humid areas due to various factors, including climatic differences and" Human Activities" Degradation causes many changes in soil properties due to various deterioration factors.

Therefore, monitoring land degradation and knowing its causes is part of the activities to reduce the phenomenon of desertification, which is a process involving determining changes in their vegetation cover, estimating the state of land degradation in these areas, and identifying hot areas. The causes constitute the driving forces and pressures that led to the phenomenon.

Drought is the consequence of a natural reduction in the amount of precipitation over some time, usually a season or more in length, often associated with other climatic factors (such as high temperatures, high winds, and low relative humidity) that can aggravate the severity of the event, (Sivakumar, 2005). Drought is the most complex of all natural hazards, as it affects more people than any other; according to the EM/DAT data quoted in the World Disaster Report (2007), about 2.63 million people were affected by hydro-metrological disasters globally during the period (1997–2006) approximately 41.82% are affected by drought, 38.87% of them were affected during the year 2002.

During 1997/2006, hydro-metrological disasters caused an estimated damage of US$ 66.8 billion per year on average out of this, 4.62% was caused by drought average number of people reported killed million per year, Asia (81.11), Africa (26.69), Americas (2.57), Europe (0.14) (Erian et al. 2011). The effects of droughts are seriously worsened by human factors such as population growth that forces people into increasingly drier regions and inappropriate cropping and herding practices. The impacts of drought are likely to become ever more severe due to development processes and population increases (Squires, 2001).

Droughts often stimulate sequences of actions and reactions leading to long-term land degradation (Erian 2010 and Erian et al. 2011).

Wadi El Farigh is considered one of the important valleys that received much concern by many factors such as suitable land, water potentials, and its geographic location, in proximity to the old agricultural area with seasonal labor, which is considered central importance in attracting more investments.

The study aims to monitor vegetation cover and land degradation change in Wadi El Farigh from 2000 to 2019 due to the changes in the soil improvement which were affected by land degradation in the study area. Updated soil classifications were produced using remote sensing and geostatistical analyses through the environment of the geographic information system. A geopedological approach was used to produce the physiographic and soil maps of the studied area.

MATERIALS AND METHODS

The following materials and methods were used to achieve the objectives of the studied area.

Materials

The following materials were used:

- High-resolution satellite image resolution (Sentinel-2A, 10-meter resolution).
- The study of land degradation for the period 2000–2017.
- Topographic map at scale 1:50,000 produced by (EGSA, 1990).
- Geological maps of study area scale 1: 500,000. (EGPC, 1988).
- Previous studies and reports of soil maps were employed:
  - Soil map of Egypt (Hammad, 1975).
  - Land resources database of Egypt for agriculture usage (Gad et al., 2009).

Methods

We made an analysis and interpretation of satellite images monitoring soil improvement and land degradation in the studied area. The hard copy formats of existing soil maps and topographic maps were scanned, re-projected, then converted to digital formats (vector format) by digitized, generalized, coded, and standardized Geographic Information System. The study of land degradation depends on trend line analysis of satellite images from the archive type MODES NDVI 250 m. In the period of 2000–2020 the monitoring changes in the biomass of vegetation were used, and extract mapping classes of each soil degradation and soil improvement.

Creation of physiographic mapping units goes the following steps: the contour lines, including the ground control points, were delineated from the topographic maps, and converted contour lines to points format compiled them with ground control points to create the Digital Elevation Model (DEM) using the geostatistical analysis. The predicted values of all contour points. Geostatistical analysis was calculated the experimental semi-variogram and fitting a model, which is used to interpolate DEM (Stein, 1998). The geomorphic mapping units were created based on the result of the histogram of the DEM value map. The geopedological soil map approach (Zinck, 2016) was followed to create the physiographic mapping units by combining the geomorphic mapping units with the geological map.

In total, 73 soil locations (40 soil profiles followed by 33 Augers) were elaborated to study the soil characteristics and classify the soils to Great group level (USDA, 2014). Morphological sheet descriptions were filled in according to soil staff guidelines (USDA., 1993, USDA, 2006). On the basis of the morphological descriptions, soil samples were subjected to physical and chemical analyses. Soil color for both moist and dry samples was examined using Munsell color charts USDA soil survey staff (1975).

Soil samples were air-dried, gently crushed, and then sieved through a 2-mm sieve. Fractions below 2 mm were subjected to soil analysis. Laboratory analyses include the chemical and physical properties of the soil samples. The physical analyses included particle size distribution by the pipette method (Gee and Bander,1986), soil organic matter content by Walkley and Black method (Dewis and Freites, 1970), Calcium carbonate was determined by the calcimeter method (Nelson, 1982). The chemical analyses included electrical conductivity and pH using an electrical conductivity meter and pH meter according to ICARDA (2013). Soluble cations and anions were carried out in water and soil according to ICARDA (2013), and SAR was calculated according to FAO (2008). Finally, the physiographic soil map is obtained by integrating the physiographic mapping units with the soil properties classification maps.

LOCATION OF THE STUDIED AREA

Wadi El Farigh is located in the northwestern part of Egypt, 60 to 70 km west of the Cairo-Alex desert road. It is situated between 30° 28′ 21.58″ E and 30° 43′ 27.32″ E and between 30° 09′ 13.86″ N and 30° 18′ 20.44″ N. The selected studied area covers part of the soils in the western part of the Nile Delta (Desert fringes areas) with an area of 34977 feddans. Figure 1 show the location map of the studied area.

METROLOGICAL DATA – SOUTH TAHRIR STATION

Climatological data were collected from the South Tahrir meteorological station to identify the climatic norms of the studied area. The area has a semi-dry climate characterized by rainy winter and a long hot and dry summer. According to Koppen's classification, the region's climate is the hot desert type. The mean annual temperature is ranged between 13.6–28.3 °C with an average of 21.6 °C. The maximum monthly temperature ranged from 19.4 to 35.2 °C with an average of 27.38 °C, and the minimum temperature ranged from 7.9 to 20.9 °C with an average of 14.49 °C in February. Annual rainfall is low and ranges from 0 to 1:1.2 mm, and most precipitation falls in winter

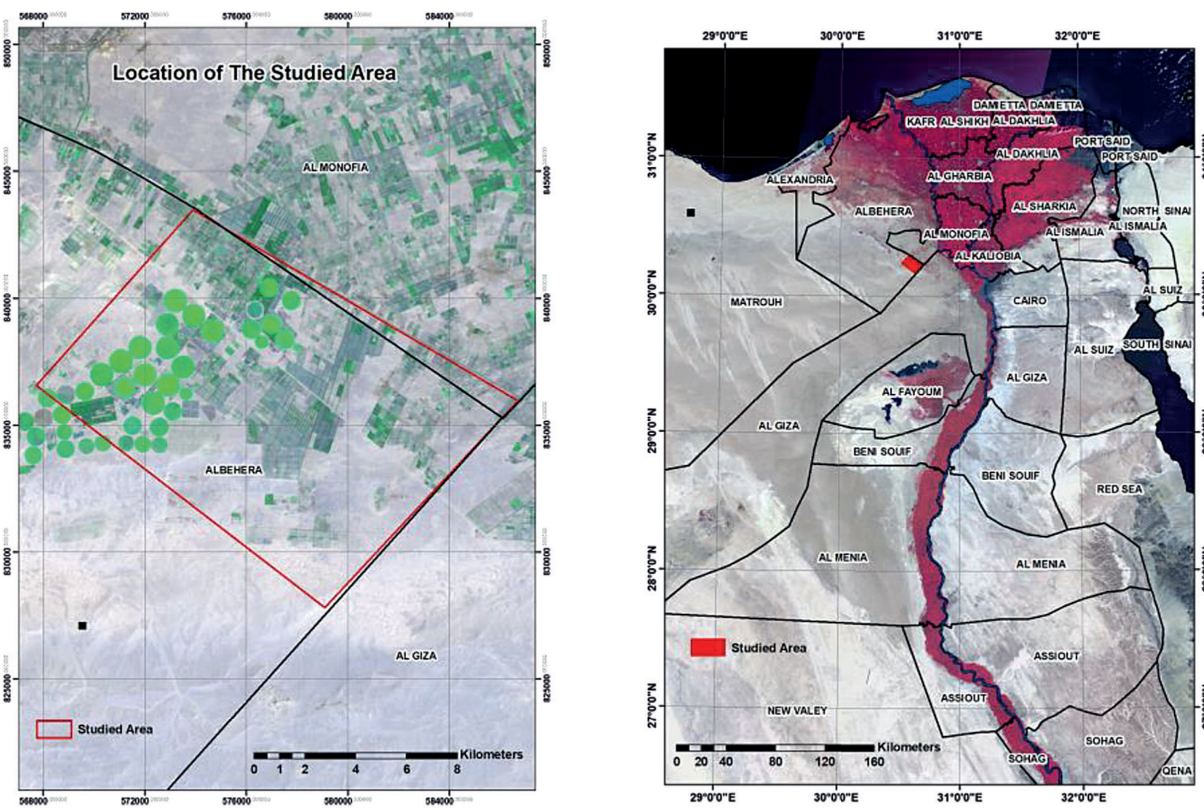


Figure 1. General and zoomed location of the studied area

(from November to April). The relative humidity ranges between 60% and averages 65.75%. The lowest values were recorded in May and June, while the highest were in August, October, and December.

Soil climate according to USDA, 2014

- The soil moisture regime in the study area is torric or aridic.
- The soil temperature regime in the study area is thermic.

The standard precipitation evapotranspiration index

The Standardized Precipitation Evapotranspiration Index (SPEI) has significant potential as a meteorological drought index, because it uses a more comprehensive measure of water availability and climatic water balance. Figure 2 show the trend of Increased Drought Frequency and Intensity.

RESULTS

Land degradation classes

Land degradation was observed by monitoring the changes in vegetation cover using the results of vegetation cover change in 2000–2020 by classifying MODES NDVI. The results illustrated that about 43.19% of the studied area was classified as non-degraded soil, and 7.02% were classified as moderately degraded areas from 2000 to 2005. In addition, the results illustrated that about 31.85% of the studied area was classified as non-degraded soil, and 15.45% were classified as moderately degraded asea during 2005–2010. Moreover, the results illustrated that about 33.96% of the studied area was classified as non-degraded soil, and 12.06% were classified as moderately degraded areas from 2010–2015. Finally, the results illustrated that about 19.71% of the studied area was classified as non-degraded soil, and 24.27% were classified as moderately degraded areas during 2015–2020. Therefore, the results of the last five years (2015–2020) illustrated that the non-degraded soil and moderately degraded soil classes increased during this period through the use of saline irrigation water. Figure 3 and Table 1 show the land cover changes in each period (2000–2005, 2005–2010, 2010–2015, and 2015–2020).

Physiographic mapping units

The contour lines, including the ground control points, were extracted from topographic maps. The total number of contour points values map after the converted contour segments map and combined with the spot height map are 3066 contour point values, ranging from 29 meters asl to 119 meters asl, with an average of 81.82 meters asl, the standard deviation of 18.95 and standard error of 0.0342.

The Digital Elevation Model (DEM) was created using the geo-statistical analysis parameters of the contour points map (Figure 4).

Figure 2. The trend of increased drought frequency and intensity

Table 1. Land cover changes in each period

Land cover change		Area 2000–2005		Area 2005–2010		Area 2010–2015		Area 2015–2020	
Code	Classes	Feddan	%	Feddan	%	Feddan	%	Feddan	%
1	VH-Deg	913.88	2.61	804.8	2.3	446.19	1.28	674.98	1.93
2	H-Deg	2375.1	6.79	2964.1	8.47	3375.1	9.65	6779.6	19.38
3	M-Deg	2456.8	7.02	5403.9	15.45	4216.6	12.06	8488.2	24.27
4	L-Deg	513.32	1.47	753.66	2.15	452.98	1.3	1507.8	4.31
5	VL-Deg	2470.2	7.06	5034.1	14.39	3338.6	9.55	4245.2	12.14
6	N	15108	43.19	11139	31.85	11878	33.96	6895.2	19.71
7	VL-Dev	5803	16.59	4675.8	13.37	5948.7	17.01	3289.8	9.41
8	L-Dev	3074.8	8.79	2567.5	7.34	2472.6	7.07	1361.7	3.89
9	M-Dev	1385.4	3.96	1063.4	3.04	1139.8	3.26	853.59	2.44
10	H-Dev	876.37	2.51	570.65	1.63	1708.5	4.88	881.02	2.52
Total area		34977	100	34977	100	34977	100	34977	100

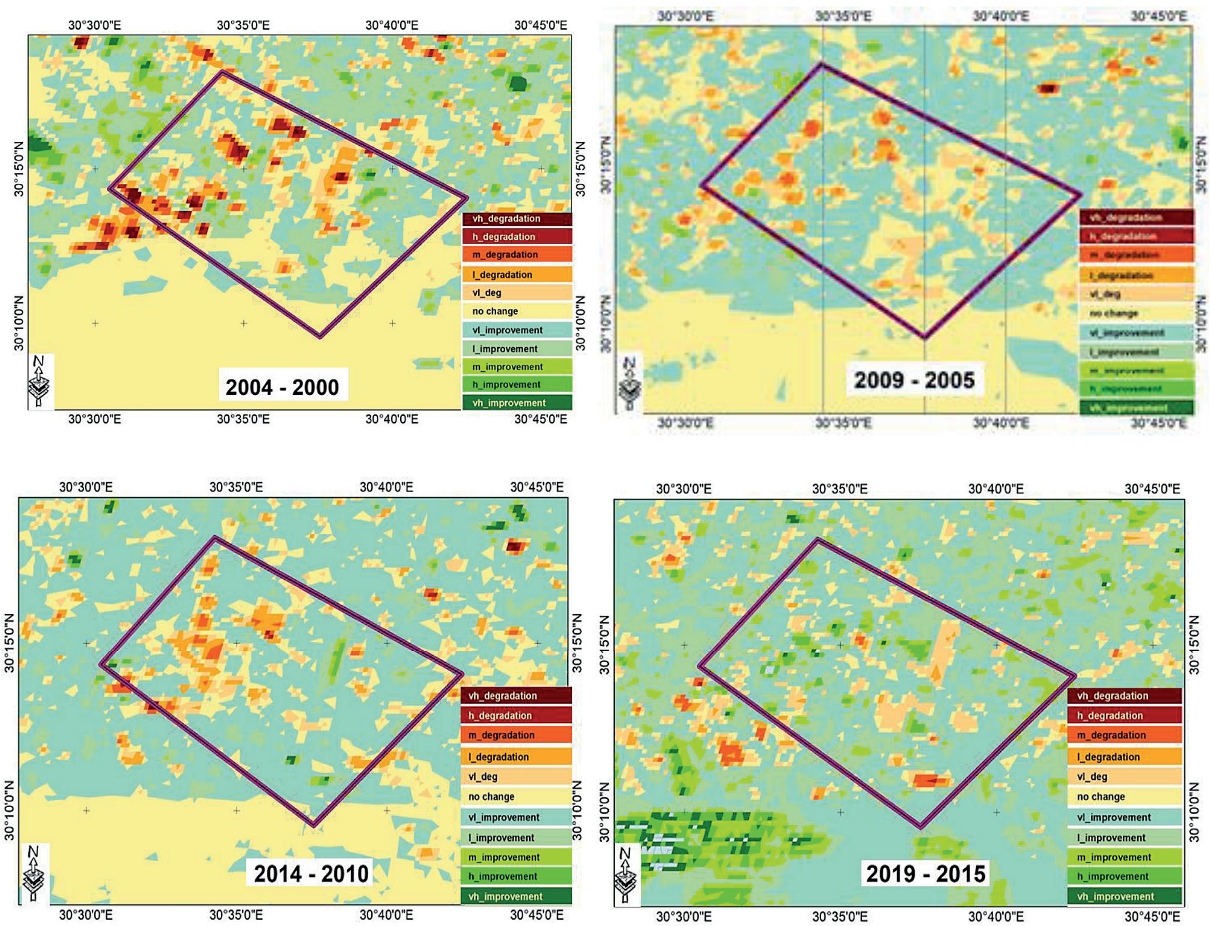


Figure 3. The land cover changes in each period

On the basis of the histogram of the digital elevation model (DEM), the geomorphic mapping units were created. Then, the geomorphic mapping units combined with the geologic map to create the physiographic mapping units, according to Zinck, 2017. The geopedological approach was followed (Zinck, 2017) for identifying the central physiographic mapping units (Landscape, Relief, Lithology, and Landform).

Table 2 show the physiographic mapping unit of the studied area. Figure 5 shows the physiographic mapping units overlaid by soil sample suits of the studied area.

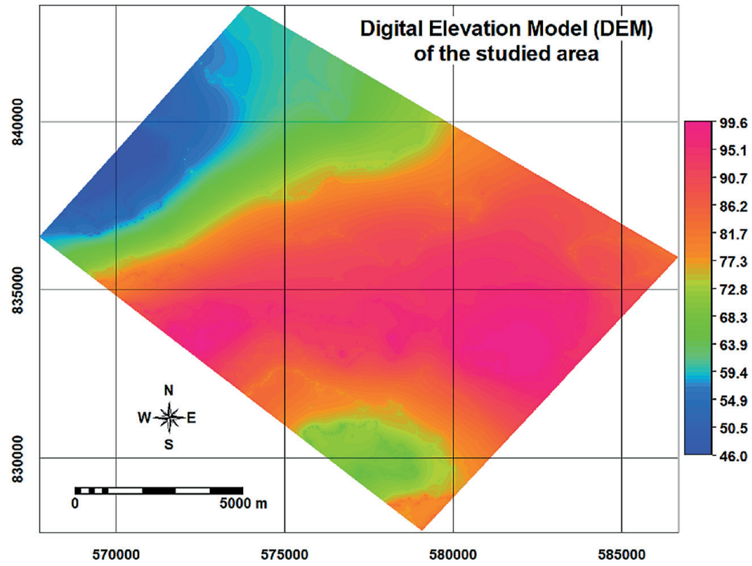


Figure 4. The Raster DEM values map of the studied area

Table 2. The physiographic mapping unit of the studied area

Landscape	Relief	Lithology	Landform	Area in	
				Feddan	%
Alluvial plain	Plain	Marmica formation, stabilized sand dunes	PL111-Longitudinal sand dune	193.7	0.55
			PL112-Pyramid sand dune	5.4	0.02
		Marmica formation, sand sheet	PL121-Sand sheet relatively low	12863.7	36.78
			PL122-Sand sheet relatively high	1027.2	2.94
Plateau	Marut tableland	Moghra formation	PU231-Relatively low terraces	12380.4	35.40
			PU232-Relatively high terraces	6467.7	18.49
			PU233-Sand dune	2039.0	5.83
Total area				34977	100

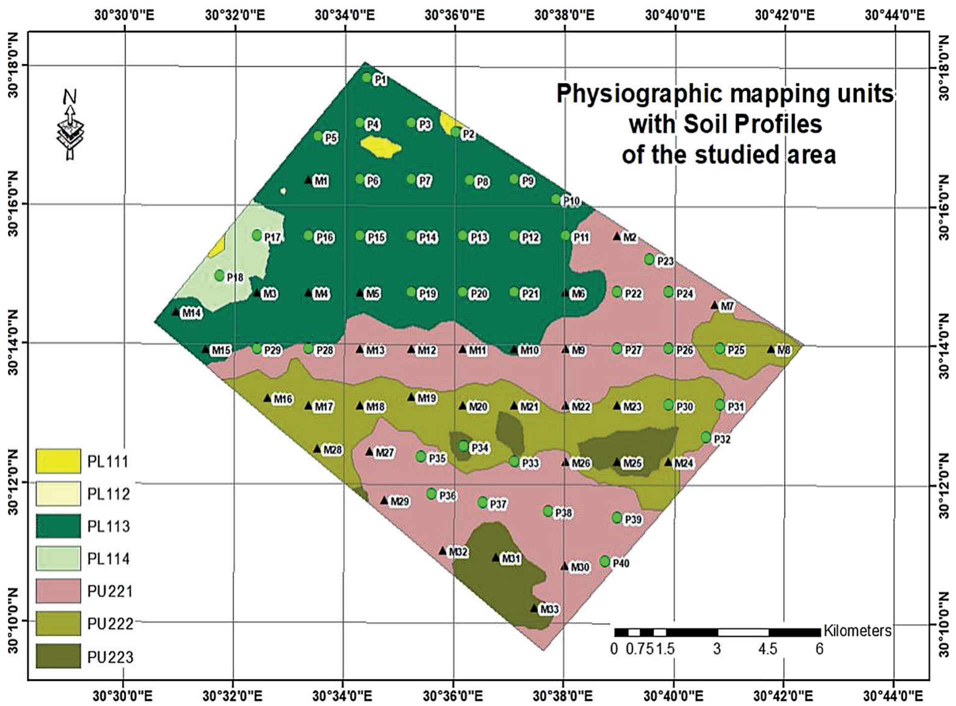


Figure 5. Physiographic mapping units overlay by soil sample

Fieldwork performance

In total, 73 soil profiles were dug to study morphological description and collect soil samples in the studied area with a fixed grade system and selected 40 soil profiles with 33 soil augers. Morphological description in the field was done using (FOA, 2006), and preliminary soil taxonomy was classified in situ using (USDA, 2014). This soil taxonomy classification was verified with the necessary lab investigation achievement and the morphological description of soil profiles.

Produce soil properties maps

Morphological description, chemicals, physicals, and fertility soil properties of the studied area were determined to create all thematic maps. Two types of data were used to produce the thematic maps. Thematic maps were produced from value data (effective soil depth, soil salinity, soil alkalinity, water table depth, water table salinity, $CaCO_3$%, Gypsum %, and OM%). Thematic maps from descriptive data (soil texture and soil taxonomy classes) were produced. The geostatistical analyses were tested for all physical and chemical soil properties. The parameters of the best-fitted curves of significant correlation with thematic soil properties were used to interpolate each thematic map using the kriging method. The test, insignificant due to the real nugget, was interpolated using the moving average method.

The soil salinity classes show that about 52.21% of the studied area is wedged between non-saline and slightly saline soils. Moreover, only 23.23% of the studied area was moderately saline soils, and 24.56% ranged between strongly saline and very strongly saline soils. Moreover, the soil alkalinity map results show that about 99.21% of the studied area ranges between non-alkaline and slightly alkaline soils. Moreover, only about 0.79% of the studied area is alkaline soils (no need for gypsum added). The results of effective soil depth show that about 63.34% of the studied area is classified as very deep soils. Moreover, 36.66% of the studied area is classified as deep soils.

The results of calcium carbonate content classes show that about 0.20% of the studied area is classified as noncalcareous to slightly calcareous soils, and about 85.47% of the studied area is classified as moderately calcareous soils.

Finally, about 14.33% of the studied area is classified as strongly calcareous soils. The results of gypsum content classes show that about 98.3% of the studied area is classified as slightly gypsic soils, and the remaining (1.7%) was classified as non-gypsic. Moreover, the results of organic matter content show that about 99.40% of the studied area is classified as very low, and only 0.40% of the studied area is classified as having low organic matter content. Figure 6 shows the maps of physical and chemical soil properties.

The results of soil texture classes illustrated that the sand classes cover about 43.61% of the studied area, and 35.68% of the studied area was classified as loamy sand soils. Only 20.71% of the studied area was classified as sandy loam.

Finally, the results of soil taxonomic units show that the dominant sub-great groups are *Typic Torripsamments* (59.35%), *Typic Torriorthents* (20.76%), *Typic Haplocalcids* (19.03%), and *Sodic Haplocalcids* (0.85%).

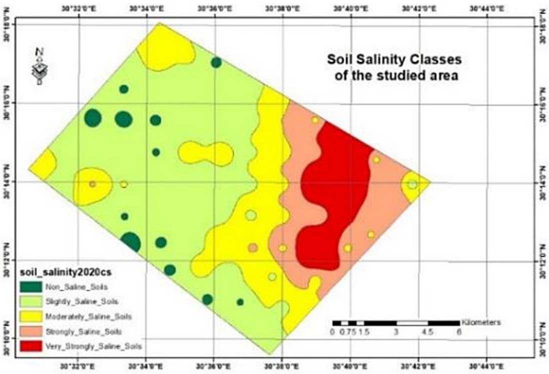
CONCLUSIONS

Land use and farm management systems in Wadi El Farigh vary, where farms are managed with state-of-the-art irrigation systems with high investment capabilities, can interact with all the variables in the quality of water and economies, and farms that follow modern irrigation systems but have problems in the ability to address the adverse conditions experienced by the area.

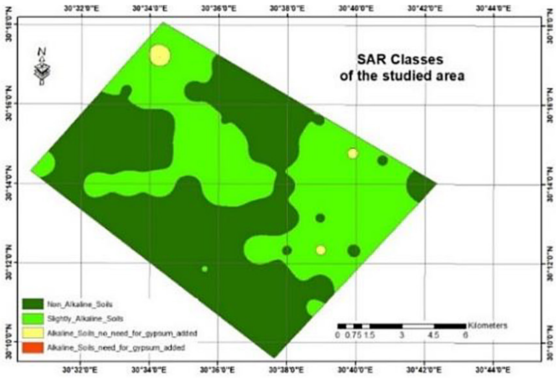
The agriculture in Wadi El Farigh has expanded significantly depending on the previous two approaches referred to in the farm administration. Land use and farm management systems in Wadi Al-Farigh are diverse, where farms are managed with the latest irrigation systems with high investment potential and can interact with all variables in water quality and economies. Other farms follow modern irrigation systems but have problems being able to address the adverse conditions experienced by the region.

A change in Wadi El Farigh water quality has been observed on many farms and could consider one of the reasons for the change in the types of agriculture on many farms.

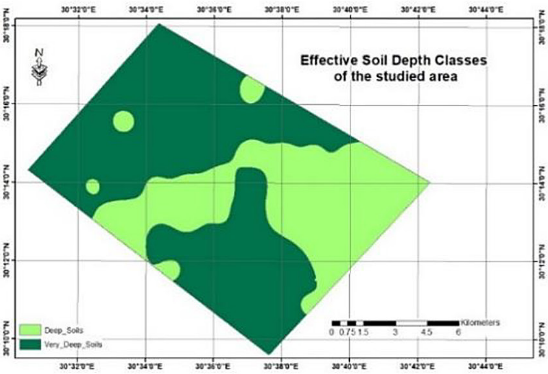
Winter plastic tunnel plantings, which have been extensively expanded in the region, appear in space images as degradation because they do not reflect chlorophyll, which is one of the flaws of the space image-based study system. This requires linking the studies based on space images with land degradation trends with field studies to ensure the dynamics of changes.



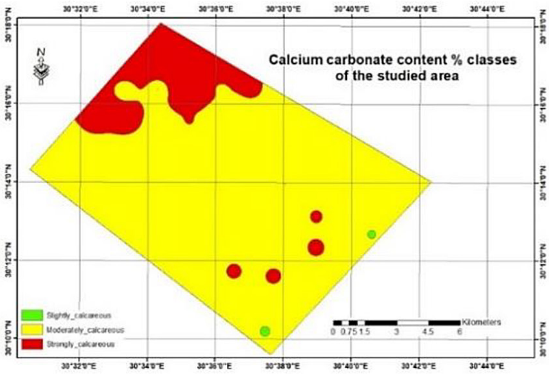
Soil salinity classes map



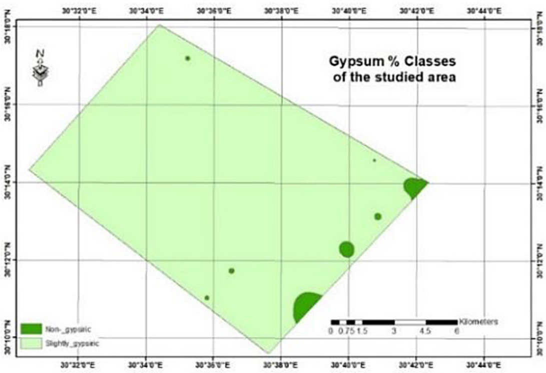
Soil alkalinity classes



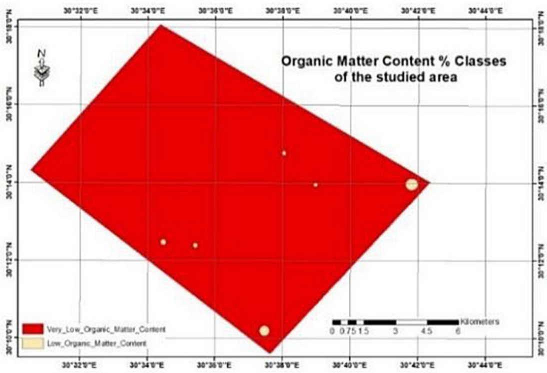
Effective soil depth classes



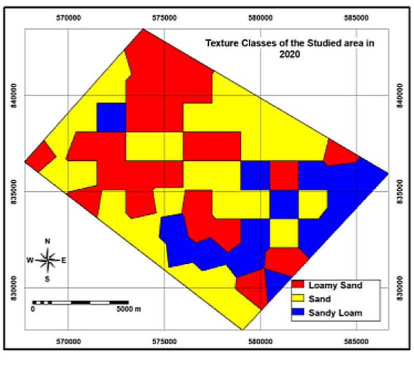
Calcium carbonate content % classes



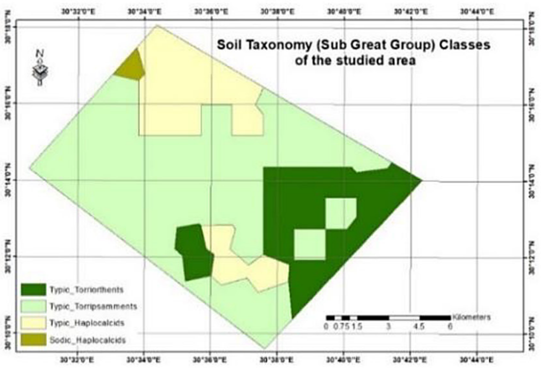
Gypsum content classes



Organic matter content classes



Soil texture classes



Soil taxonomic units

Figure 6. Maps of physical and chemical soil properties

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