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Research

Monitoring of Land Reclamation Development in Newly Reclaimed Area in El-Mania Governorate, Egypt

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Abstract

Agricultural expansion is one of the main strategies for reducing the food gab in developing countries. In Egypt, land reclamation projects have been started for over 50 years and have a significant contribution to food production. Some of the newly reclaimed areas progressed well, while others faced some problems that decreased the production. Recently, a new project for land reclamation have been initiated to make an expansion towards the desert areas along the old agricultural land. The current study aims at monitoring the reclamation development and changes in land use/cover (LULC) in a newly reclaimed area in El-Mania, Egypt. Multi-temporal remotely sensed data were utilized for land use mapping in 2014 and 2017, then monitoring the changes in LULC. Different image enhancement and processing techniques were used, where supervised classification approach followed by post-classification change detection algorithms were applied, in addition to Normalized Difference Vegetation Index (NDVI) for vegetation monitoring. Regarding to agricultural areas, the results showed that there are two types of changes occurred, first; decreasing in cultivated areas that belong to the pioneer agricultural company and the second; significant increase in the areas which reclaimed by individual farmers. The obtained results could help in following up the newly reclaimed areas and setting the proper management system that could be flexible to the changes.

Keywords: Remote Sensing; Change Detection; Land Reclamation; El-Mania; Egypt

Introduction

Agriculture is one of the world's most important activities supporting human life. While the population growth is very fast, the land resources regeneration is very slow. However, on a global scale, agriculture has the proven potential to increase food supplies faster than the growth of the population [1]. Arid and semi-arid regions are quite vulnerable, because the water shortage, usually compensated by ground water, is not felt in the short term and resources may be over-utilized. On the other hand, the occurrence of saline and alkaline soils as well as poor soil and water management increase the vulnerability [2].

The challenge in the next decades is to ensure that global and regional food security increases food production for the survival of the growing population. However, this puts increased pressure on land resources, which may result in land degradation, particularly in countries with restricted water and other natural resources [3]. As a result, food security is one of the top agricultural policies in developing countries, in addition to the land evaluation for current and future agricultural uses.

Egypt has a total land area of approximately one million km^2, most of which is desert and only 5.5% is inhabited. Settlements are concentrated in and around the Nile Delta and the Nile Valley, which narrows considerably in Upper Egypt. The total cultivated land area is about 3.6 million ha (8.6 million Fadden) representing 3% of the total land of Egypt and consists mostly of the old agricultural land in addition to newly reclaimed areas. The climate is arid with very scarce rainfall in a narrow strip along the north coast. The Nile River is the main and almost exclusive source of surface water in Egypt. Agriculture depends on the Nile waters and consumes about 80-85% of the annual water supply [4]. Accordingly, there was an urgent need to increase the agricultural production by optimizing the usage of the available land and water resources mainly through horizontal expansion or land reclamation and application of modern agriculture and irrigation systems.

In Egypt, land reclamation projects have been started for over 50 years, and have a significant contribution to food production. Nowadays, a

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new national project for land reclamation have been planned to make an expansion towards the desert areas along the old agricultural land. In general, some of the reclaimed areas progressed well, while others faced some problems that could significantly reduce the production or cause land degradation. Therefore, land use/cover (LULC) changes monitoring is very important for the planners and governments, particularly in case of increasing pressures from human and natural activities on the adjacent environment [5]. Where land cover changes over time naturally or as a result of anthropogenic activities [6,7]. Studying the trend, rate, and causes of LULC changes are necessary for the development of rational land use policy [8]. in addition, land cover mapping is highly acknowledged for water resources management [9].

Remotely sensed (RS) data have been widely used to map and monitor the earth surface changes over a large area [6] since these data are characterized by the high temporal frequency, digital format, synoptic view, and variation of spatial and spectral resolutions [10]. Land sat imagery are one of the most important sources of data for investigating and monitoring various types of land cover change, i.e. agriculture expansion and intensification, urban growth, deforestation, in addition to land surface biophysical and geophysical properties [7,11,12]. Recently, Land sat 8 offers significant improvements in both data quality (i.e., noise reduction) and spectral coverage [13]. Furthermore, integration of remote sensing (RS) and geographic information systems (GIS) provides a great capability for analyzing, modeling and planning the LULC. Hence, the environmental driving forces of LU expansion could be investigated, the present conditions could be handled by means of geospatial tools, and representing the expected scenarios in the future. Consequently offers a noticeable help in planning and conserving the natural resources [5].

Regarding land reclamation, vegetation is considered as the primary indicator of land cover. Thus, quantitative analysis of the changes in its composition, biomass and vigor helps understand land cover modifications [14]. RS data have proved a potential contribution in monitoring and predicting vegetation changes over large regions in a repeatable manner. As the satellite-based Normalized Difference Vegetation Index (NDVI) has been confirmed to be a successful indicator of vegetation activities [15]. Vegetation indices, i.e. NDVI and Enhanced Vegetation Index (EVI), employ the large differences of reflectance between the near infrared (NIR) and the red (R) bands to estimate vegetation cover. Generally, NDVI is more sensitive to chlorophyll activity and most widely used index, whereas variation in vegetation structure is more related to EVI [9,16].

Digital change detection utilizes the co-registered, multi-temporal remotely sensed data to determine and quantify the changes [17]. This process is affected by various elements including spatial, spectral, thematic and temporal constraints, radiometric resolution, atmospheric conditions, and soil moisture conditions [18]. There are several methods for change detection, which can be categorized in two approaches: 1) a spectral-based approach by which simultaneous analysis of multi-temporal and/or multispectral data is conducted, and 2) a post-classification based approach when the changes are derived from comparing the independently classified images. Additionally, a hybrid approach using both types can also be adopted [17].

The current study aims at mapping the land use/cover (LULC) of a newly reclaimed area at successive periods in order to assess the changes in LULC, and to investigate the causes of such changes. Therefore, the available Land sat 8 imagery covering the studied period were processed in order to map LULC for further change detection analysis. Emphasize was given to the agricultural areas and the main reasons of their changes, in order to help the decision makers in planning and following up the reclamation projects, moreover, to overcome any rising problems.

The Study Area

The study area lies in the Northwest of El-Mania Governorate, Egypt. It is a part of the Western desert and bounded by Western Asyut-Cairo desert-road from the eastern side. It extends from Latitude 28° 18′ 36.86″ to 28° 32′ 5.81″ N and Longitude 30° 20′ 40.50″ to 30° 36′ 23.6″ E (Figure 1) and covers approximately 53731 ha (127931 Fadden). The study area is situated in the arid and desert zones of Egypt, and characterized by long hot summer, short with rare rainfall winter, high evaporation rate, and moderate relative humidity. The minimum and maximum temperature are 4.6°C (January) to 21.1°C (July) and 20.4°C (January) to 36.9°C (July). The average daily temperature is 11.9°C in (January) and 29.2°C in (July). The rainfall rate is zero in July and increasing gradually reaching the maximum value (1.74 mm/month) in March, and the annually rainfall is about 4 mm/year. Evaporation rate ranges from 3.5 mm/day in December to 14.6 mm/day in (June), with average value 8.8 mm/day, while the evapotranspiration is about 4897.91 mm/year [19].

The mean monthly relative humidity during daytime according to Egyptian Meteorological Authority data ranged from 39.2 % in May to 68.8 % in December, with average value 54.76 %. Wind comes from north direction represent the main winds direction represented by 43% followed by northwest direction about 24 %, northeast direction about 12 %, quit state about 6 %, south direction, about 4 %, southeast direction about 4 %, west direction about 3 % and southwest direction about 3 %. The maximum wind speed 9.4 knot/hour in (June) and the minimum speed 4.9 knot/hour in December, with average 7 knot/hour.

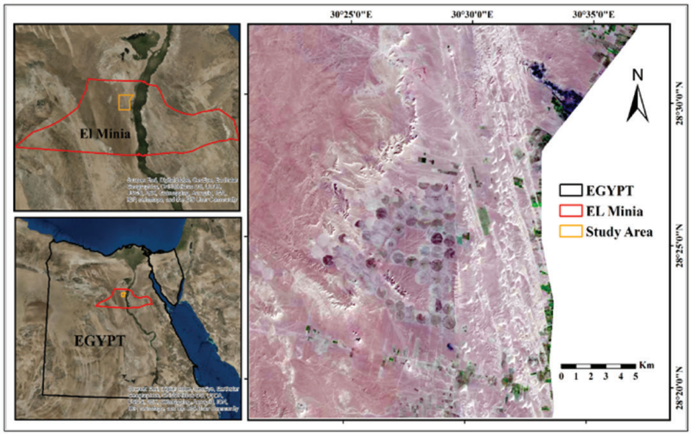


Figure 1: Location of the study area.

Material and Methods

Spatial Data and Processing

Landsat 8 (operational land imager, OLI) imagery of 2014 and 2017 with spatial resolution 30 m were used to map the land use and analyze temporal changes in the study area. The Land sat data provided by The United States Geological Survey (USGS) (http://glovis.usgs.gov) were reprojected to UTM projection system with datum WGS 84 zone 36N.

Then the images were radio-metrically corrected in two steps; the atmospheric correction was executed using ENVI 5.3 software to remove the influence of the atmospheric interference using the dark object subtraction (DOS) technique. Then, radiometric calibration module in ENVI 5.3 was used to convert digital number (DN) of image pixels to reflectance values of the ground objects. Normalized difference vegetation index (NDVI) for both images of 2014 and 2017 was used in order to distinguish and investigate the changes in the vegetation land cover. This index was produced using ERDAS IMAGINE 2014 program according to the following equitation for Land sat 8:

NDVI = (band 5 – band 4)/ (band 5 + band 4)

The value of NDVI ranges between −1 and 1, simply positive values correspond to vegetated areas the higher the index, the greater the chlorophyll content of the target [20].

On the other hand, in order to have historical view of land reclamation activities in the study area, Google earth imagery covering the period from 2008 to 2013 were downloaded (taking into consideration the acquisition date to be close to each other) and presented only for visual interpretation and monitoring the changes progress.

Image Classification

Enhanced false color composite (bands: 5, 4, 1) for Land sat 8 images were visually interpreted as a pre-field work step and then verified during the field work with the aid of GPS to collect the ground truth information. The fieldwork was carried out during February 2014 and for the image of 2017 the land use/cover information was gathered by interviews with some farms' owners. The collected data coupled with visual interpretation were used to generate vector layers as training and reference data for the classification process. The main land use/cover classes of the study area are described in Table (1).

Land cover classes were mapped from remotely sensed data through the supervised classification technique (executed in ENVI 5.3). The maximum likelihood classifier was chosen for classification, as it quantitatively evaluates both the variance and covariance of category spectral response pattern when classifying an unknown pixel. So that, it is considered to be one of the most accurate classifiers since it is based on statistical parameters [8].

Classification Accuracy Assessment

Classification accuracy was determined empirically by selecting a sample of pixels from the classified image and checking their labels against classes determined by reference data. The percentage of pixels from each class labeled in the image correctly by the classifier was estimated as well as the proportion of pixels from each class erroneously labeled into every other class. These results were expressed in tabular form referred to as the error matrix [21]. A kappa coefficient was calculated as it is commonly used to assess the agreement between the classified map and the reference or standard data [22]. Values of kappa greater than 0.75 indicate strong agreement, values between 0.4 and 0.75 indicate fair to good, and values below 0.40 indicate poor agreement. In the current study, the classification

Class	Description
Barren land	Land areas of exposed soil surface as influenced by human impacts and/or natural causes. This land refers to uncultivated land without vegetation cover.
Agriculture	Areas cultivated with annual crops, vegetables, or orchards. These crops are irrigated mainly from the groundwater.
Sand dunes	Hills of loose sand that consist of any accumulation of sand grains shaped into a mound or ridge by the wind under the influence of gravity.
Basalt quarries	Areas with human-induced effects that result in exposing soil surface layers and/or changes in topsoil. Includes areas with active excavation and mining of basalt.

Table 1: Description of different land use/cover classes of the study area.

accuracy assessment performed based on 400 random points for each image, which identified and located using stratified random method to represent the different LULC classes of the study area.

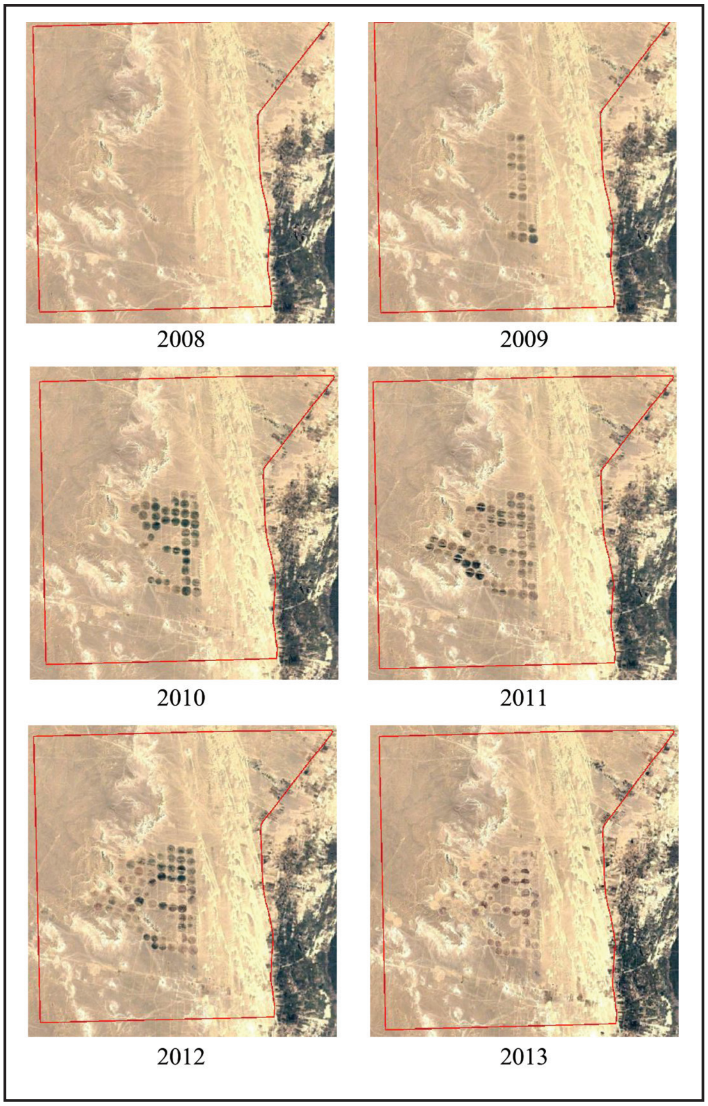
Change Detection of Land Use/Cover

There are several methods to implement change detection. In this study, post-classification method was adopted to perform change detection using thematic change workflow in ENVI 5.3 to explore and quantify the changes of LULC classes occurred between 2014 and 2017.

Results And Discussion

Historical View of Reclamation Progress Since 2009

The collected information from the local farmers in the study area together with Google earth data (Figure 2) showed that land reclamation activities have various stages. The reclamation process initiated in 2009 by a large agricultural corporation using pivot sprinkler irrigation system mainly for sugar beet cultivation which appears as circular shapes in the central part of the images. Then, the agricultural area increased significantly in 2010 2011 and 2012. In 2013 the company suspended its activities due to the political conditions and some administrative problems. Afterwards, in 2014 the company resumed its activity before it finally stopped in 2015 (Figures 3 and 4). On other hand, land reclamation practices by individual farmers have been considerably increasing.


2008 2009

2010 2011

2012 2013

Figure 2: Historical images for the study area from 2008 to 2013 (source: google earth).

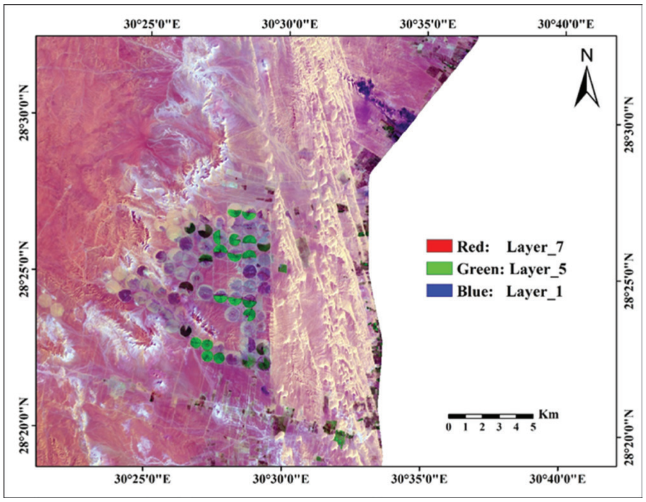


Figure 3: Landsat 8 (OLI) image of the study area in 2014.

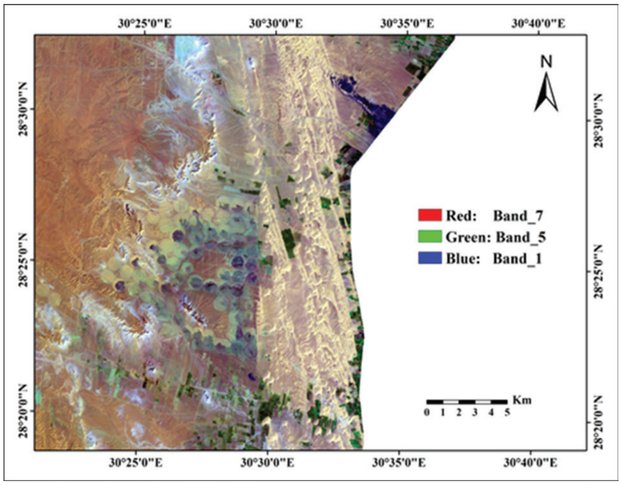


Figure 4: Landsat 8 (OLI) image of the study area in 2017.

Land Use/Cover Mapping

Supervised classification of the image of 2014 (Figure 5) revealed that "barren land" was the highest class representing about 81.3 % of the total study area with area of about 43660 ha (Table 2). While the agricultural area (reclaimed land) represented 6.1 % (about 3298 ha). The classification accuracy assessment of 2014 classified image showed an overall accuracy of 91.50 % and Kappa coefficient of 0.88 (Table 3). In 2017 (Figure 6) the area of agricultural land increased overall the study area reaching 7.5 % with an area of about 4037 ha (Table 2) although some cultivated lands which irrigated by the sprinkler pivot irrigation system were declined. The classification accuracy showed an overall accuracy of 90.75 % and Kappa coefficient of 0.87 (Table 3).

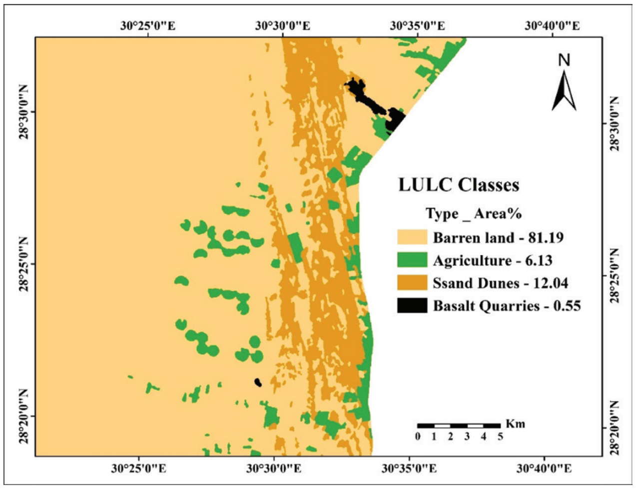


Figure 5: Land use/cover map of the study area in 2014.

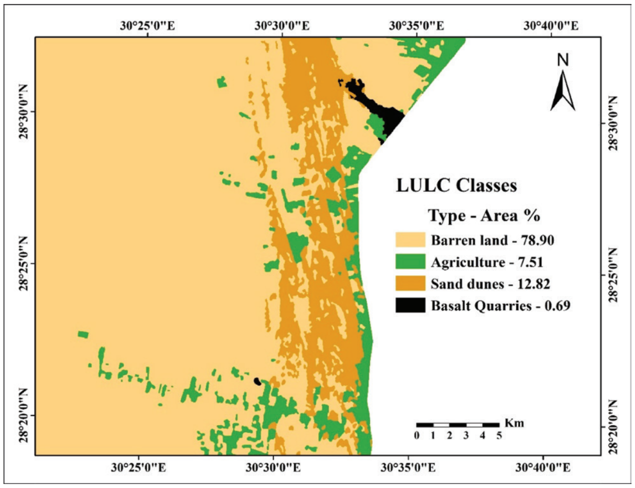


Figure 6: Land use/cover map of the study area in 2017.

Land cover class	2014		2017		The change	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agriculture	3298	6.1	4037	7.5	739	22.4
Barren land	43660	81.3	42431	79.0	-1230	-2.8
Sand dunes	6475	12.1	6894	12.8	419	6.5
Basalt quarries	297	0.6	370	0.7	73	24.4

Table 2: Area and percentage of LULC classes for 2014 and 2017 and their changes.

	LULC Classes	Reference data				Classification accuracy			
		Agriculture	Barren land	Sand dunes	Basalt quarries	Producers accuracy	Users accuracy	Overall accuracy	Kappa coefficient
2014 Classified data	**Agriculture**	91	4	2	2	86.1	88.6		
	Barren land	5	140	5	3	88.8	87.0		
	Sand dunes	3	4	91	1	88.6	88.6		
	Basalt Quarries	1	2	2	44	80.0	80.0		
								91.50	**0.88**
2017 Classified data	**Agriculture**	92	5	3	3	83.6	87.1		
	Barren land	3	141	6	4	86.4	89.0		
	Sand dunes	4	2	90	3	85.7	85.7		
	Basalt Quarries	1	2	1	40	85.7	60.0		
								90.75	**0.87**

Table 3: Error matrices and total accuracy for classified images of 2014 and 2017.

NDVI Analysis

As demonstrated in Figures (7 and 8), the high values of NDVI indicated a dense vegetation cover or a healthy field crops. While the low values of NDVI indicated orchard trees, where the space between the trees is large enough to get mixture reflectance from both the canopy of the trees (high values) and soil (low values). Furthermore, the low values of NDVI could be also due to the sparse or not healthy vegetation. Figure (7) shows that most of the reclaimed areas in 2014 were situated in the central and eastern (adjacent to the Cairo-Asyut road) parts of the study area. Whereas in 2017 the most of the reclaimed areas concentrated in the eastern and southern part as illustrated in Figure (8). The obtained NDVI images were utilized to monitor the changes in vegetation between 2014 and 2017, and Figure (9) shows areas with increased or decreased vegetation. This demonstrates the importance of NDVI for monitoring the vegetation conditions and its changes.

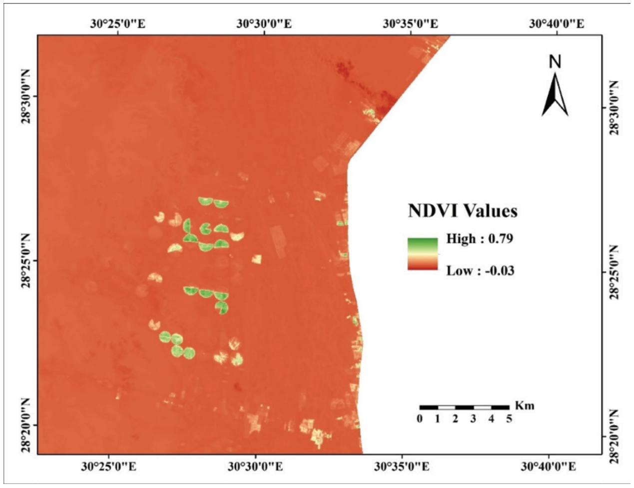


Figure 7: Normalized difference vegetation index of the study area in 2014.

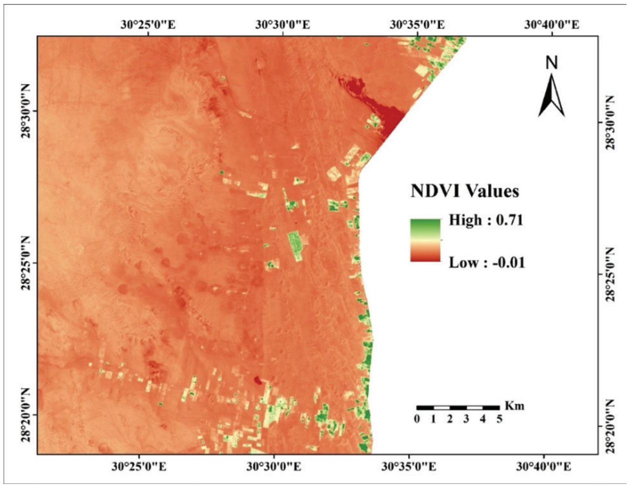


Figure 8: Normalized difference vegetation index of the study area in 2017.

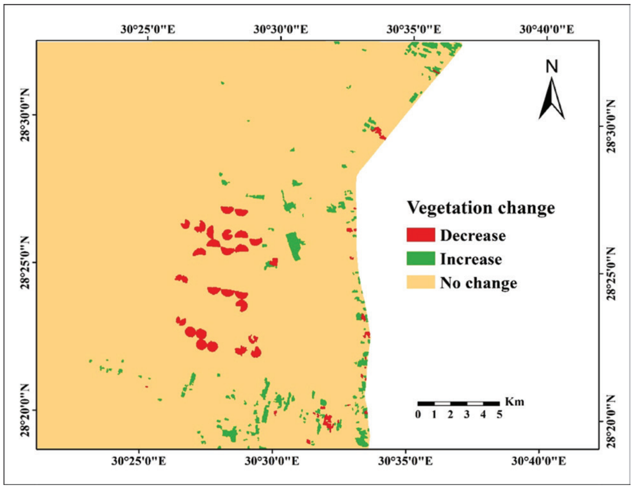


Figure 9: The changes of vegetation between 2014 and 2017 (using NDVI difference).

Change Detection of Land Use/Cover

The LULC maps of 2014 and 2017 were utilized in post-classification change detection algorithms in order to generate LULC changes map (Figure 10). The percentage and magnitude of changes in each LULC class are shown in Table (2). The cross-tabulation matrix (Table 4) between the two dates illustrated that, the major observed change occurred in barren land that decreased from 43648.3 to 42426.0 ha, which attributed to the reclamation of new areas. The area of agricultural land use was increased from 3296.3 to 4026.2, despite of the disappearance of some areas that were cultivated using sprinkler pivot irrigation. The increment in agricultural areas gained from 1702.2 ha (3.9 %) of barren land, also from conversion of 141.7 ha from sand dunes to agriculture, while the least change was the conversion of 0.4 ha from basalt quarries to agriculture. On the other hand, 883.8 ha were converted in 2017 to sand dunes resulted from agriculture (59.2 ha), barren land (814.8 ha) and basalt quarries (9.8 ha).

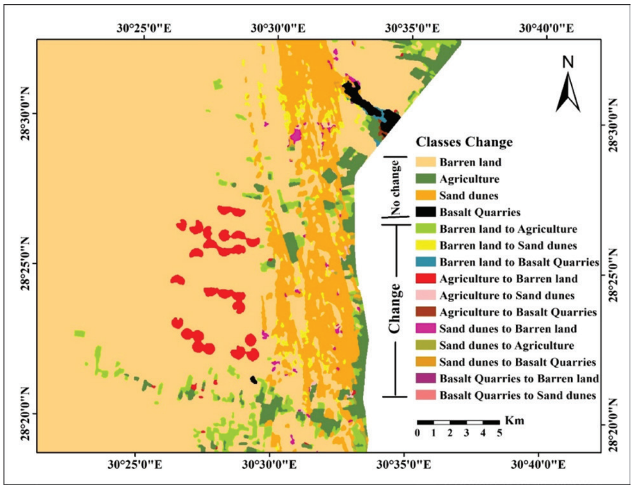


Figure 10: Spatial distribution of LULC changes between 2014 and 2017.

	LULC classes	2014				
		Agriculture	Barren land	Sand dunes	Basalt quarries	Class total
2017	**Agriculture**	2182.1	1702.2	141.7	0.4	**4026.2**
	Barren land	1034.1	41078.4	309.8	3.7	**42426.0**
	Sand dunes	59.2	814.8	6009.7	9.8	**6893.5**
	Basalt quarries	21.0	52.9	12.2	283.2	**369.4**
	Class total	**3296.3**	**43648.3**	**6473.3**	**297.1**	
	Class change	**1114.3**	**2569.9**	**463.7**	**13.9**	
	Final difference	**729.9**	**-1222.3**	**420.1**	**72.3**	

Table 4: Cross-tabulation of land use/cover area (ha) between 2014 and 2017.

Conclusion

Land use/cover change is a global phenomenon and accurate monitoring of such change is of great importance for land and water resource management. The current study was conducted in order to monitor the changes in land use/cover in a newly reclaimed area in El-Mania Governorate, Egypt. In order to achieve that goal, multi-temporal remotely sensed data were analyzed to extract land use/cover information for monitoring LULC changes, with more emphasize on vegetation changes. Supervised classification was applied to Land sat 8 imagery acquired in 2014 and 2017, followed by post-classification change detection technique. Moreover, Normalized Difference Vegetation Index (NDVI) was extracted for both images to evaluate the changes in vegetation cover. The results showed that, the reclamation process initiated in 2009 and the agricultural area increased significantly until 2012. Afterword, due to the political conditions, administrative and financial problems, the agricultural activities were stopped in some areas 2015. Simultaneously, land reclamation activities by individual farmers were considerably increasing.

The classification of remotely sensed imagery showed that, in 2014 the agricultural area represented 6.13 % (about 3298 ha), while in 2017 the agricultural land had increased overall the study area reaching 7.51% (about 4037 ha). In general, the major observed change was from barren land to agriculture with an area of about 1702.2 ha. Moreover NDVI proved the potentiality for monitoring the vegetation conditions and its changes. Finally, the results could help the decision makers to put management plans with various scenarios, and to monitor and evaluate the progress in land reclamation for optimum land and water resource management.

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