Chapter 6
Application of Remote Sensing for Monitoring Changes in Natural Ecosystems: Case Studies from Egypt

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Abstract In Egypt, monitoring and assessing the changes in natural biodiversity by the traditional site-based methods involve considerable effort and costs. Alternatively, remote sensing can be used as a promising technique to provide complete coverage of habitat, and vegetation species at a specific study area over a given period. Hence, this chapter considers the state-of-the-art of remote sensing for mapping the environmental variables at different locations in Egypt, including deserts, oases, sand dunes, saltmarshes, fish farms, reed vegetation, and agricultural lands. Moreover, the detections of land use/land cover (LULC), soil properties, spatial rainfall distribution, and surface runoff, as well as the management of flood and water resources, by geographical information systems (GIS) were demonstrated. The chapter undertakes useful information and knowledge about the Egyptian environment, giving multiple benefits to researchers, policy planners, and stakeholders. The study objectives are illustrated regarding previous articles reported in the literature.

Keywords Ecological monitoring · Egyptian environment · Habitat detection · Landsat satellite · Remote sensing

6.1 Introduction

Recently, in Egypt, urbanization, anthropogenic activities, and exponential population growth have resulted in severe reductions in water bodies and agricultural lands (Halmy 2019). Remotely sensed data, including satellite images, and aerial photos

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can be used to monitor the surface features and human activities at various regions in Egypt (Shalaby and Tateishi 2007). Remote sensing also plays a significant role in environmental and conservational applications, especially for monitoring the changes in biodiversity and natural ecosystems (El-Asmar et al. 2013). Remote sensing technologies offer periodic repeat coverage of satellite-based maps, which can be used to understand and asses the management of natural resources (Hegazy and Kaloop 2015). Hence, the subject of remote sensing should be comprehensively investigated to provide a complete evaluation of ecological and environmental conditions in various regions.

The use of traditional field surveys entails considerable efforts to offer accurate spatial and temporal coverages of natural ecosystems (Halmy et al. 2015). The integration of in situ observations with remotely sensed data is useful to obtain inclusive outcomes, such as site allocation, terrestrial biodiversity, and habitat classification (Maxwell et al. 2018). This trend could be due to the inaccessibility to some regions having steep slopes, dense mangrove forests, polluted area, and water body obstacle (El-Asmar et al. 2013; Belal and Moghanm 2011). Moreover, a standardized sampling protocol should be provided to evaluate the spatial habitat heterogeneity, species-habitat relationships, and other environmental properties (Abdel-Kader 2018). For instance, Wang et al. (2012) investigated the integration of in-situ sampling with remote sensing in the University of Wyoming King Air (UWKA) to study the cloud microphysical properties and dynamical processes. Moreover, the sampling protocol can be linked to species distribution models to forecast the patterns of species across the place, time, and attributes using environmental and geographic data (Faid and Abdulaziz 2012). Furthermore, physical variables such as elevation, slope, texture, orientation, and temperature have also proven to be appropriate inputs to prepare high-resolution images (Halmy et al. 2019).

Recently, large quantities of global data have become readily accessible due to the development of remote-sensing methods (Ghassemian 2016). Moreover, earth-surveying techniques have been integrated with remote-sensing technologies to attain sufficient information about the biodiversity profile over time in a given region (Araujo Barbosa et al. 2015). However, still, the application of remote sensing to monitor the environmental and biodiversity changes in Egypt requires broad studies (Afifi and Semary 2018). Hence, this chapter provides an overview of the recent applications of remotely sensed data for monitoring the biodiversity and ecosystem changes in some regions of Egypt. Moreover, this chapter represents the use of satellite-based remote sensing for the detection and description of environmental pollutants. The potential and limitations of the application of remote sensing technologies in the arid ecosystems of the Egyptian desert are discussed. This work attempts to overcome the problems of the complexity and high cost of data acquisition, the unavailability of specialized search engines, and the absence of satisfactory geographic database.

6.2 Recent Applications of Remote Sensing: Case Studies in Egypt

This work attempts to obtain a broad and realistic view of the recently published articles regarding the application of remote sensing in Egypt during the last few decades. The search in Scopus database using the terms “remote”, “sensing”, and “Egypt” resulted in 60 documents for 1980–1990, 68 documents for 1991–2000, 211 papers for 2001–2010, and 470 documents for 2011–2019. The publications included about 70% articles, 15% conference papers, 5% book chapters, 2% review, and 8% other document types. This trend implies that the Egyptian government is exerting high efforts for the widespread application of remote sensing at various regions. In this context, this chapter represents an essential survey that can be helpful to the public and private sectors in Egypt.

Shalaby and Tateishi (2007) applied the remote sensing, and geographic information system (GIS) approaches to monitor the LULC change in the Northwestern coast of Egypt between 1987 and 2001. The study demonstrated that agricultural practices and tourist development plans caused a severe change in the land cover in the study area. This pattern was linked to land degradation, loss of vegetation cover, water shortage, and wind erosion.

Belal and Moghanm (2011) monitored the LULC change in the Middle of Nile Delta, Egypt, using remote sensing and GIS techniques during 1972–2005. The study demonstrated that the urban areas expanded by 5.8–7.2%, leading to the loss of productive cultivated lands. This pattern was mainly due to the exponential population growth. The findings of the article could be beneficial for the government and decision-makers to detect the illegal application of agricultural areas in Delta and Nile Valley.

Abdelkareem et al. (2012) described the evolution of paleo-rivers in the Nile basin of the eastern Sahara using Shuttle Imaging Radar (SIR-A) data. The location of the African Plate regarding the Earth’s equator and the significant shifts in paleoclimate have converted various rivers into dry channels obscured by sand deposits. The study also displayed the evolution stages of the Nile River and the change in its deposits from pure and silica-rich sandstone to kaolinite-rich sediments.

Faid and Abdulaziz (2012) investigated the LULC change in the desert of Kom Ombo area, South Egypt regarding urban expansion and agricultural development. Their study demonstrated that the agricultural sector improved by 39.2% through the years 1988–2008 with an average rate of 8.7 km^2 per year. Moreover, the study observed a total expansion in the urbanization of about 28.0 km^2 and a 70% increase in the canal length over the same period. The observations of this work could be useful in establishing policies and strategies for sustainable natural resource management.

AbuBakr et al. (2013) used remote sensing and GIS to define the past shape and flow direction of Wadi El-Arish, i.e., the most extensive ephemeral drainage system in the Sinai Peninsula, Egypt. Moreover, the study attempted to describe the reasons that caused the deviation of the study area from its original course. It was revealed that Wadi El-Arish shifted from northwest to northeast due to the recent uplifting of the Syrian Arc System that blocked the water flow across the main drainage course. It was suggested that a canal connecting the present drainage course with the previous one should be constructed to redirect the occasional runoff for sustainable agriculture development.

El-Asmar et al. (2013) applied the remote sensing approach to detect the changes in the surface area of the Burullus Lagoon, North of the Nile Delta, Egypt during 1973–2011. It was demonstrated that about 43% of the lagoon's surface area was reduced due to the impacts of reclamation activities for aquaculture, agricultural wastes rich in fertilizers and nutrients, and the movement of sand dunes from the coastal line. In addition, anthropogenic activities, population stresses, and soil pollution have led to the environmental degradation of Burullus Lake.

Elhag et al. (2013) applied the remote sensing method to monitor and understand the LULC changes in the Nile Delta region of Egypt from 1984 through 2005. The land-use information was described regarding the agricultural area, urban zone, desert region, fish farm, and surface water. The study found that urban and farming lands increased by almost 6.0% and 6.5%, respectively. A large portion of the desert area was changed to agricultural land due to the reclamation processes and human intervention. Moreover, the patterns of land cover were influenced by cropland degradation, desertification, and urban encroachment. Their work also proposed that remote sensing was a cost-effective technique that could acquire enough information about land development patterns and processes.

Gabr and El Bastawesy (2015) used field investigations and multiple sets of remote sensing data to estimate the hydrological parameters of flash flood events that affected Ras Sudr, Sinai, Egypt, during 2010. Results obtained from the Shuttle Radar Topography Mission (SRTM) and GIS depicted that the peak flow rate was 70 m^3/s, with a total discharge of 5.7×10^6 m^3. The study suggested that the extreme flash flood could be mitigated via (a) using an alluvial fan to adjust the natural flow dispersion, (b) building small dams at the fingertip channels, and (c) transferring the resulting discharge into a single channel.

Halmy et al. (2015) investigated the LULC distribution in the north-western desert of Egypt using the Cellular Automata (CA)-Markov chain technique during 1988–2011. The study demonstrated that built-up, resorts, cropland, and quarrying areas expanded by about 150%, 250%, 200%, and 120%, respectively. This pattern was influenced by agriculture intensification, land degradation, and deforestation. The proposed model predicted expansion in quarries, urbanization of the landscape, and growth in residential areas for 2023.

Hegazy and Kaloop (2015) studied the LULC change in Daqahlia governorate, Egypt using remote sensing data and GIS during 1985–2010. The work indicated that the rate of urbanization resulted in the loss of water bodies and agricultural areas. For instance, the urban land expanded by about 32% (i.e., from 28 to 255 km^2) along with a decrease in the agricultural sector by 33%. This pattern was influenced by the exponential population growth, unorganized land expansion, and increased immigration. The article would provide beneficial strategic plans for the economy and energy use to similar areas in Egypt.

Abdel-Kader (2018) investigated the seasonal and spatial variations of LULC in the northwest coast of Egypt during 2001–2016. The study depicted that the driest (89 mm/year) and the wettest (690 mm/year) years were 2010 and 2016, respectively. Moreover, the vegetation cover at Barrani increased to 38%, which could be linked to the impact of climate and human interactions.

Afifi and El Semary (2018) employed remote sensing and GIS to determine the impact of exhaustive and continuous cropping on soil degradation at the northern part of the Nile Delta during 1961–2016. The study demonstrated that the intensive application of soil for rice cultivation and poor land management caused a significant reduction in land capability and quality.

Yousif et al. (2018) used remote sensing and geological data to detect the occurrence of groundwater at the Western Desert of Egypt. Field studies, geophysical data, microfacies analysis, and GIS application were also demonstrated. The groundwater of Nubian sandstone was found under the confined condition, whereas that of Middle Eocene limestone and Oligocene sandstone was described as an unconfined aquifer. Moreover, the study clarified the infiltration and recharge reasons of groundwater during the pluvial time.

Bakr and Afifi (2019) investigated the LULC change in the Northern Nile Delta, Egypt, using maximum likelihood classifier for the years of 1972, 1984, 2003, and 2016. Accurate thematic maps were obtained using the post-classification tools of sieve classes, majority analysis, and clump classes. The study depicted that the agricultural area increased by approximately 10% between 1972 and 2003 due to the reclamation contribution. Concurrently, the urban land expanded from 5 to 9% during the same period. In addition, the fish farms stretched from 4% in 1983 to 11% by 2016, whereas the area of the Burullus Lake reduced from 480 to 222 km^2 during 1972–2016. These changes affected the rice cultivation and productivity in the monitored area.

Ghoraba et al. (2019) applied the Red List of Ecosystems (RLE) protocol to describe the disruption of the biotic processes in the Burullus Lake located at the north of the Nile Delta of Egypt. The LULC of salt marshes, fish farms, reed vegetation, agricultural lands, sand plain, and bare soil at 1973, 1978, 1999, 2003, 2014, 2015, and 2016 were represented using supervised classification of Landsat images. The study demonstrated that the remotely sensed approach succeeded to cope with the data insufficiency. The lake was influenced by nutrient-rich multisource discharges, which degraded the integrity and natural quality of the ecosystem. The threats impacting the Burullus wetland included biological resource use, pollution from domestic and urban wastewater, human intrusion and disturbances, transportation and service corridors, residential and commercial development, and agriculture and aquaculture.

Halmy (2019) used the Floristic quality (FQ) indices to investigate the effect of anthropogenic practices due to the LULC changes on the environmental quality of the northwestern coast of Egypt. The anthropogenic disturbance indices (ADIs) during 2011–2015 was reported for sand dunes, non-saline depression, salt marshes, and coastal dunes. However, in the past, the Mediterranean coastal desert ecosystem was influenced by the grazing and rain-fed agriculture practices. These factors provided negative impacts on the existing natural habitats, environmental integrity, vegetation quality, and species structure.

Halmy et al. (2019) used remotely sensed data to monitor the composition and distribution of alien plant species at the northwestern coastal desert of Egypt from 2011 to 2014. The collected environmental variables included soil type, vegetation index, topographic roughness index, and distances to roads, coast, resorts, and irrigation canals. The study depicted that the involvement of alien species into new regions due to human activities caused severe issues and threats to the biodiversity system. The data obtained via the species distribution modeling (SDM) approach predicted that at least one alien species could infest over 40% of the study region.

6.3 Changes in Coastal Saltmarsh Distribution as an Indicator of Climate Change

6.3.1 Problem Statement

Recently, satellite measurements have revealed a rise in both absolute sea level and sea level relative to land along the Egyptian coastline. Sea level rise due to climate change is an essential factor that affects the distribution of saltmarshes in many coastal regions (Halmy et al. 2014). Saltmarshes are also influenced by multiple factors such as invasive species, environmental pollution, and LULC change (Saintilan et al. 2018). Saltmarshes link the land and sea, and they deliver various advantages to the coastal communities, such as shoreline and marine biodiversity protection, sustainable fishery support, water quality enhancement, carbon sequestration, and wildlife habitat recovery. A study by Hansen and Reiss (2015) represented the impacts of saltmarshes on ecosystem services, and it highlighted various steps that could be used to mitigate and restore saltmarshes. Deviation in the distribution of the coastal salt marshes is an essential indicator of environmental change, and it has been recently proposed as an indicator of global warming. Hence, the current study aims at representing the distribution of saltmarshes at the northwestern coast of Egypt during 1984–2014.

6.3.2 Methodology

The study area is part of the Western Desert of Egypt located at the west side of Alexandria city. It stretches about 100 km from the Mediterranean coast to the southward of the Qattara Depression and extends westward to El-Alamein city (see Fig. 6.1). Grazing and rainfed agriculture are the primary land use activities in the region.

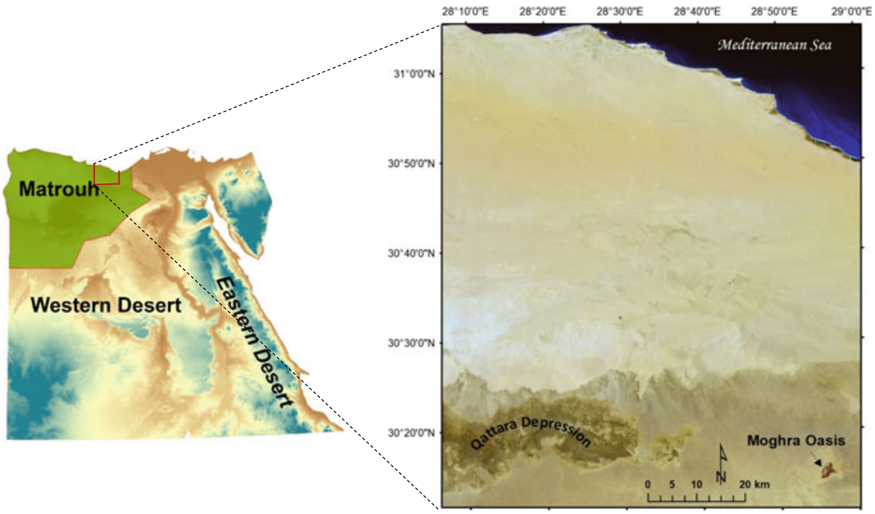

Fig. 6.1 Map of study area located at the Western Desert of Egypt (from 30° 20′ 0″ N to 31° 0′ 0″ N, and 28° 10′ 10″ E to 29° 0′ 0″ E) (*source* Halmy 2014a)

Figure 6.2 displays the flowchart of the methodology used for mapping the changes in the distribution of the coastal saltmarshes at the study area. The procedures have been reported in a previous study by Halmy et al. (2019). The major step was to obtain a time series of low-cost, high quality, and cloud-free imagery that could provide adequate information about the land surface features. Landsat 5 Thematic Mapper (TM) and Landsat 8 operational land imager (OLI) were used to acquire Landsat data during 1984–2003 and 2014, respectively. Radiometric corrections were carried out following Chander et al. (2009) for Landsat 5 TM data and Landsat 8 Data Users Handbook (Survey 2015). Topographic parameters derived from the SRTM data and vegetation indices obtained from Landsat data were included as ancillary observations to map the distribution of the coastal saltmarshes.

The Random Forest (RF) Algorithm was used as a machine learning technique for the classification of the multi-date subsets (Breiman 2001). This technique has been successfully employed for the classification of remotely sensed data, and it was reported to yield highly accurate groupings compared to the conventional classification methods (Belgiu and Drăguţ 2016). For example, a review article by Belgiu and Drăguţ (2016) represented the recent applications of the RF method to handle large data in remote sensing. Random forest models of size 500 decision trees and two variables at each split node were generated after successive trials of different combinations. The randomForest R package within the open-source R 3.0.3 (Core Team 2018) was used for conducting the classification process. The produced LULC maps were evaluated using the overall accuracy and Kappa coefficient (Ghoraba et al. 2019). The post-classification comparison approach was used to detect the LULC changes (Jensen 2005), which were used to assess the spatial distribution of saltmarshes over the study period.

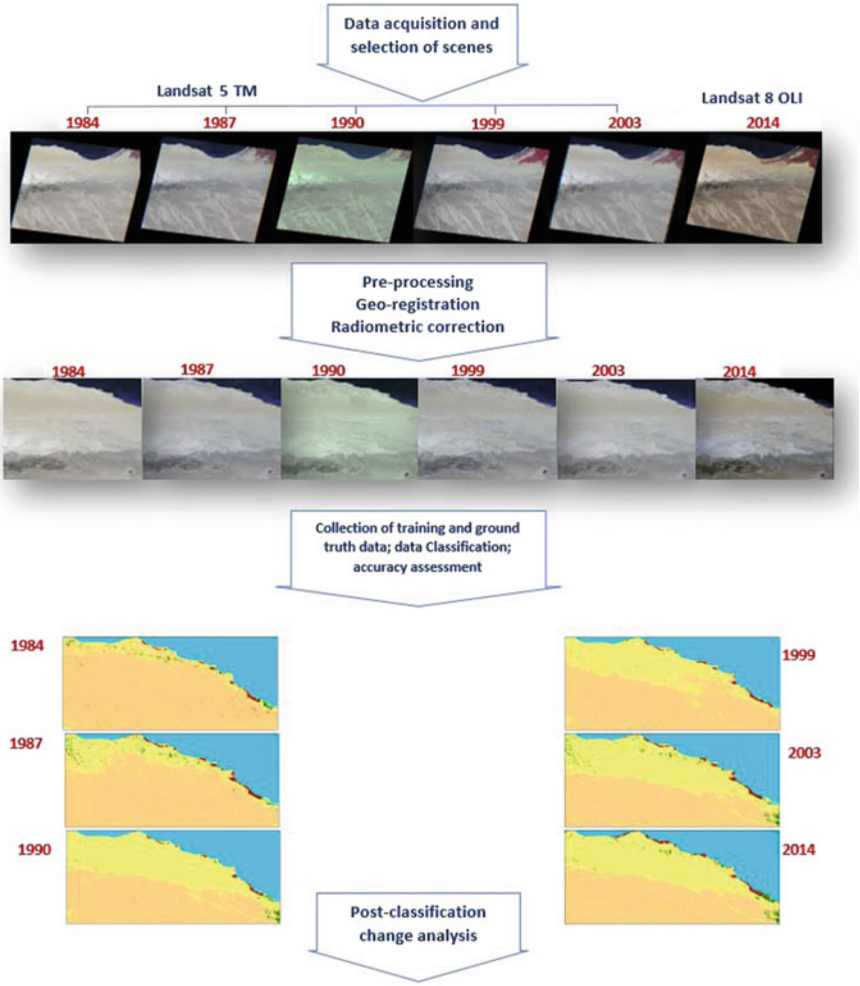

Fig. 6.2 Flowchart of the methodology used for mapping coastal saltmarshes along the northwestern coast of Egypt using Landsat 5 TM and Landsat 8 OLI (*source* Halmy 2014a)

6.3.3 Results and Discussion

Classification using the RF method resulted in highly accurate LULC maps with an overall accuracy higher than 85% and kappa coefficients over 0.81 (see Table 6.1). These results indicated that the RF technique successfully classified the current and past distribution of coastal saltmarshes in the study area.

Figure 6.3 shows that the saltmarsh areas expanded during 1984–1990, and then declined between 1990 and 2014. The loss in coastal salt marshes and wetland areas at specific periods could be attributed to the intensive human modifications as well

Table 6.1 Overall accuracy and kappa statistic for LULC classification of the years 1984, 1987, 1990, 1999, 2003 and 2014 (*source* Halmy 2014a)

Year	Overall accuracy (%)	Kappa
1984	90.53	0.87
1987	88.77	0.85
1990	86.30	0.84
1999	91.20	0.88
2003	85.33	0.82
2014	88.11	0.86

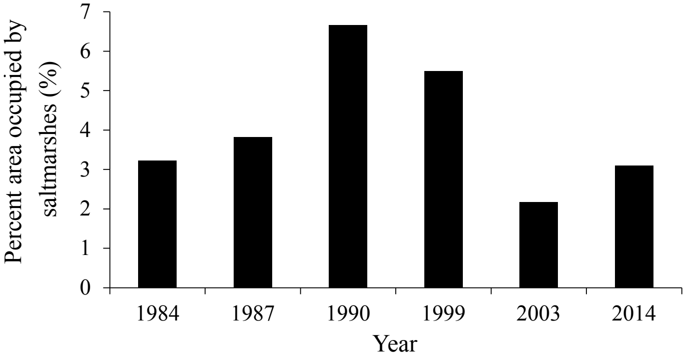

Fig. 6.3 Proportion of area occupied by coastal salt marsh as a percentage of the total area monitored during 1984, 1987, 1990, 1999, 2003, and 2014 (*source* Halmy 2014a)

as tourism and farming practices. Other factors, such as groundwater levels, flooding, and wind waves, could also influence the distribution of saltmarshes. Similarly, Halmy (2019) reported that the northwestern coast of Egypt (including salt marshes) had experienced dynamic changes due to various anthropogenic activities and the creation of artificial lands such as quarries, roads, resorts, and croplands. Their study reported that saltmarshes were dominated by the species of *Arthrocnemum macrostachyum*, *Sarcocorinia fruticose*, and *Atriplex halimus* (Halmy 2019). Consequently, the salt marsh-related habitats and natural vegetation cover were seriously influenced in the area.

The period between 1990 and 1999 has noticed the highest percentage of coastal saltmarshes (see Fig. 6.3). This observation could be linked to seawater intrusion in the coastal region due to the impacts of global warming and sea-level rise (Fagherazzi et al. 2019). A review article by Fagherazzi et al. (2019) has illustrated the conversion of agricultural fields into salt marshes due to the influence of sea-level rise. Their work also demonstrated that sea-level rise and storms profoundly influenced farming fields compared to woodlands and grasslands (Fagherazzi et al. 2019). Further investigations are required to illustrate the phenomenon of marshes migration into agricultural fields, uplands, and suburban lawns.

6.4 Modeling the Distribution of Plant Communities in Moghra Oasis

6.4.1 Problem Statement

Halmy (2014) used the potentialities offered by Landsat satellite images to detect and explore the distribution of plant communities in Moghra Oasis located at Egypt's Western Desert. As shown in Fig. 6.4, Moghra is situated at the northeastern zone of the Qattara Depression; i.e., approximately Longitudes 28° 10′–29° 10′ E and Latitudes 29° 50′–30° 41′ N.

Moghra Oasis is an uninhabited and small oasis having an area of about 630 km^2, and it is recognized as a valuable inland wetland (Sayed et al. 2019). Moghra is also considered a vital oasis to the local inhabitants of the northern coast because it can be used as alternative rangeland during the dry season. Studying the vegetation resources of Moghra Oasis was overlooked, most probably due to the difficulties in accessing to the oasis. The main habitats in the study area were sand dunes, salt marshes, the reed-swamp at the west, followed by sandy hummocks, sandplains and gravel desert at the east. The habitats and their associated vegetation communities were formed due to the variation of several factors such as geographic elevation, water table depth, the nature of the surface deposits, and soil salinity (Halmy et al. 2015).

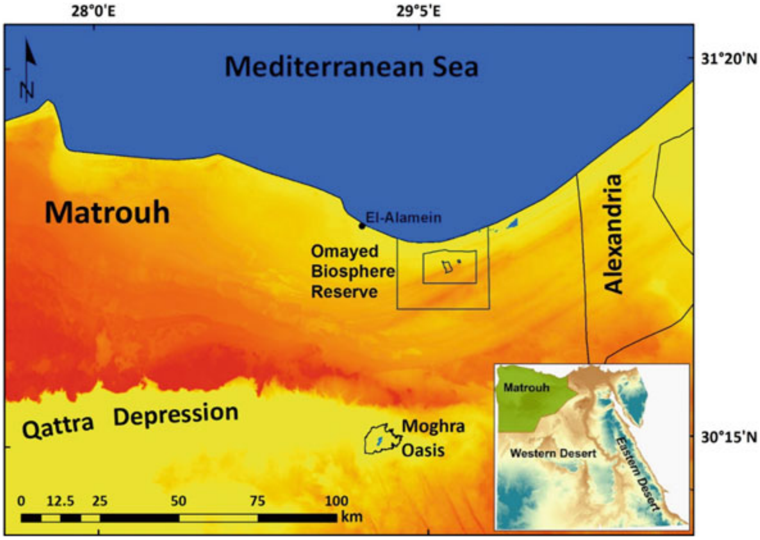

Fig. 6.4 Map of the north-western coastal desert showing the location of Moghra Oasis at the south of Omayed Biosphere Reserve and the northeast side of the Qattara Depression in the Western Desert of Egypt (*source* Halmy 2014b)

6.4.2 Methodology

Field surveys were conducted to monitor the natural plant resources of Moghra Oasis. More than 150 plots, each with an area of 400 m^2, were randomly selected to account for the significant physiographic variation, habitat types, and plant species in the study area. The Latin names of species were reported according to Boulos (1999, 2000, 2002, 2005), whereas nomenclature and identification were updated following Täckholm (1974). Non-metric multidimensional scaling (NMDS) based on Bray-Curtis dissimilarity matrices (Woods et al. 2018) was employed to analyze the vegetation data. Hierarchical clustering by Ward's method, known as a dendrogram, was applied to find groups within the data based on feature similarity and dissimilarity (Shirkhorshidi et al. 2015).

6.4.3 Results and Discussion

The clustering process depicted that the vegetation data could be classified into six major groups. The vegetation clusters were identified regarding the maximum relative frequency and the highest indicator value in each group. Several species characterized each group (see Table 6.2), and the groups could be defined as follows:

Group I was dominated by *Artemisia monosperma*, and *Minuartia geniculate*.
Group II was dominated by *Nitraria retusa*, *Tetraena alba*, and *Sporobolus spicatus*.
Group III was dominated by *Phragmites australis*, and *Juncus rigidus*.
Group IV was dominated by *Zygophyllum album*, and *Alhagi graecorum*.
Group V was dominated by *Tamarix nilotica*, and *Calligonum polygonoides*.
Group VI was dominated by *Arthrocnemum macrostachyum*, and *Halocnemum strobilaceum*.

Figure 6.5 shows the distribution of vegetation groups within Moghra Oasis using the RF model. The high overall accuracy (>90%) and Cohen's kappa coefficient higher than 0.8 indicated that the model was adequate for predicting the distribution of the identified plant communities. The relationship between species abundance and groups of sites revealed that 71% of all species were significantly associated with previously established vegetation types ($p < 0.05$). This result depicted that the spatial distribution of the major plant communities in Moghra Oasis was undergoing dynamic changes between 1984 and 2011. Moreover, the community group "Art-Min" occupied the most area of the oasis with values of 2644 and 2376 ha during 1984 and 2011, respectively. Similarly, Khelifi Touhami et al. (2019) used processing optical remote sensing data to define the spatial-morphological mapping of cultivated lands in the northern-eastern oasis, Algeria. Their work (2019) demonstrated that the satellite images were classified into several subsets (e.g., palm trees, sand, agricultural land, and buildings), and the total salt occupation rate was 24% of the study area.

Table 6.2 List of vegetation species recorded in Moghra Oasis (*source* Halmy 2014b)

Species	Group
Alhagi graecorum Boiss	I + III + IV
Artemisia monosperma Delile	I + II
Arthrocnemum macrostachyum (Moric.) K. Koch	III + VI
Calligonum polygonoides L.	I + II + V
Convolvulus lanatus Vahl	I
Cynodon dactylon (L.) Pers	IV
Ephedra alata Decne	I
Halocnemum strobilaceum (Pall.) M.Bieb	VI
Imperata cylindrica (L.) Raeusch	III + IV
Limbarda crithmoides (L.) Dumort	III
Juncus rigidus Desf	III
Minuartia geniculata (Poir.) Thell	I
Nitraria retusa (Forssk.) Asch	II
Panicum turgidum Forssk	I
Phoenix dactylifera L.	III
Phragmites australis (Cav.) Trin ex. Steud	III
Sarcocornia fruticosa (L.) A.J.Scott	III + VI
Sporobolus spicatus (Vahl) Kunth	II
Stipagrostis obtusa (Delile) Nees	I
Tamarix nilotica (Ehrenb.) Bunge	V
Zygophyllum album L.f.	I + II + IV

6.5 Conclusions

This work represents the recent applications of remote sensing and GIS techniques for monitoring the environmental and ecological changes in various regions of Egypt. The methods and techniques used for data analyses reported in the literature are illustrated. To the best of our knowledge, the study provided useful information to the public and private sectors, policymakers, and stakeholders. The main conclusions of the study are:

- Remote sensing offers appropriate spatial and temporal coverage to compensate for the limitations of ecological site-based data.
- The Egyptian government is exerting high efforts to widen the application of remote sensing at various regions.
- Multiple factors, such as grazing, agricultural activities, and environmental pollution, have caused considerable LULC changes.
- Land degradation, loss of vegetation cover, and water shortage and salinity have been reported in Delta and Nile Valley during the past few decades.

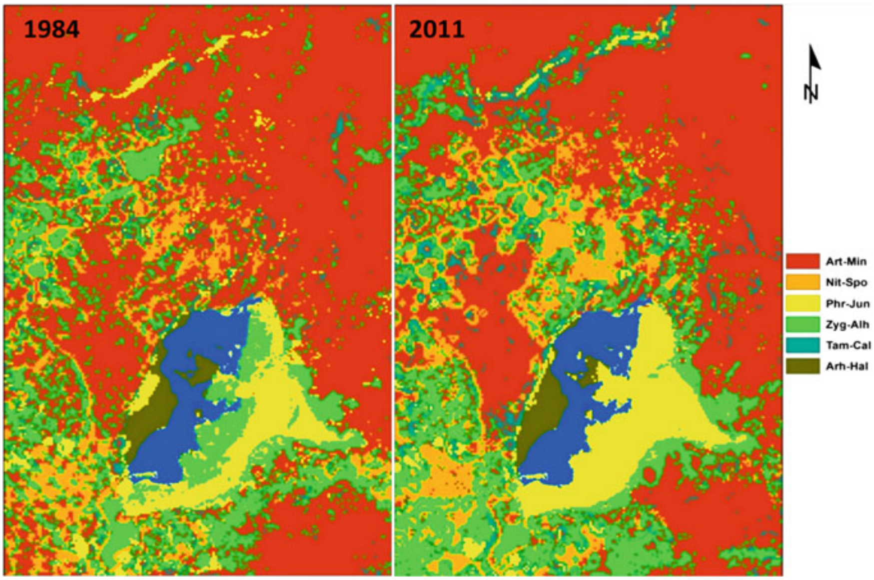

Fig. 6.5 Distribution of the identified plant communities in Moghra Oasis in 1984 and 2011 using Random forest model (*source* Halmy 2014b)

- Reclamation activities for aquaculture, agricultural wastes rich in fertilizers, and the shift of sand dunes have negatively impacted the water bodies located at the northern part of Egypt.
- The salt marsh areas along the northwestern coast of Egypt expanded during 1984–1990 and then declined between 1990 and 2014, which could be due to various anthropogenic activities and climate change.
- The spatial distribution of the major plant communities in Moghra Oasis was undergoing dynamic changes between 1984 and 2011.

6.6 Recommendations

This chapter aims at providing a comprehensive summary for the recent works performed to monitor the Egyptian ecosystem using remote sensing. Some recommendations can be addressed from the study:

- Integrating remote sensing data with field observations should be considered to map the species distribution appropriately.
- Remote sensing should be employed to detect the illegal application of agricultural areas in Delta and Nile Valley.
- Necessary policies and regulations should be established for sustainable natural resource management.

- It is suggested that land and water managers and policymakers use remote sensing techniques to perform soil erosion risk assessment.
- The carbon storage capacity of salt marshes in the coastal lands of Egypt should be assessed.

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