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Case Study | Open Access

Land Use/Land Cover Change Detection and Classification using Remote Sensing and GIS Techniques: A Case Study at Siwa Oasis, Northwestern Desert of Egypt

Abd El hay Aly Farrag[1], El Sayed Ahmed El Sayed[2], and Hanaa Ahmed Megahed[2]

[1]Geology Department, Faculty of Science, Assiut University, Egypt
[2]Geological Applications and Mineral Resources Division, National Authority for Remote Sensing and Space Sciences (NARSS) Egypt

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Abstract Monitoring and analysis of the recent land cover/land use changes through the integration of remote sensing and GIS to detect change in land use and land cover pattern by providing more reliable direct quantitative information also could provide base information for documenting water salinity, soil change and expansion in surface lakes. Therefore in the present study an attempt is made on Siwa Oasis to bring out the quantitative information through field campaigns and the study of satellite imageries those freely available at National Authority for Remote Sensing and Space Sciences (NARSS) and Global Land Cover Forecasting (GLCF) site. The results obtained through this study using imageries of 1987, 2000 and 2014 of Siwa Oasis are presented.
Keywords *Land Use/Land Cover; Classification; Remote Sensing; GIS; Change Detection; Siwa Oasis.*

1. Introduction

Land cover and land use change detection is one of the most important application areas of remote sensing. Change detection involves the ability to quantify temporal changes in land use and landcover using multitemporal data sets (Singh, 1989; Ridd and Liu, 1998). During the past three decades, many change detection algorithms have been developed, and they vary widely in their sophistication and performance (Collins and Woodcock, 1996; Ola and Hay, 2003). The choice of a particular technique depends largely on the particulars of the study area, the nature of the expected landcover change, and the temporal and spatial resolution of the data (Kaufman and Seto, 2001). This paper is an attempt to assess the changes in land use/land cover at Siwa Oasis over a 27 year period.

1.1. Location and Description of the Study Area

Siwa Oasis is one of the depressions located in the northern part of the Western Desert of Egypt, to the west of the great Qattara Depression and continuing westward to the Gaghbub depression in Libya. It is about 300 km south of the Mediterranean Sea coast (Matrouh city) and extends in an E-W direction for approximately 82 km, with a width that varies between 9 and 28 km and has an area of about 2,950 km^2. It lies between latitudes 29° 07' 18" N and 29° 20' 36" N and longitudes 25° 18' 21" E and 26° 03' 05" E (Figure 1). It has an irregular elongate shape narrowing westward. The depression is bordered from the north by the steep escarpment of the Miocene Marmarica Limestone plateau attaining an elevation of about 150 m (a.s.l), which extends as far as the Mediterranean coast, while towards the south; it is limited by the dunes of the Great Sand Sea.

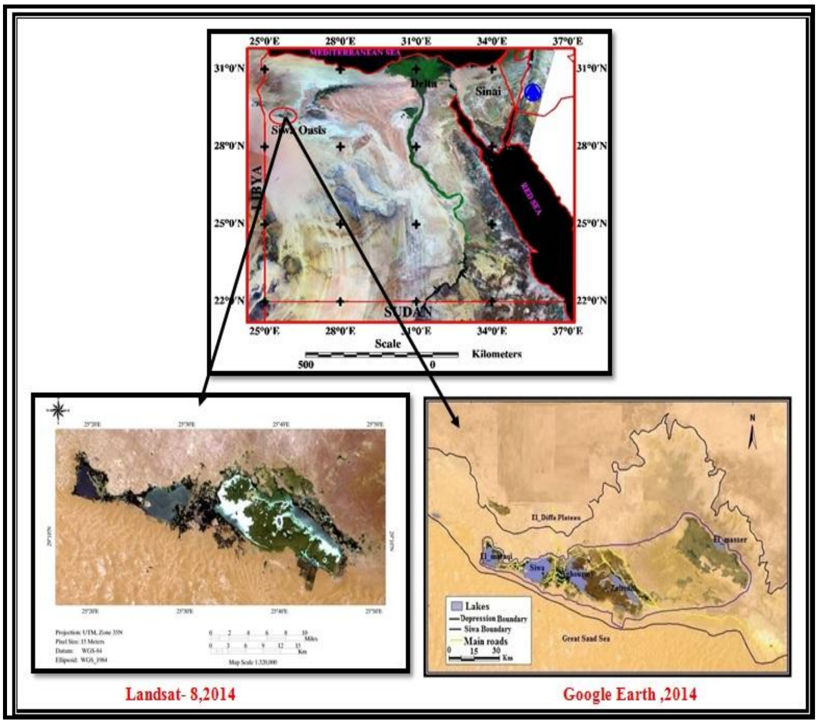

Figure 1: *Location of the Investigation Area on Landsat* -8 *Image and Google Earth*

Climatologically, the climate of Siwa Oasis is arid characterized by a short winter season and a long hot summer. The summer season is dry and very hot with maximum temperature reaching up to 30°C (Figures 2&3).

The monthly mean minimum temperatures range from 4°C in January to 21°C in July. The study of relative humidity values indicates that the monthly variations vary between 33.0 and 60.0 %. The annual relative humidity is 45.0 %.

Evaporation ranges from 283 mm/month in July to 76 mm/month in December (Figure 4). Because the oasis lies in a depression it is somewhat protected from the hot desert winds and evapotranspiration is slightly lower than in other desert environments. (Table 1)

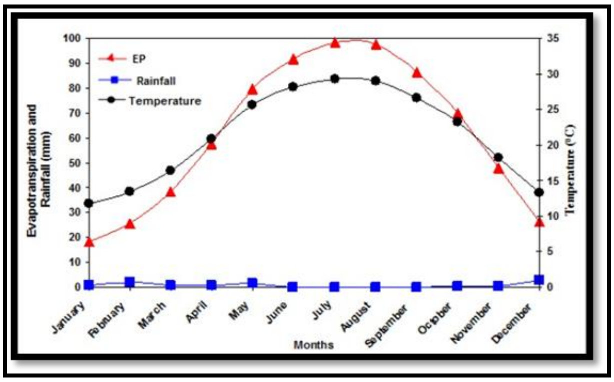

Figure 2: *Relationship between Temperature, Rainfall, and Evapotranspiration*

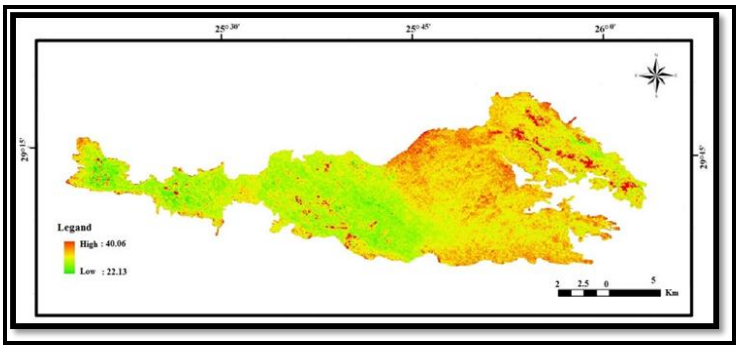

Figure 3: *Land Surface Temperature Spatial Distribution in Siwa Oasis*

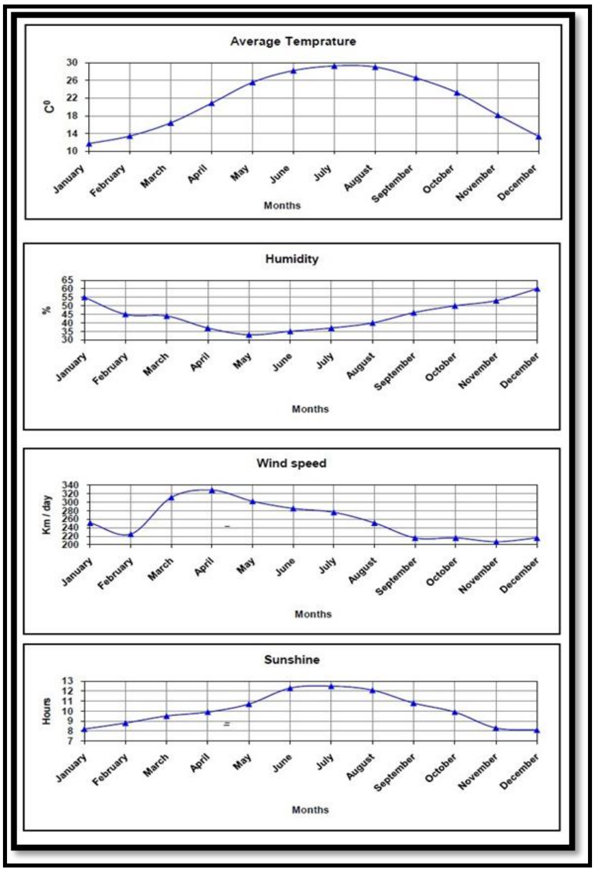

Figure 4: *Climatological Diagram of the Study Area*

Table 1: *Climatological Data of Siwa Oasis, Monthly Averages during the Period (average of latest 20 years), Siwa Meteorological Station*

Meteorology Station; Siwa (20yr.)				Altitude: - 13 m a.s.l			Co-ordinates: 29.12 N, 25.29 E			
Month	Temperature			Rainfall mm/month	Relative Humidity %	Wind velocity m/sec	Sunshine Hours	Solar. Radiation MJ/m^2_/day	EP mm/Month	ET_o (mm/day)
	Max. Temp. °C	Min. Temp. °C	Mean Temp °C							
January	19.60	3.80	11.70	0.80	55.0	2.90	8.20	13.90	62	3.20
February	21.50	5.30	13.40	2.00	45.0	2.60	8.80	16.90	101	3.90
March	24.80	8.0	16.40	0.70	44.0	3.60	9.50	20.90	175	5.60
April	29.70	12.0	20.85	0.90	37.0	3.79	9.90	23.70	229	7.40
May	34.50	16.60	25.55	1.50	33.0	3.49	10.70	25.80	274	8.70
June	37.30	19.10	28.20	0.00	35.0	3.30	12.30	28.50	276	9.30
July	38.0	20.50	29.25	0.00	37.0	3.19	12.50	28.50	283	9.20
August	37.70	20.30	29.0	0.00	40.0	2.90	12.10	27.10	255	8.40
September	35.10	18.0	26.55	0.00	46.0	2.50	10.80	23.30	192	6.70
October	31.80	14.60	23.20	0.30	50.0	2.50	9.90	19.20	151	5.30
November	26.30	10.0	18.15	0.60	53.0	2.39	8.30	14.60	100	3.80
December	21.10	5.50	13.30	2.80	60.0	2.50	8.10	13.10	67	2.90
Annual mean	29.80	12.80	21.30	-	45.0	2.97	10.10	21.30	188.75	74.40
Annual total	-	-	-	9.60	-	-	-	-	2265.0	-

Geologically, the study area is underlain and surrounded by sedimentary rocks, belonging to the Eocene, Pliocene, Pleistocene and Recent times (Figure 5). Stratigraphically, these sedimentary rocks can be divided into Upper, Lower and Middle Eocene, and Pleistocene and Holocene Deposits, (Said, 1990).

The same authors Gindy and El-Askary (1969) added that throughout the Siwa depression, three lithostratigraphic marine divisions can readily be recognized in the field, I-the lowest division (oasis member) which consists of shale and marl beds. The overall color is greenish buff, mostly khaki colored, II-the middle division (Siwa escarpment member) which consists mostly of relatively thick and snow-white chalky beds, with a pinkish stain common on the more weathered surfaces, and III- the upper-most division (plateau member) which consists of thin chalky limestone beds. The fossiliferous beds appear gray or grayish brown, but freshly broken surface range from white to cream color. The upper members (El-Diffa plateau and Siwa escarpment member) are equivalent to the Marmarica formation of western desert suggested by Said (1962).

2. Objectives

The study is aimed to identify the changes that happened in land use/land cover during the period of 1987-2014. The main observed changes could be expressed by: 1) - Enlargement of lake areas as a result of over-pumping from springs and wells and misuse of water for irrigation purposes, 2) - Change in wet sabkhas and dry areas and 3) - change in agriculture areas using remotely sensed data .

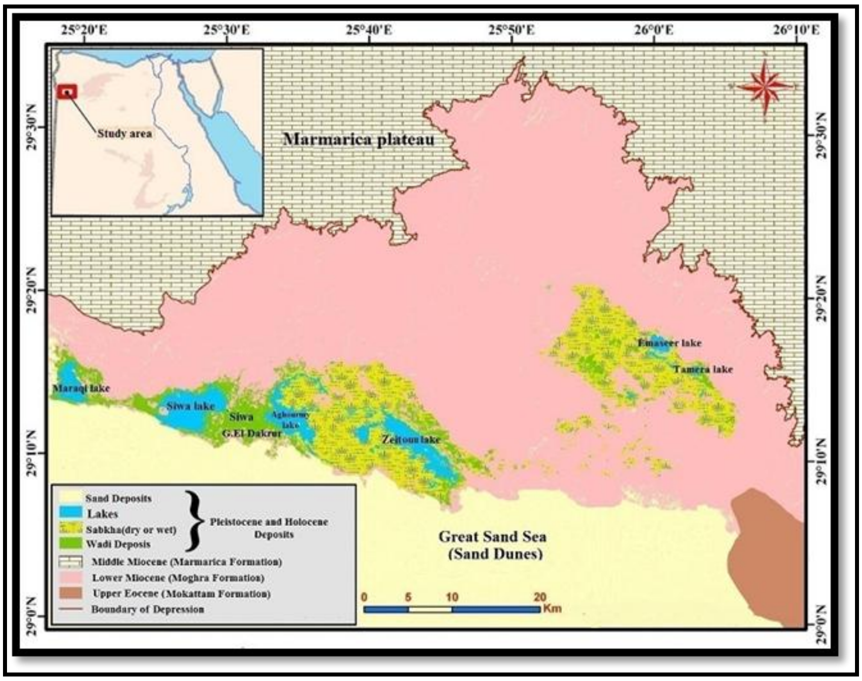

Figure 5: *Schematic Geological Map of the Study Area. Digitized from Maps of CONOCO (1998) and Landsat-8 Image (2014)*

3. Methodology

The methodology used in this work is summarized in the next flowchart; (Figure 6) includes supervised classification of landsat TM 1987, ETM+ 2000 & Landsat 8 (2014) images while the second will encompass change detection analysis.

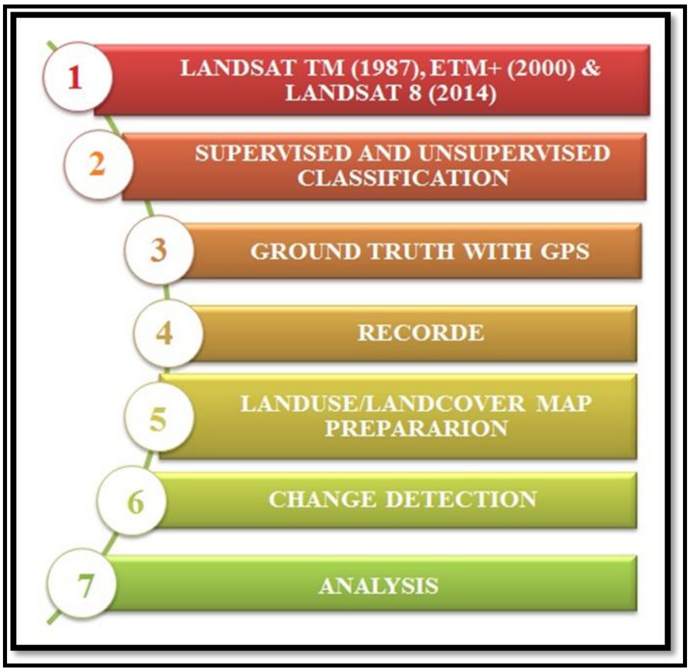

Figure 6: *Flow Chart of Methodology*

All images are collected from TM (1987), ETM+ (2000) & Landsat 8 (2014) Figures (7a, 7 b and 7c) where chronologically arranged and were subjected to unsupervised and supervised classification. An attempt was made to classify the images under four classes Vegetation, Water body, Wet sabkha-salt crusts and Dry sabkha. Out of the available modes of supervised classification Maximum likelihood classification algorithm technique is used considering its potential and suitability in the study planned. In this method care was taken to define signatures of each class after defining the signatures for each land cover category. The software uses those signatures to classify the remaining pixels. The classified land use/ land cover images were taken for ground truth. Ground truth was conducted by using GPS (Global Positioning System) and land use class was corrected by using recode technique, wherever it was needed based on the ground truth information.

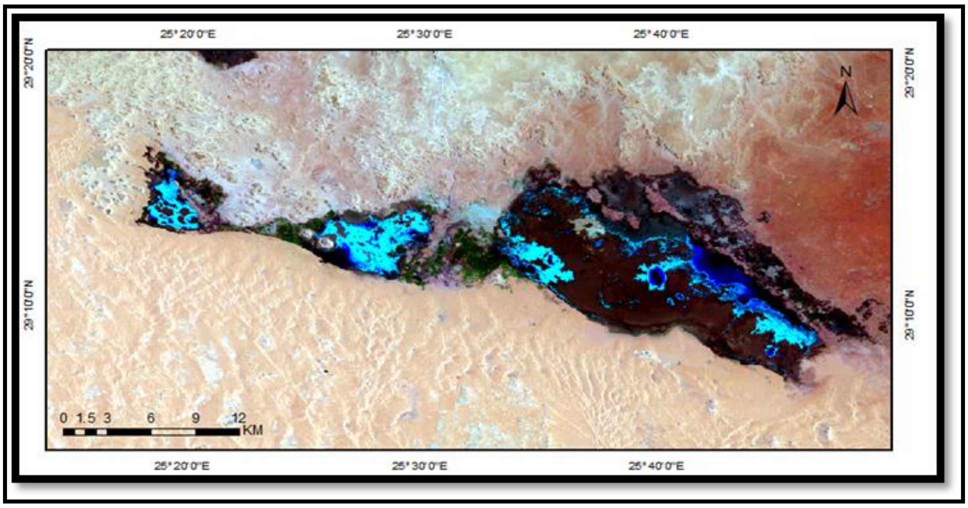

Figure (7a): *Raw Image of Landsat TM, Band (RGB 7,4,2), (Acquisition Date: Nov, 1987)*

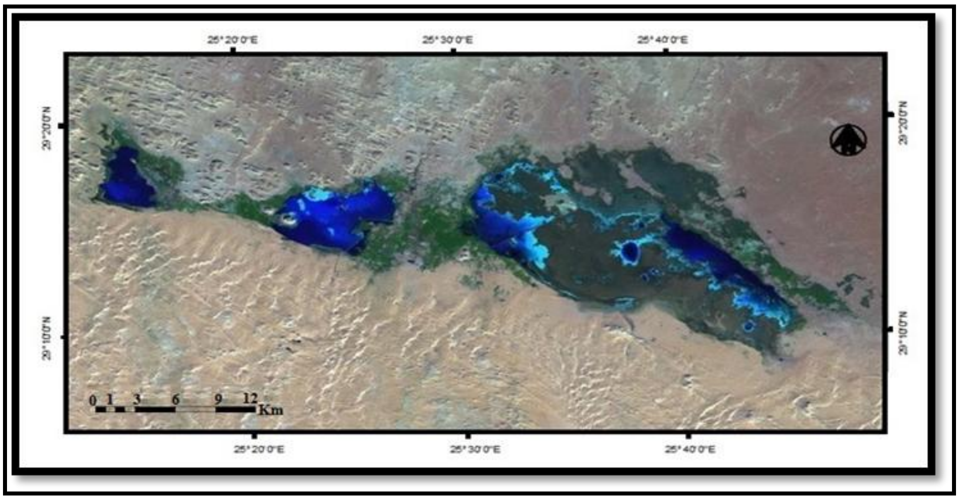

Figure (7b): *Raw Image of Landsat ETM^{+}, Band (RGB 7,4,2), (Acquisition Date: Oct, 2000)*

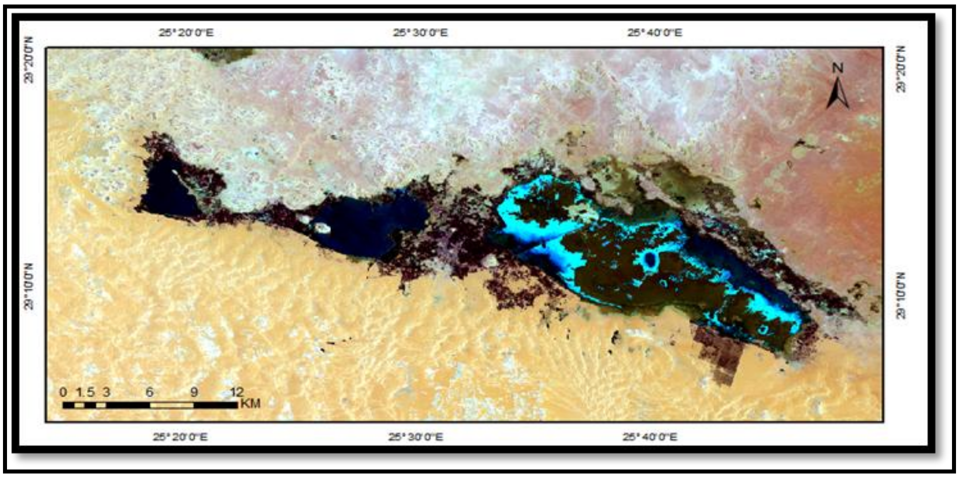

Figure (7c): *Raw Image of Landsat 8, Band (RGB 7,4,2), (Acquisition Date: May, 2014)*

4. Results and Discussion

The unsupervised classification techniques available are ISODATA and K-Means. ISODATA unsupervised classification calculates class means evenly distributed in the data space then iteratively clusters the remaining pixels using minimum distance techniques. This process continues until the number of pixels in each class changes by less than the selected pixel change threshold or the maximum number of iterations is reached. This method resulted in 7 classes as shown in Figure 8.

K-Means unsupervised classification calculates initial class means evenly distributed in the data space then iteratively clusters the pixels into the nearest class using a minimum distance technique. This process continues until the number of pixels in each class changes by less than the selected pixel change threshold or the maximum number of iterations is reached. This method resulted in 5 classes as shown in Figure 9.

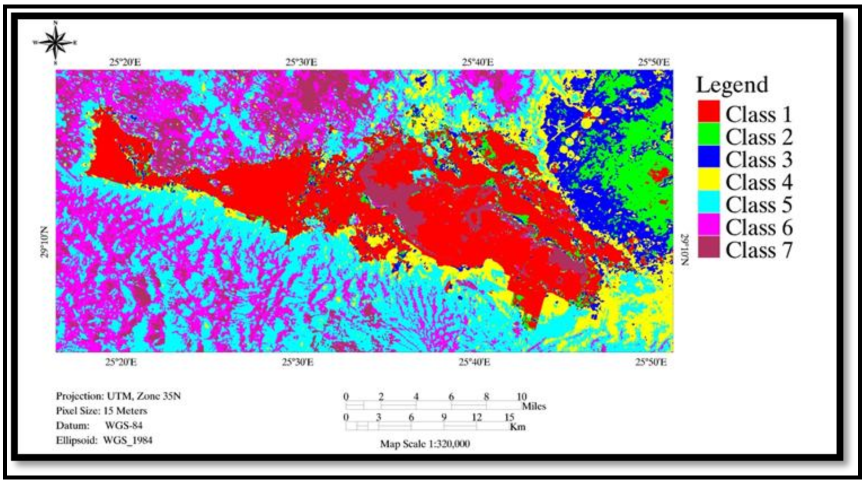

Figure 8: *ISODATA Unsupervised Classification of the Study Area*

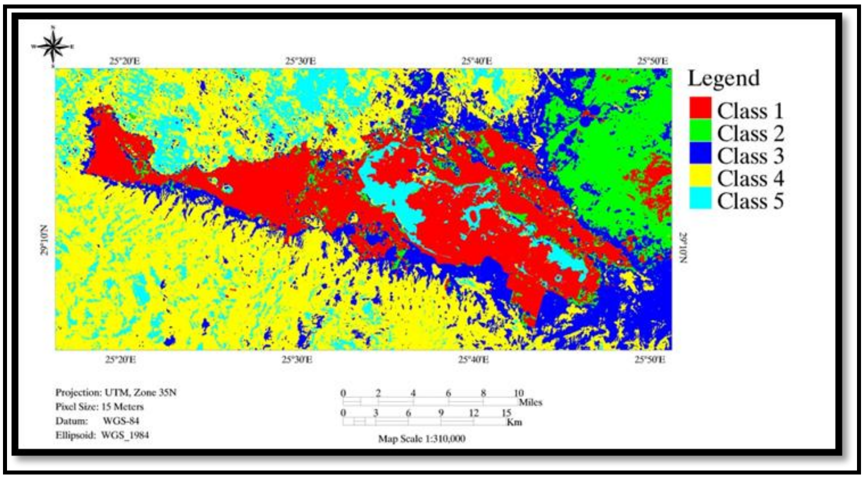

Figure 9: *K-Means Unsupervised Classification of the Study Area*

The result obtained through the study of imageries to evolve change in the land use and land cover of Siwa district are evaluated from 27 years of study period i.e. 1987, 2000, 2014 present in Figures 10, 11 and 12.

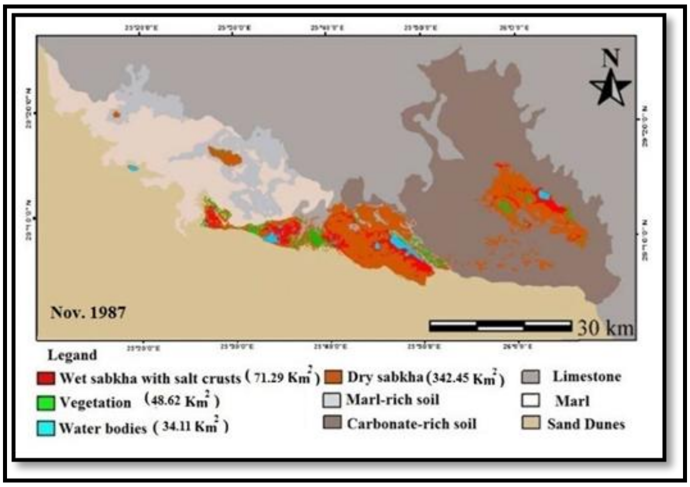

Figure 10: *Land Use / Land Cover of Siwa District Year* 1987

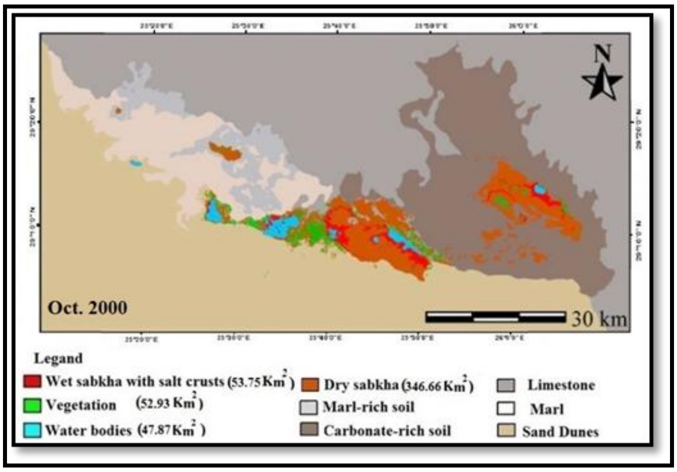

Figure 11: *Land Use / Land Cover of Siwa District Year 2000*

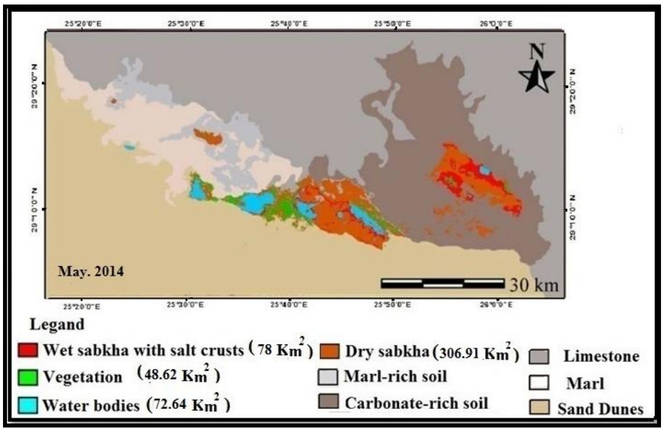

Figure 12: *Land Use / Land Cover of Siwa District Year 2014*

Spatio-temporal changes in different landcover classes, which were monitored in the whole area and surrounded the main four lakes in study area during three different dates 1987, 2000 and 2014, are shown in Figures 13, 14, 15 and Table 2. Change results confirmed a gradual increase in the extent of the surface waters in all of the study areas except Massir, which showed a slight decrease. For the 1987–2000 period of monitoring, an increase in water extent has resulted in an increase of vegetation cover in the study areas.

Moreover, a decrease in the extent of dry sabkha in Maraqi, Siwa, and Massir was observed, as was an increase in dry sabkha in Zaitun and the whole study area. Further, the extent of wet sabkha with salt crusts has increased in Zaitun and Massir but declined in Maraqi and Siwa as well as the whole study area. For the 2000–2014 period, the gradual increase in water extent resulted in a decrease in vegetation cover in the whole area.

In addition, a decrease in the extent of wet sabkha with salt crusts was observed in Maraqi, Siwa, and Zaitun, while in Massir and the whole study area it increased. The extent of dry sabkha showed a decline in Siwa, Zaitun, Massir, and in the whole study area, while a slight increase was observed in Maraqi. These results indicate that the direct proportional relationship between the extent of surface water and vegetation coverage reversed after the year 2000.

Field investigations, interviews with Siwa planners, and visual inspections of the 2000 and 2014 colour composite images showed that the only change in the infrastructure of the area is a road and drainage network that was set up after the year 2000. Such practices are thought to greatly affect the hydrologic characteristics of the surrounding lakes. Where the total coverage of the dry sabkha was lowered due to an increase in the surface extent of the lake waters in the study area, a considerable extension of the sabkha was near the vegetation cover and urban centers. Moreover, an increase in the clear-cut areas of the natural vegetation, including date palms and olive trees, was clear and at a high rate. Most of the vegetation was located in direct contact with the saline lake waters, the wet sabkhas, or near urban centers, thereby enhancing the evapo-transpiration rate of the nearby vegetation. The removal of vegetation cover significantly increases the soil moisture content due to reduced evapo-transpiration, which consequently raises the shallow water-table (Gates and Williams, 1988). In addition, the density of vegetation cover is of significant importance in governing the rate of evapo-transpiration. The edges of dense vegetation have a high rate of evapo-transpiration and hence are at-risk for dryness, and this is evident in the study area. Estimation of the vegetation coverage detected and predicted in the whole study area was carried out using GIS functions.

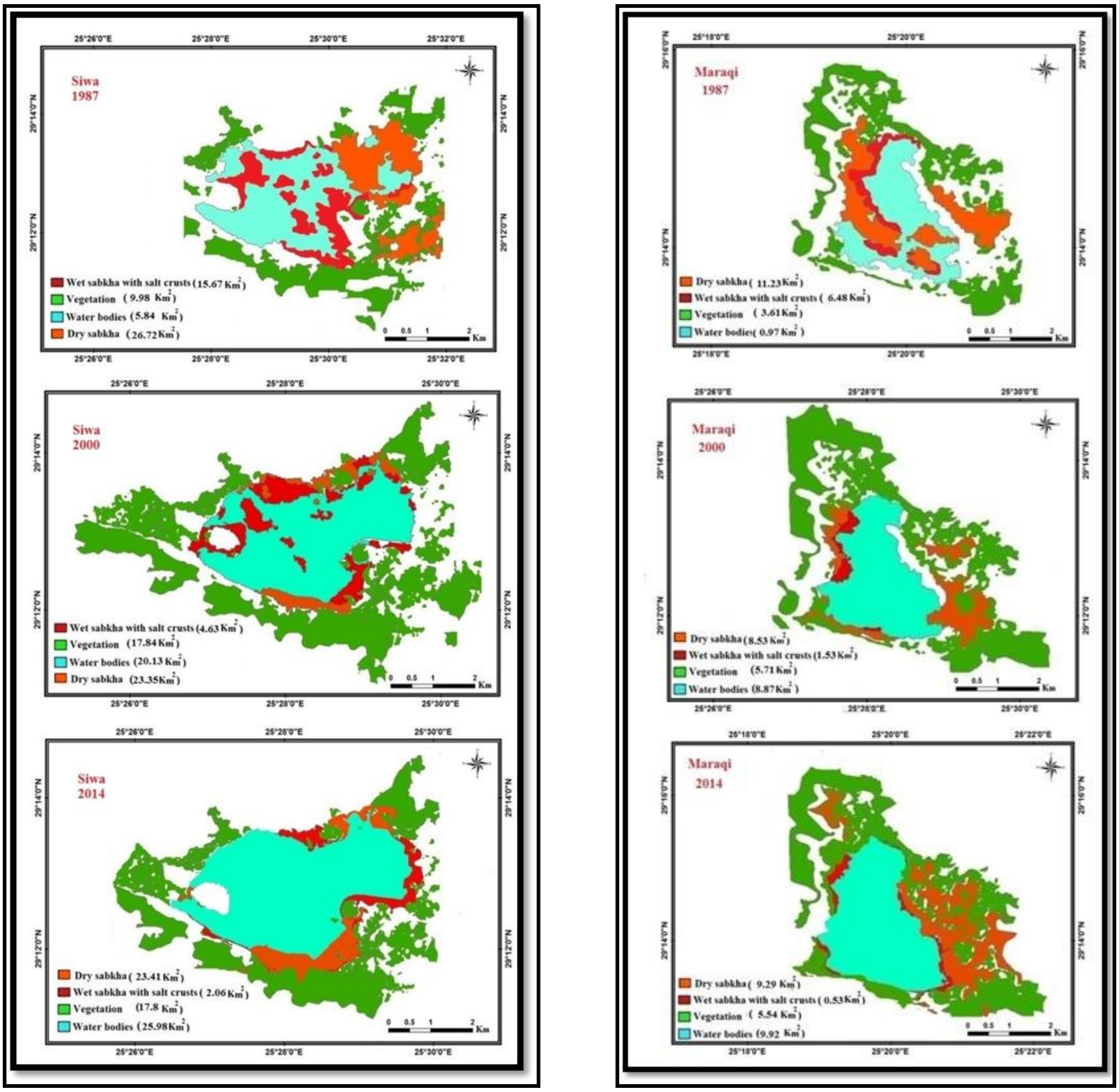

Figure 13: *Change Detection (Km^2) During the Period of 1987-2014 in El Maraqi and Siwa Lake*

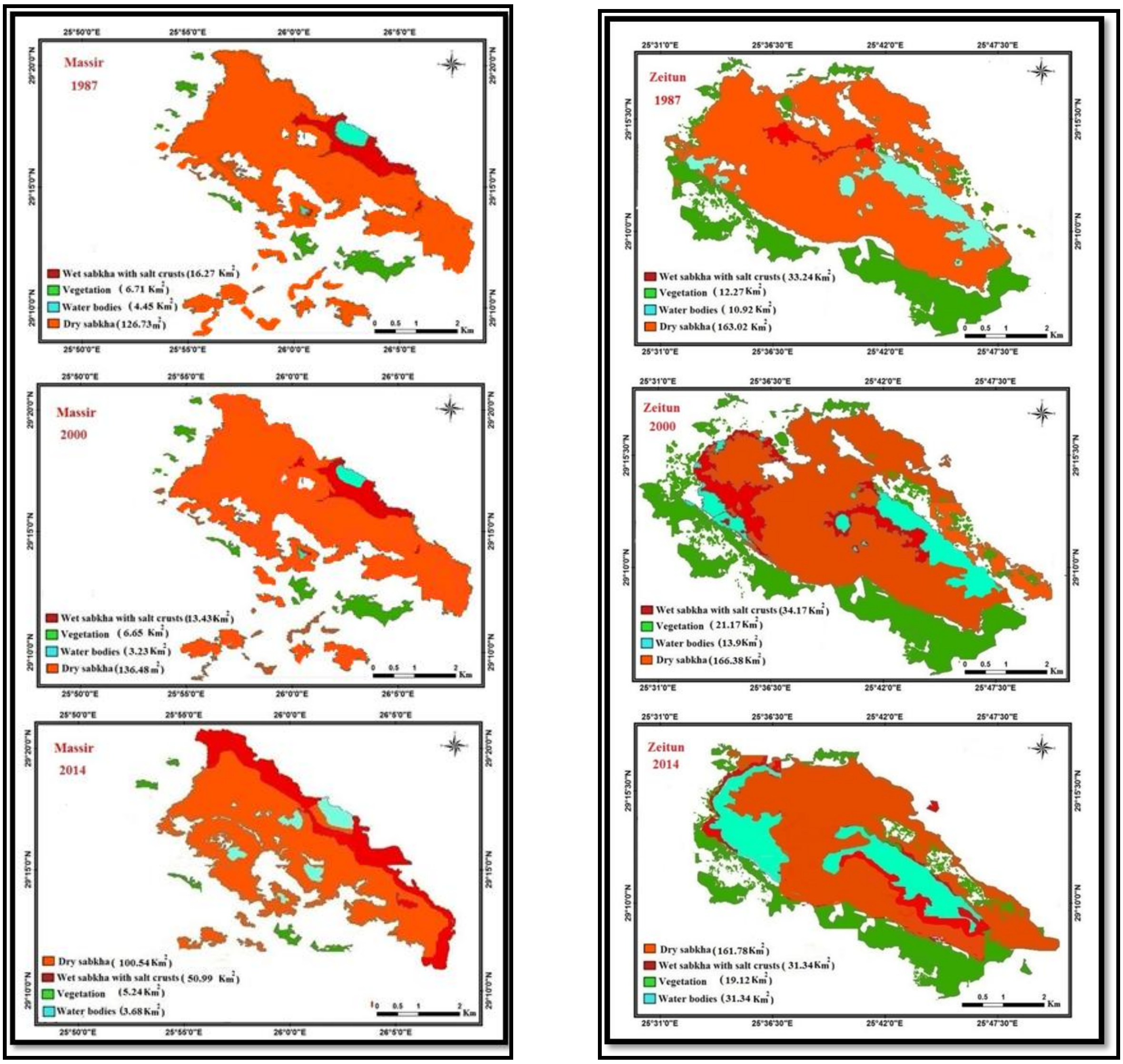

Figure 14: *Change Detection (km^2) during the Period of 1987-2014 in Zeitun and Massir Lake*

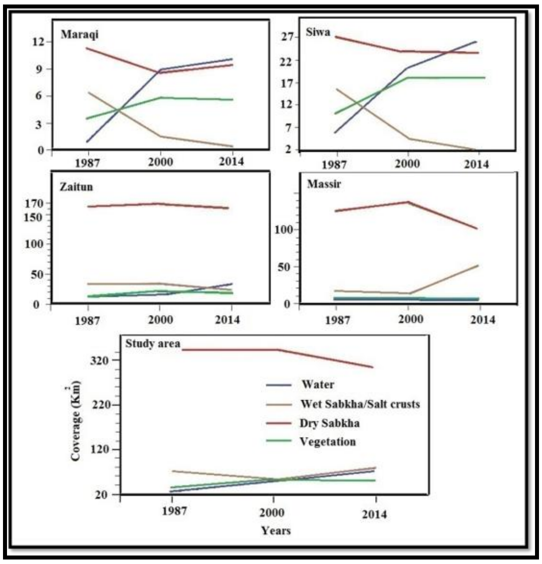

Figure 15: *Diagrams Showing Temporal Changes in Different Landcover Classes in the Study Area and the Areas Surrounding the Main Four Lakes in Siwa Region*

Table 2: *Change Detection (Km²) Monitored in the 1987–2014 Period in the Study Area the Areas Surrounding the Main Four Lakes in Siwa Region*

Area /Years Lake/landcovers	Area/Km² (1987)	Area/Km² (2000)	Area/ Km² (2014)	1987/2000 Changes	1987/2014 Changes	2000/2014 Changes
Maraqi						
Water bodies	0.97	8.87	9.92	7.9 (Increase)	8.95 (Increase)	1.05 (Increase)
Wet sabkha-salt crusts	6.48	1.53	0.53	-4.95 (Decrease)	-5.95 (Decrease)	-1 (Decrease)
Dry sabkha	11.23	8.53	9.29	-2.7 (Decrease)	-1.94 (Decrease)	0.76 (Increase)
Vegetation	3.61	5.71	5.54	2.1 (Increase)	1.93 (Decrease)	-0.17 (Decrease)
Siwa						
Water bodies	5.84	20.13	25.98	14.29 (Increase)	20.14 (Increase)	5.85 (Increase)
Wet sabkha-salt crusts	15.67	4.63	2.06	-11.04 (Decrease)	-13.61 (Decrease)	-2.57 (Decrease)
Dry sabkha	26.72	23.35	23.41	-3.37 (Decrease)	-3.31 (Decrease)	0.06 (Increase)
Vegetation	9.98	17.84	17.81	7.86 (Increase)	7.83 (Increase)	-0.03 (Decrease)
Zeitun						
Water bodies	10.92	13.9	31.34	2.98 (Increase)	20.42 (Increase)	17.44 (Increase)
Wet sabkha-salt crusts	33.24	34.17	24.3	0.93 (Increase)	-8.94 (Decrease)	-9.87 (Decrease)
Dry sabkha	163.02	166.38	161.78	3.36 (Increase)	-1.24 (Decrease)	-4.6 (Decrease)
Vegetation	12.27	21.17	19.12	8.9 (Increase)	6.85 (Increase)	-2.05 (Decrease)
Massir						
Water bodies	4.45	3.23	3.68	-1.22 (Decrease)	-0.77 (Decrease)	0.45 (Increase)
Wet sabkha-salt crusts	16.27	13.43	50.99	-2.84 (Decrease)	34.72 (Increase)	37.56 (Increase)
Dry sabkha	126.73	136.48	100.54	9.75 (Increase)	-26.19 (Decrease)	-35.94 (Decrease)
Vegetation	6.71	6.65	5.24	-0.06 (Decrease)	-1.47 (Decrease)	-1.41 (Decrease)
Study area						
Water bodies	22.78	47.87	72.64	25.09 (Increase)	49.86 (Increase)	24.77 (Increase)
Wet sabkha-salt crusts	71.29	53.75	78	-17.54 (Decrease)	6.71 (Increase)	24.25 (Increase)
Dry sabkha	342.45	346.66	306.91	4.2 1 (Increase)	-35.54 (Decrease)	-39.75 (Decrease)
Vegetation	34.11	52.93	48.62	18.82 (Increase)	14.51 (Increase)	-4.31 (Decrease)

5. Conclusion

Remote Sensing and Geographical Information System (GIS) are well accepted and more dependable advance techniques to detect change in land use and land cover pattern by providing more reliable direct quantitative information. Our results accurately quantify the land cover changes and delineate their spatial patterns, demonstrating the Utility of Landsat data in analyzing landscape dynamics over time. Such information is critical for making efficient and sustainable policies for resource management.

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