# MONITORING BURULLUS LAKE USING REMOTE SENSING TECHNIQUES

**Dr. Noha Samir Donia[1] and Dr Hanan farag[2]**

[1] Department of Environmental Engineering Science, Institute of Environmental Studies and Research, Ain Shams University, Egypt
[2] Institute of environment, national water research center, Ministry of water resources and irrigation, Egypt

## ABSTRACT

Land use and land cover change has been recognized as one of the most important indicators for global and regional environmental changes. In this study, the maximum likelihood supervised classification and the post-classification comparison change detection are applied in order to detect the land use/land cover changes along the north part of the Nile delta, by using the ERDAS IMAGINE software. Three multi-spectral satellite imageries were selected to monitor the floating vegetation and the soil moisture areas during the past two decades for the periods 1990-2000 and 2000-2009 using Landsat (TM and ETM+) and Envisat MERIS imageries. The results showed that the soil moisture areas were decreased within the period 2000-2006 by the half of its area within the period 1990-2000. The floating vegetation areas were on increase inside the Lake Burullus water during the periods 1990-2000 and 2000-2009. The indicators contributed to the trend change in the floating vegetation and the soil moisture areas are examined in this study using the remote sensing techniques. The objective of this study is to map and determine the nature, extent and rate of changes land use/land cover changes in the Burullus region which can help the output planners optimize the use of natural resources and accommodate development whilst minimizing the impact on the environment.

**Keywords**: Change Detection, Maximum likelihood supervised classification, Post-classification comparison algorithm, Pixel-based Techniques, Land Cover Changes.

## 1. INTRODUCTION

Land use and land cover is dynamic in nature and is an important factor for the comprehension of the interaction and relationship of anthropogenic activities with the environment. Knowledge of the nature of land use and land cover change (LUCC) and their configuration across spatial and temporal scales is consequently indispensable for sustainable environmental management and development (Turner *et al.* 1994). LUCC has become one of the major issues for environment change monitoring and natural resource management. Identifying, delineating and mapping of the types of land use and land cover are important activities in support of sustainable natural resource management. To understand how LUCC affects and interacts with environmental systems, information is needed regarding what changes occur, where and when they occur, the rates at which they occur, and the social and physical forces that drive those changes (Lambin *et al.* 2003).

Various techniques have been successfully used in the land use/land cover classification and change detection, e.g., pixel based classification (Foody 1996, Duda *et al.* 2001), object oriented classification (Geneletti and Gorte 2003, Elmqvist *et al.* 2008), artificial neural network classification (Kanellopoulos *et al.* 1992, Liu *et al.* 2004), post-classification comparison change detection (Serra *et al.* 2003), and visual interpretation (Liu *et al.* 2005). Post-classification comparison is a common method used for change detection. This method involves independently produced spectral classification results from each end of time interval of interest, followed by a pixel by pixel to detect changes in cover type. A complete matrix is obtained and change classes can be defined by the proper coding of the classification results. The major advantage of this method is the capability of providing a matrix of change information and reducing external impact from atmospheric and environmental differences between the multi-temporal images (Lu *et al.* 2004).

In this paper, the multi-temporal satellite dataset in the Burullus region has been analyzed to understand LUCC as a consequence of driving factors. This study focused on the following three aspects: (1) to estimate LUCC changes for the 10-year period from 1990 to 2000 using Landsat (TM and ETM+) imageries and (2) to incorporate and analyze the soil moisture changes in the Burullus region using these estimated results.

## 2. STUDY AREA: BURULLUS REGION

The Burullus region lies on the eastern side of the Rosetta branch of the Nile River, occupying a central position along the Mediterranean Nile delta coast of Egypt. It extends between longitudes 300 30’ and 310 10’ E and latitudes 310 21’ and 300 35’N (figure 1). The total area of Burullus region is about 2068km2, includes the water body of the lake. Burullus Lake is considered the second largest lake of the Nile delta, which is about 53km long, 13km wide and has water depths ranging from 0.5 to 2.5m (Frihy and Dewidar 1993). Burullus Lake is connected to the sea at its north-eastern edge through the Burullus inlet, which is about 250m wide and 5m deep. The northern border is separated from the Mediterranean Sea by a strip of land covered with sand bars and dunes. Seven drains and fresh water canals are connected to its eastern, southern and western shores. The lake barriers are sandy and range from 0.4 to 5.5km in width. They are generally < 1.5m above mean sea level, with beach face slopes ranging between 50 and 130. Low relief backshore and fore dunes characterize the western barrier. The eastern barrier is narrow and backed by coastal barchans dunes. These dunes encroach landward onto a cultivated coastal flat.

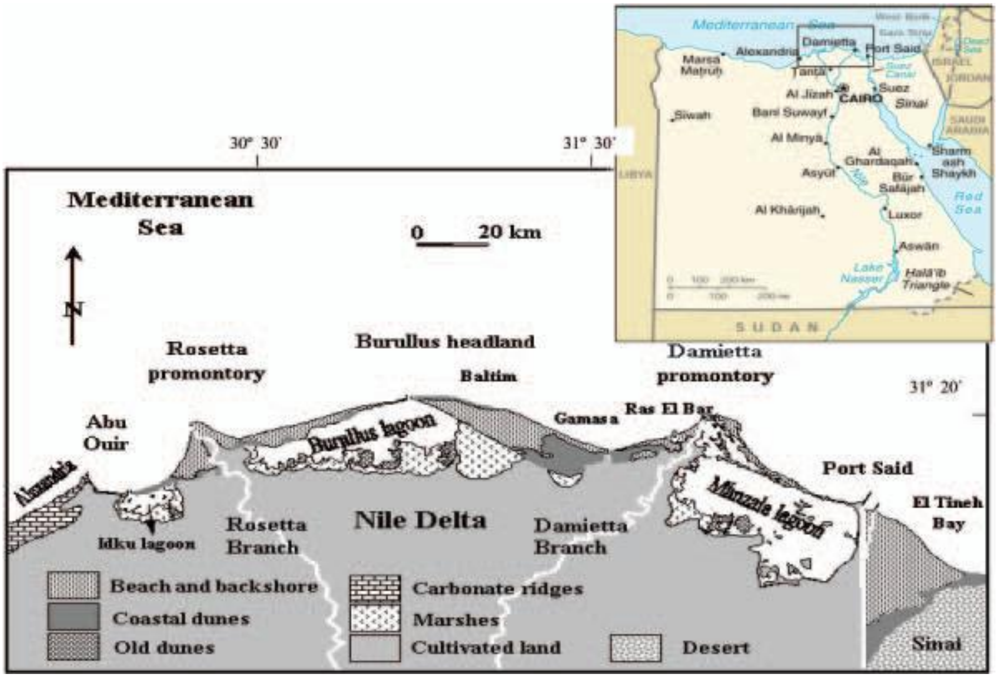


**Figure 1. The Burullus Region**

The agricultural year of Egypt has three crop seasons. The winter season starts from October to December and ends between April and June. Its main crops are wheat, barley, berseem, lentils, winter onions and vegetables. The summer crops cotton, rice, maize, sorghum, sesame, groundnuts, summer onions and vegetables are sown from March to June and harvested from August to November. A third growing season known as 'nili' is a delayed summer season where rice, sorghum, berseem and some vegetables are grown. A piece of land cannot be planted in both summer and nili crops in any 1 year because nili and summer cropping seasons overlap (Dewidar 2004).

## 3. METHODOLOGY

### 3.1Satellite Data and Image preprocessing

Multi-spectral satellite data of different sensors (TM, ETM+, and MERIS) were used for the analysis. Both sensors (TM and ETM+) have spatial resolution of 30m (NASA 2007) for Path 177 and Row 38 whereas the MERIS image has spatial resolution of 300m (GLOBCOVER, 2010). Characteristics of data are shown in table 1.

**Table 1. Satellite Data Characteristics**

| Index | Satellite | Sensor | Bands | Acquisition Date |
|---|---|---|---|---|
| 1990 | Landsat-5 | TM | 7 | 03-08-1990 |
| 2000 | Landsat-7 | ETM+ | 8 | 03-08-2000 |
| 2009 | Envisat | MERIS | 32 | 25-07-2009 |

Image pre-processing steps were applied to the images using the ERDAS IMAGINE software. The 1990 and 2000 Landsat scenes were already co-registered into the same projection (UTM, WGS 84). Layer stacking of the bands was conducted to create color composite images of 1990 and 2000 Landsat scenes. During this process, the thermal band 6 was removed from the Landsat TM scenes while the thermal bands (61 and 62) were removed from the Landsat ETM+ scenes. The 2009 MERIS imagery was co-registered into the projection (UTM, WGS 84). The 2009 MERIS imagery was imported into the ERDAS IMAGINE with 15 bands excluding the remained 32 bands. Cropping the images is inquired at specific map locations between longitudes $30^0$ 33' and $31^0$ 08' E and latitudes $31^0$ 34' and $31^0$ 13'N. The RGB color composite of bands (4, 3, and 2) of Landsat imageries and bands (13, 4, and 2) of the fused MERIS imagery were selected for the mapping of the different land cover types in the Burullus region.

## 3.2Classification

The Maximum Likelihood (ML) classification method is well known for the analysis of satellite images. The satellite image interpretation using the ML approach was mostly applied for land cover classification (Huang *et al*. 2007) and monitoring of land use changes (Shalaby and Tateishi 2007). The Maximum Likelihood supervised classification is used for the classification of the three images of years 1990, 2000, and 2009 into six land cover classes which are recognized as follows; Water1, Water2, Agriculture, Urban, Floating Vegetation, and Soil Moisture. The areas are then computed for each of the land cover types in each of the classified images in square kilometer unit. Table 2 shows descriptions for the land cover types used for the analysis of the study area.

**Table 2. Class name and description for land cover types**

| Class Name | Description |
|---|---|
| Water1 | Mediterranean Sea |
| Water2 | Lake Burullus and Fish Ponds |
| Agriculture | Cultivated Lands surrounding the Lake Burullus area |
| Urban | Sand bar and Sand Dunes |
| Floating Vegetation | - |
| Soil Moisture | - |

## 3.3Post-classification Comparison Change Detection

The most common technique for detecting changes is the post-classification technique (Bauer et al. 2003). It is used in this study to compare the land cover types of the two classified thematic maps by pixels during the periods (1990-2000) and (2000-2009). The produced change maps will be used to examine the trend change in the floating vegetation and the soil moisture areas in terms of increase or decrease during the past two decades from 1990 to 2000 and then from 2000 to 2009. Table 3 shows the 4 change categories that were created by an overlaying analysis on the change maps. The areas of increase or decrease are then computed for each of the change detection maps in kilometer square unit.

**Table 3. Class name and description for each of the 4 change categories**

| **Change Class Category** | **Description** |
|---|---|
| Other Classes | The conversion between the different land cover types excluding the floating vegetation or soil moisture according to the produced change detection map. |
| Changed To | Increase in the floating vegetation or soil moisture according to the produced change detection map. |
| Changed From | Decrease in floating vegetation or soil moisture according to the produced change detection map. |
| No Change | No change in the floating vegetation or the soil moisture between the two different years. |

## 5 RESULTS AND DISCUSSIONS

One of the objectives of this study was to determine the percentage coverage of each LULC. This was done after the classification process. Figures 2-4 show the classified images of the study area in the years of 1990, 2000, and 2009 respectively.

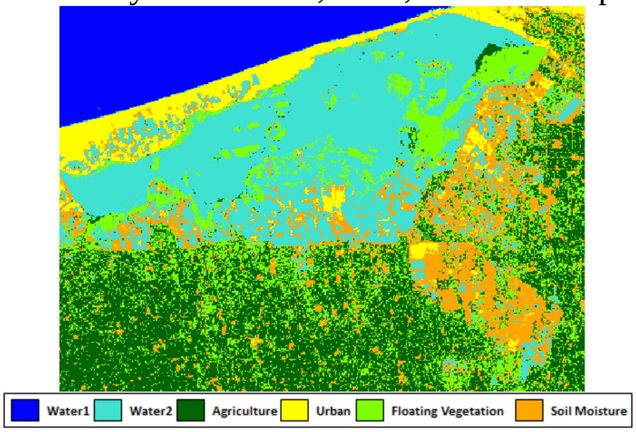


**Figure 2. Classified image of the area in 1990**

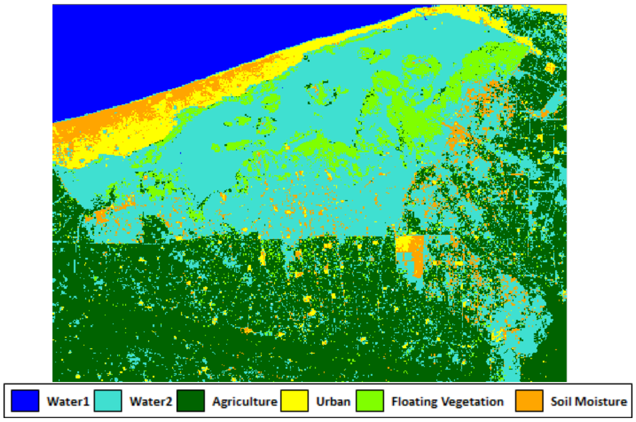


**Figure 3. Classified image of the area in 2000**

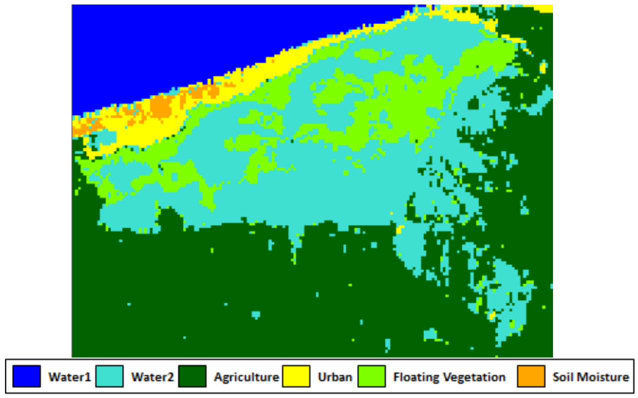


**Figure 4. Classified image of the area in 2009**

Figures 5-7 show the coverage of the land cover classes in square kilometer after classification according to the supervised ML classification on the images 1990, 2000, and 2009 respectively. The study demonstrates that the floating vegetation is decreased by 205.92 $Km^2$ during 1990-2000 and then increased by 82.47 $Km^2$ during 2000-2009. As can be seen from figures 3-4, this increase can be attributed to the conversion of Water2 (i.e. Lake Burullus water) into floating vegetation inside the Lake Burullus water. On the other hand, the study reveals that the soil moisture is on decrease from 1990 to 2000 and then from 2000 to 2009 by 183.92 $Km^2$ and 95.08 $Km^2$ respectively. From the figures 2-4, it can be observed that the soil moisture areas is dropped in the last decade during 2000-2009 by the half of its areas during 1990-2000 due to the decrease of fish ponds located within the Lake Burullus boundary in the south east of the Lake Burullus and at the sand bar of the Mediterranean Sea in 2009.

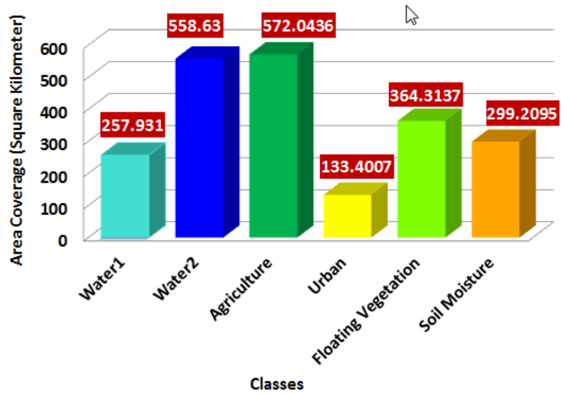


**Figure 5. Computed areas versus classes of year 1990**

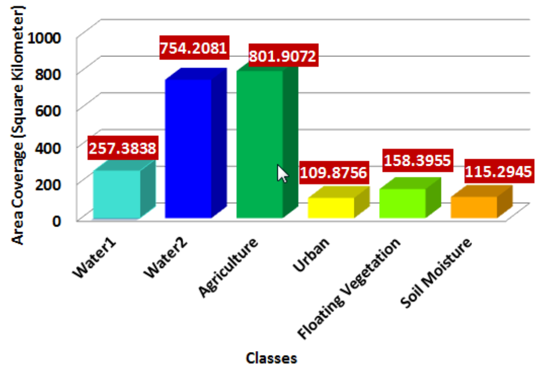


**Figure 6. Computed areas versus classes of year 2000**

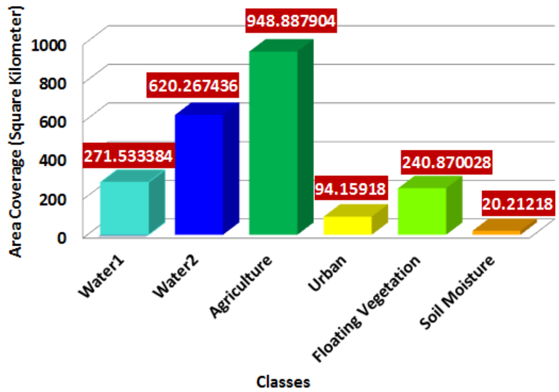


**Figure 7. Computed areas versus classes of year 2009**

Figure 8 and Table 4 demonstrate visually and analytically the Floating Vegetation change detection map for exploring the trend change in the floating vegetation areas from 1990 to 2000. The results showed that there was an increase of 3.31% in the floating vegetation areas as observed inside the Lake Burullus water. This can be mainly attributed to the conversion of 52.94 $Km^2$ in Water2 (Lake Burullus water) areas into the floating vegetation areas. From the results obtained in Table 4, the floating vegetation areas is decreased by 12.76% during 1990-2000 due to the significant increase of 211.67 $Km^2$ in the cultivated lands located within the surroundings of the Lake Burullus as shown in figure 8.

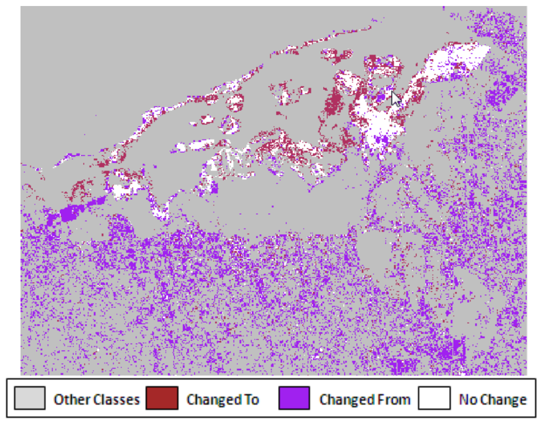


**Figure 8. Floating Vegetation Change Detection Map from year 1990 to 2000**

**Table 4. Results of analysis based on the Floating Vegetation Change Detection from year 1990 to 2000**

| Class Names | Area ($Km^2$) | Change (%) |
|---|---|---|
| Other Classes | 1745.64 | 79.99 |
| Changed To | 72.3 | 3.31 |
| Changed From | 278.35 | 12.76 |
| No Change | 85.97 | 3.94 |

Figure 9 and Table 5 demonstrate visually and analytically the Soil Moisture change detection map for exploring the trend change in the Soil Moisture areas from 1990 to 2000. According to the obtained data in table 5, it was determined that there was a decrease of 11.44% in the soil moisture areas from 1990 to 2000 due to the conversion towards the Water2 (i.e. Lake Burullus water and Fish Ponds) areas and vegetation areas by 153.11 $Km^2$ and 63.47 $Km^2$ respectively. The soil moisture areas were increased by 3% due to the conversion of 42.54 $Km^2$ of the urban areas into the soil moisture areas. This can be mainly attributed to reclamation process of the fish ponds at the sand bar of the Mediterranean Sea.

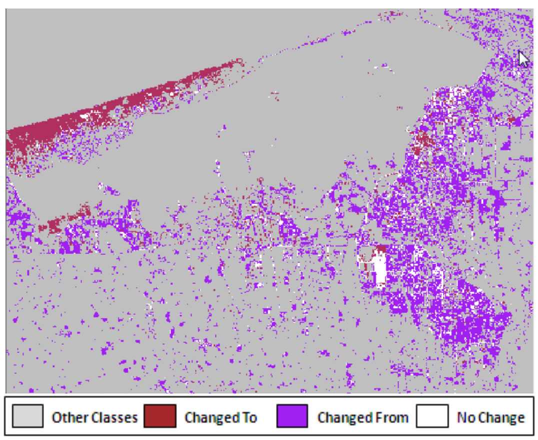


**Figure 9. Soil Moisture Change Detection Map from year 1990 to 2000**

**Table 5. Results of analysis based on the Soil Moisture Change Detection from year 1990 to 2000**

| Class Names | Area ($Km^2$) | Change (%) |
|---|---|---|
| Other Classes | 1817.72 | 83.29 |
| Changed To | 65.45 | 3 |
| Changed From | 249.63 | 11.44 |
| No Change | 49.46 | 2.27 |

Figure 10 and Table 6 demonstrate visually and analytically the Floating Vegetation change detection map for exploring the trend change in the Floating Vegetation areas from 2000 to 2006. According to the obtained data in table 5, the floating vegetation areas was increased by 6.46% due to the significant decrease of 123.18 $Km^2$of Water2 (i.e. Lake Burullus water) inside the Lake Burullus water. There was a decrease of 2.63% in the floating vegetation areas during the period 2000-2006. This can be mainly attributed to the conversion towards the Water2 (i.e. Lake Burullus water) areas and the vegetation areas by 32 $Km^2$ and 23.67 $Km^2$ respectively.

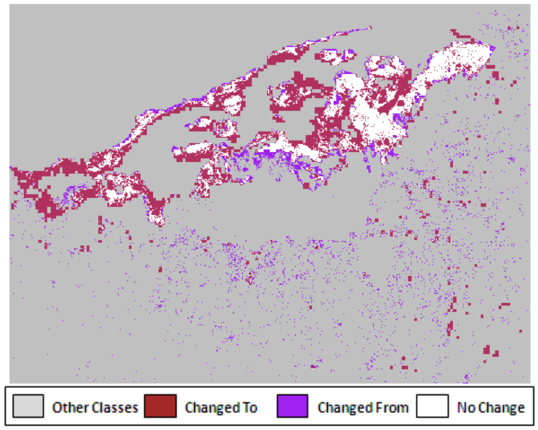


**Figure 10. Floating Vegetation Change Detection Map from year 2000 to 2009**

**Table 6. Results of analysis based on the Floating Vegetation Change Detection from year 2000 to 2009**

| **Class Names** | **Area ($Km^2$)** | **Change (%)** |
|---|---|---|
| Other Classes | 1867.8 | 86.24 |
| Changed To | 139.81 | 6.46 |
| Changed From | 56.89 | 2.63 |
| No Change | 101.2 | 4.67 |

Figure 11 and Table 6 demonstrate visually and analytically the Soil Moisture change detection map for exploring the trend change in the Soil Moisture areas from 2000 to 2009. According to the obtained data in table 7, the soil moisture was insignificantly increased by 0.25% due to the decrease of 5.32 $Km^2$ in the urban areas at the sand bar of the Mediterranean Sea. This can be attributed to the intrusion of the Lake Burullus water into the sand bar of the Mediterranean Sea. The results demonstrated also that there was a decrease of 4.64% in the soil moisture areas in the same period due to the conversion towards the Water2 (i.e. Lake Burullus water and Fish Ponds) areas and vegetation areas by 55.36 $Km^2$ and 20.48 $Km^2$ respectively. A 20.09 $Km^2$ of soil moisture areas was also transformed into the sand dunes at the sand bar of the Mediterranean Sea. This decrease can be contributed to the reclamation and the drying processes in the Burullus region.

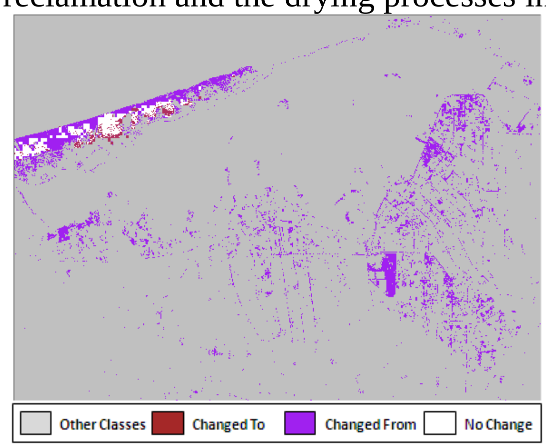


**Figure 11. Soil Moisture Change Detection Map from year 2000 to 2009**

**Table 7. Results of analysis based on the Soil Moisture Change Detection from year 2000 to 2009**

| Class Names | Area ($Km^2$) | Change (%) |
|---|---|---|
| Other Classes | 2045.27 | 94.43 |
| Changed To | 5.42 | 0.25 |
| Changed From | 100.41 | 4.64 |
| No Change | 14.6 | 0.67 |

## 6 CONCLUSIONS

The Maximum Likelihood supervised classification and the Post-classification change detection technique are used in this study for monitoring the Land Use and the Land Cover (LULC) changes within the Burullus region during the past two decades within the periods 1990-2000 and 2000-2009. The study area was classified into six land cover classes; Water1, Water2, Agriculture, Urban, Floating Vegetation, and Soil Moisture.

The study proved that there was a trend change in the floating vegetation and the soil moisture areas within the Burullus region. The floating vegetation is on increase inside the Lake Burullus water from 1990 to 2000 and from 2000 to 2009 due to the drying of the Lake Burullus water within the Burullus region. The soil moisture areas were decreased during the period 2000-2009 by the half of its areas during the period 1990-2000. This decrease is mainly attributed to the reclamation and the drying processes of the fish ponds in both of the south east of the Burullus region and at the sand bar of Mediterranean Sea in addition to the increase in the Lake Burullus water and cultivated lands areas. Focus should be given to the effect of floating vegetation and the fish ponds growth in the Burullus region.

The study has shown that information from satellite remote sensing can play a useful role in understanding the nature and extent of changes in land use/ land cover, where they are occurring and monitoring these changes at local scale.

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