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# Remote Sensing Technology for Studying the Impact of Anthropogenic Activities on the Environmental Change of Burullus Lake, Egypt

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**Abstract:** Burullus Lake is one of the Nile Delta lakes and the second largest lake along the coastline of the Mediterranean Sea. Negative human activities play an important role in biodiversity deterioration of Burullus Lake. Remote sensing techniques were applied for assessing the impact of anthropogenic activities. Landsat data were acquired in 2001, 2013 and 2018 with radiometric and atmospheric corrections. Vegetation cover, water bodies and bare lands of Burullus Lake were calculated using normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and Bare-soil index (DBSI). The study typically showed that the vegetation cover was approximately 106.89 $Km^2$ (23.14%), 180.44 $Km^2$ (39.06%) and 154.92 $Km^2$ (33.53%) in 2001, 2013 and 2018, respectively. Water bodies adequately represent the largest area of Burullus Lake. Water bodies were about 288.55 $Km^2$ (62.45%), 274.59 $Km^2$ (59.43%) and 300.60 $Km^2$ (65.06%) in 2001, 2013 and 2018, respectively. Bare-soil of Burullus Lake affects adversely on the biodiversity. Bare lands were typically about 66.55 $Km^2$, (14.4%) 6.98 $Km^2$ (1.51%) and 6.48 $Km^2$ (1.40%) in 2001, 2013 and 2018, respectively. The amount of drying decreased from 2001 to 2018. The effective percent of drying is about 10.4%, 7.2% and 3.9 % from 2001 to 2013, 2001 to 2018 and from 2013 to 2018, respectively. Chlorophyll as an indicator of eutrophication is studied using Landsat images and accurately showed high reflectance in the year of 2013 and 2018 as a possible indication for increasing tremendously the discharge of wastes especially from agricultural and fish farm sources. But more management was observed in various sites in the year of 2018. The results will carefully help the decision-makers to take aback the necessary procedures to typically reduce the environmental risk and maintain the lake to sustain the lake water area against further drying and negative human activities.

**Key words:** Burullus Lake, Remote sensing, NDVI, NDWI, Anthropogenic, Chlorophyll

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# 1. Introduction

Burullus Lake plays an important role in biodiversity for more migrant birds and different plants. It has a major role in fish farming and the reception of migratory birds. It typically contains some rare birds and some rare marine plants. So, it declared as a nature reserve in 1998. The decrease in Burullus surface area affects negatively on the biodiversity, therefore the lake attracts great interest from academic researchers and local officials. But, in general, the Egyptian Nile Delta lakes suffer from some serious challenges like an incremental, flow of freshwater, pollution, land degradation, a high rate of population growth and erosion rates [1]. Fundamental changes in vegetation cover and water bodies in Burullus Lake are very important to sustainable development. Studying environmental changes is vital to properly understand the direct impact of human activities on the environment of the Lake. Burullus Lake is typically the second-largest northern lakes in Egypt, along the Mediterranean seashore. It is one of the most vulnerable lagoons along the delta's coastline. Ozesmi and Bauer [2] prominently mentioned that remote sensing technology is suitable for wetland mapping and monitoring where funds are typically limited and reliable data on wetland areas, surrounding land uses, and wetland losses over time are unavailable. The Landsat program has typically provided calibrated and high-resolution spatial data of the Earth's surface for more than 45 years. Landsat-8, launched in February 2013, is the latest satellite in a continuous series of land remote sensing satellites that began in 1972 [3]. The successful integration of remote sensing and modern GIS techniques amply provide more details about spatial and temporal changes in biodiversity of the lake [4]. McFeeters [5] estimated the area of water bodies typically using NDWI (Normalized Difference Water Index) based on the normalized relationship between the reflection in the green and the near infrared (NIR) portions of the spectrum. The NDVI algorithm directly correlates with the green biomass, and it is properly applied to positively enhance the vegetation spectral signature [6]; it naturally gives an appropriate measure of the vegetative cover on the land surface over wide areas. Remote sensing applications can carefully distinguish between vegetative and water changes spectral reflectance of bands. Remote sensing techniques are practical and cost-effectively for monitoring natural and human-induced coastal changes after continuous improvements in sensor design and data analysis techniques. According to El-Amier [7], the northern parts of the Burullus Lake, where there are fish farms and drainage water from agricultural areas containing high amounts of phosphate and nitrate was the limiting factor. El-Adawy *et al*. [8] stated that Burullus Lake showed a decrease in the area of vegetation and water bodies from 2010 to 2013. Of all environmental parameters, the salinity of the water body appears to be the most important factor affecting the continuous distribution and local abundance of hydrophyte vegetation communities in the lake [9]. Now, Burullus Lake environment has been under human activities threat, therefore the present study aims to detect the environmental impacts of anthropogenic activities on the unique biodiversity of the lake.

## 2. Materials and Methods

### 2.1. Study area

Burullus Lake in Egyptian Nile Delta is one of the most susceptible areas along the delta's coastline shown in **Figure 1.** The study area accurately represents Burullus lake typically extending from latitude 31° 15' N to 31° 40' N and from longitude 30° 20' to 31° 10' E. The eastern sector of the lake is the shallowest and saline, which properly contains a short canal intimately connecting the lake to the Mediterranean Sea (El-Boughaz canal). The lake depth is properly exposed to moderately large differences from day to day [10]. The present area of Burullus Lake is about 420 km$^2$ of which 370 km$^2$ is open water. Burullus Lake had an overall area of about 600 km2 in 1900, while its area was estimated by 574 km$^2$ (136,620 Feddan) in 1956 [11]. By 1974, land reclamation for agriculture in its southern part may have positively affected the size of the lake and caused it to decline to about 460 km$^2$ (110,000 Feddan), and this decline continues today. It seems that during the last 100 years, a gradual reduction in the lake area by 30% typically took place. This marked decrease is due to continuous land reclamation projects along the southern and eastern shores.

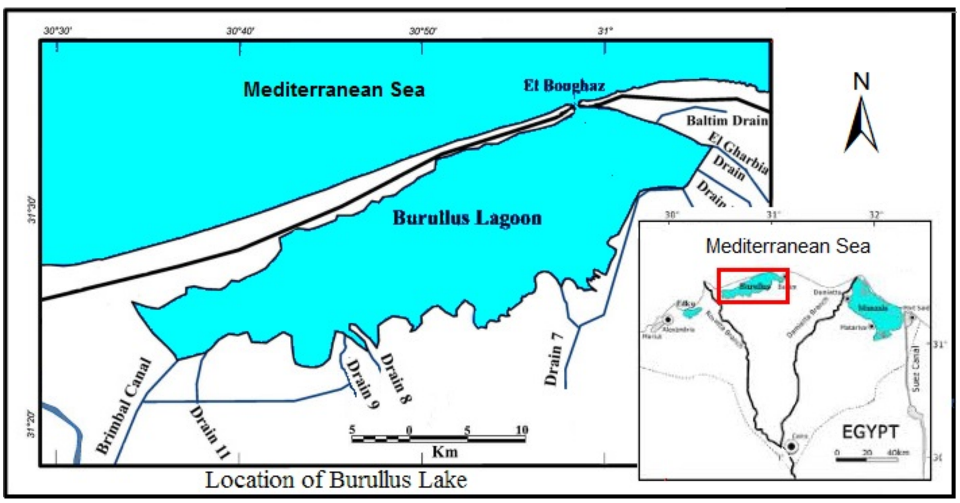


**Figure 1.** Location map of the study area.

## 2.2. Satellite data

### *2.2.1. Image preprocessing*

Satellite data were acquired from United States Geological Survey (USGS) (http://glovis.usgs.gov). These data of images were located in path 177 and row 38 as shown in **Table 1**. Satellite images were taken in 2001, 2013, and 2018. According to the different types of sensors obtained and different levels of remote sensing data, the data preprocessing in the study area mainly includes: mathematics foundation, atmospheric correction and radiometric calibration, geometric registration, image enhancement, image cropping and image mosaic. The geographical coordinates are unified by the latitude and longitude coordinate system WGS_1984_UTM_Zone_36 N, and the projection mode is horizontal axis Mercator projection. Atmospheric correction is to separate the spectral reflection information of the ground surface from the information of the atmosphere and the sun. The radiation calibration converts the pixel value into the true radiance value of the ground object, providing the necessary data foundation for the automatic interpretation of the computer using ERDAS Imagine.

**Table 1.** Satellite data applied in the present study.

| Sensor | Path/Row | Date | Resolution (m) |
|---|---|---|---|
| ETM | 177/38 | 2001 | 30 |
| OLI | 177/38 | 2013 | 30 |
| OLI | 177/38 | 2018 | 30 |

### *2.2.2. Vegetation cover*

For identification of vegetation cover of the study area, NDVI was applied using ERDAS Imagine. NDVI is the difference between the red and near infrared and combination divided by the sum of the red and near infra-red band combination. The value of this transformation varies from -1 to one, depending on the amount of vegetation. Highly vegetated areas will yield values of NDVI close to one, where poorly vegetated areas will have NDVI values close to zero. Crops were located in the moderate and dense vegetation classes whereas the sparse density class represents the naturally growing vegetation [12].

The NDVI in a Landsat-8 OLI image is computed as**:** NDVI = (B5-B4) / (B5+B4)

The NDVI in a Landsat-7 ETM image is computed as**:** NDVI = (B4-B3) / (B4+B3)

### *2.2.3. Water bodies*

NDWI was applied using the Modeler Function in ERDAS. NDWI is the difference between the green and near infrared and combination divided by the sum of the green and near infra-red band combination. NDWI images reflect the water bodies present in the study area. The value of this index varies from -1 to one, depending on the amount of water, and it resembles high water that values close to 1. NDWI was applied using the ERDAS molder to reduce any noise pixels as follows [13].

The NDWI in a Landsat-8 OLI image is computed as**:** NDWI = (B3-B5) / (B3+B5)

The NDWI in a Landsat-7 ETM image is computed as**:** NDWI = (B2-B4) / (B2+B4)

### *2.2.4. Bare lands*

It is difficult to distinguish between built-up areas and bare lands in any area. The study proposed an index to map bared lands in the selected study area. The bare land surfaces mainly include sandy land and unused land [14]. Built area can be detected and assessed using an index called Normalized Built up area index (NDBI) (equation 3). Bare-soil index (DBSI) was used to map bare areas. This index was primarily developed for Landsat TM satellite data through analysis of the spectral response of built-up areas in different bands of the imagery. The methodology comprised three arithmetic computations [15]. To calculate the bare area, we used the following equations.

The NDBI in a Landsat-8 OLI image is computed as**:** NDBI = (B6-B5) / (B6+B5)

The NDBI in a Landsat-7 ETM is computed as**:** NDBI = (B5-B4) / (B5+B4)

The DBSI in a Landsat-8 OLI is computed as**:** DBSI = (B6-B5) / (B6+B5) - NDVI

The DBSI in a Landsat-7 ETM is computed as**:** DBSI = (B5-B4) / (B5+B4) - NDVI

### *2.2.5. Mapping of drying and drilling process*

According to the number of pixels in the satellite images, the surface area was then calculated. According to the proposed indices in the study: NDVI, NDWI and DBSI, drying and drilling were applied and developed showing the direct effect of anthropogenic activities in Burullus Lake.

### *2.2.6. Mapping Chlorophyll - a*

The used images were converted from DN into reflectance using ERDAS IMAGINE. The presence of chlorophyll a determines a decrease in the reflectance in bands; blue and red on the other hand, an increase in reflectance showed in green band. Chlorophyll values have been extracted according to Brivio *et al*. [16] by subtraction of the reflectance of red from blue and normalizing by the reflectance in green.

$$Chl = 0.098 * \frac{Blue - Red}{Green}$$

After using this equation, random samples in ArcGIS software were applied and distributed at the whole body water of the lake for extracting the spectral reflectance representing the water content from chlorophyll at these sites. As water with high chlorophyll content looks green because it reflects strongly in the green part of the spectrum and gives an indication to trophic sites.

## 3. Results and Discussion

For studying the impact of human activities on the lagoon of Burullus, vegetation cover, water bodies and bare lands were applied using remote sensing techniques. Three raw satellite images were naturally acquired in 2001, 2013 and 2018. The reflectance pattern of green vegetation in the visible wavelength is due to selective absorption by chlorophyll. The high reflectance of water is due to some organic impurities and suspended matter. The reflectance of bare soil rises through the visible and near infrared wavelength ranges, typically peaking in the middle infrared range; this is due to clay minerals. The study area shows Burullus Lake with an area of 462 $Km^2$ and the spectral reflectance was illustrated showing major three classes of Burullus Lake; water, vegetation and bare lands as shown in Figure 2. Total area of Burullus Lake, its vegetation cover, water body and bare lands for the different three years were measured in $Km^2$ and percent according to Table 2. The reflectance of vegetation and bare lands has a high frequency in band 5. NDVI was applied in the present study showing the vegetation cover. Vegetation cover was precisely approximately 106.89 $Km^2$ (23.14%), 180.43 $Km^2$ (39.06%) and 154.92 $Km^2$ (33.53%) in 2001, 2013 and 2018, respectively as shown in Figure 3. It was showed that vegetation cover has typically increased from 2001 to 2013 and decreased from 2013 to 2018. The decrease of vegetation cover from 2013 to 2018 may be related to some factors. Firstly, change in climate with a high temperature from one year to another causing vegetation loss. Secondly, wastewater from industrial and agricultural drains that loaded high amount of mineral and heavy metals causing vegetation loss. Thirdly, the dipping that occurred by the government to allow high amount of water entering the lake via El-Boughaze causing low sedimentation and loading high amount of minerals causing high salinity of the lake which affects negatively on vegetation cover. Fourthly, increase the excavation work and progressively expand the surface area of water bodies. Vegetation cover in Burullus Lake needs sustainable management to reduce negative human impact. The cultivated area has increased due to reclamation, drying projects at the south-eastern part of Burullus Lake and reclamation processes for sand dunes [17]. Shaltout and Al-Sodany [18] stated that salinity and sedimentation were the main factors that governed justly the plant succession in this wetland. Abd El Hamid *et al* [19] mentioned that vegetation cover may be typically decreased according to organic matter community which is positively related to change in temperature and measurable precipitation, long-term climatic changes, human and animal activities. The agriculture area increased by 45.52% (10,529.02 ha), while the sand bar and urban area decreased mostly by the same amount during the period from 1984 to 2015; this increase in floating vegetation is mainly due to discharging of agriculture wastes and municipal wastes in the lake without adequate treatment [20]. NDWI was applied in the present study typically showing water bodies. Water bodies represent the largest area of Burullus Lake. Water bodies were approximately 288.55 $Km^2$, (62.46%) 274.59 $Km^2$ (59.43%) and 300.60 $Km^2$ (65.06%) in 2001, 2013 and 2018, respectively as shown in Figure 4. It was showed that water bodies decrease from 2001 to 2013 and increase from 2013 to 2018. Oppositely way to vegetation covers in the present study. The decrease in the open water surface area in 2013 agreed with El-Asmar *et al*. [21]. Fundamental changes in water bodies from 2013 causing the increase in the open water surface in 2018 are attributed to some human activities in Burullus Lake. These factors which causing the increase surface area are the cutting of high amount of vegetation cover in the lake for financial reasons and fishing. This can be mainly attributed to reclamation process of the fish farms inside the lake. Water logging area in the study area is mostly located in the northern parts of the study area where the soil is saturated with water forming water ponds. Wetlands areas have increased due to an increase in water table level, which may be attributed to seawater intrusion. The agricultural area is located in the southern borders where agricultural drains were properly discharging into south of Burullus lake [22]. Bare soil of Burullus Lake affects negatively on the biodiversity. DBSI index was proposed typically showing the bare areas. Bare lands were approximately 66.55 $Km^2$, (14.41%) 6.98 $Km^2$ (1.51%) and 6.48 $Km^2$ (1.40%) in 2001, 2013 and 2018, respectively as shown in Figure 5. It was convincingly showed that bare lands decrease from 2001 to 2013 and decrease from 2013 to 2018. The gradual decrease in bare land is a good indicator for biodiversity of the lake and bird migration. This decrease in bare lands is probably due to increase tremendously the area of vegetation cover. Younis and Nafea [9] stated that this decrease is due to continuous land reclamation projects and fish farming processes along the southern and eastern shores of the lake. Bare lands were like a result of the clearing of the lands for agricultural and building purposes. The urban land has doubled during the period (1984–1997) [15]. Also, the cultivated lands class has increased due to reclamation and drying projects at the southern eastern part of Burullus Lake. According to NDVI, NDWI and DBSI, percentage (%) of vegetation, water and bare areas was calculated as in Figure 6. Finally, the area of the lake increase from year to another. The drilling process increase and the drying process decrease. The results amply confirm that the amount of drying is typically decreased from 2001 to 2018. The effective percent of drying is about 10.4%, 7.2% and 3.9 % from 2001 to 2013, 2001 to 2018 and from 2013 to 2018, respectively. On the other hand, the percent of drilling is about 8.9, 11.2 and 10.5 % from 2001 to 2013, 2001 to 2018 and from 2013 to 2018, respectively. This may lead to increase tremendously the surface of the lake. Some people use drying process for reclamation and making fish farms as shown in Figure 7. Anthropogenic activities as Population growth, expanded land development, and intensified agriculture are likely causing degradation of Burullus Lake environments. Anthropogenic activities have altered Burullus Lake and led to a great effect on biodiversity.

For carefully comparing pollution status by developing maps for extracted chlorophyll values in these different years from 2001 to 2018. According to Figure 8, it sufficiently indicated low reflectance in year 2001 and increase fluctuated between 2013 and 2018 in different sites. This sufficiently indicates that the activity of agriculture and fish farms nearby the lake increase to the period 2013. Effective management of the lake in the last years to carefully keep the lake may occur through digging processes. Also different activities as deepening the Boughaz area aid to possible intrusion of sea water in the lake and reducing the effect of the drained water and may decrease the economic impact of eutrophication. It was recorded that human activities, represented by wastewater discharge, have dramatically affected the quality of water in Burullus Lake. The present study has reported favorably that chlorophyll values in Burullus Lake is more in eastern and southern parts than other areas in the lake water, owing to the polluted wastewater and drainage water discharging into these protected areas.

**Table 2.** Burullus lake environments area.

| LULC | 2001 | | 2013 | | 2018 | |
|---|---|---|---|---|---|---|
| | $Km^2$ | % | $Km^2$ | % | $Km^2$ | % |
| Vegetation cover | 106.89 | 23.14 | 180.44 | 39.06 | 154.92 | 33.53 |
| Water bodies | 288.55 | 62.46 | 274.59 | 59.43 | 300.60 | 65.07 |
| Bare lands | 66.55 | 14.41 | 6.98 | 1.51 | 6.48 | 1.40 |
| Total | 462 | 100 | 462 | 100 | 462 | 100 |

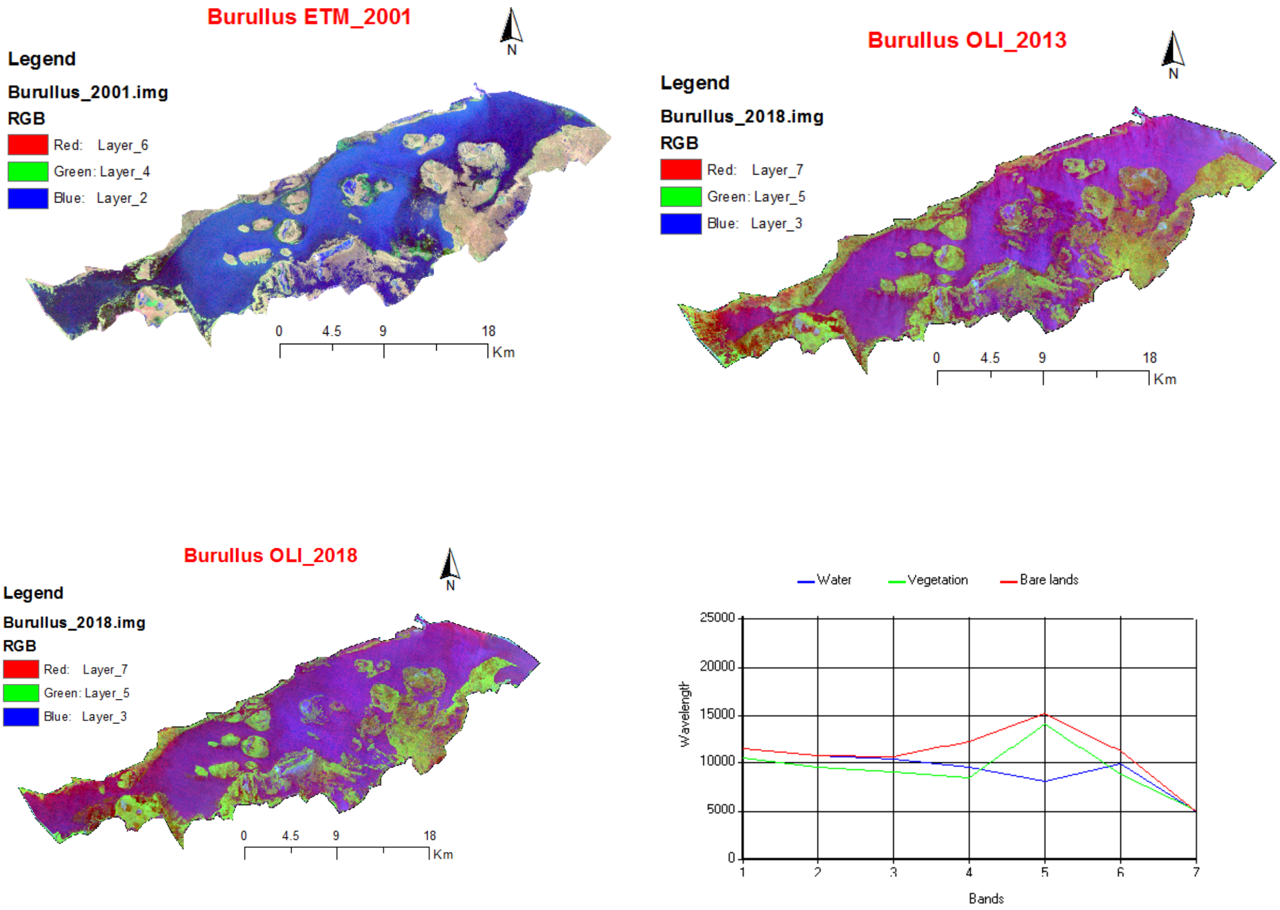


**Figure 2.** Landsat image of Burullus Lake in different years and spectral reflectance.

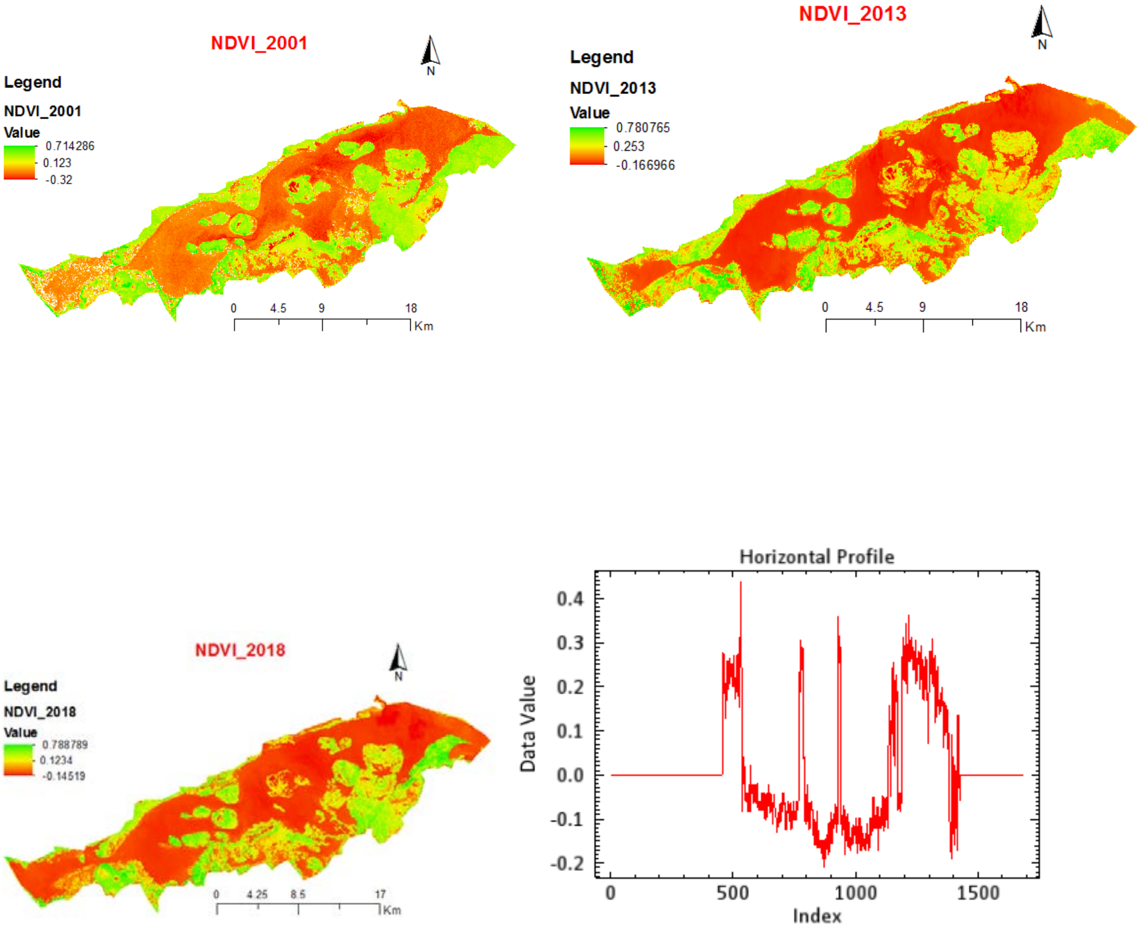


**Figure 3.** NDVI index of Burullus Lake in different years and spectral reflectance.

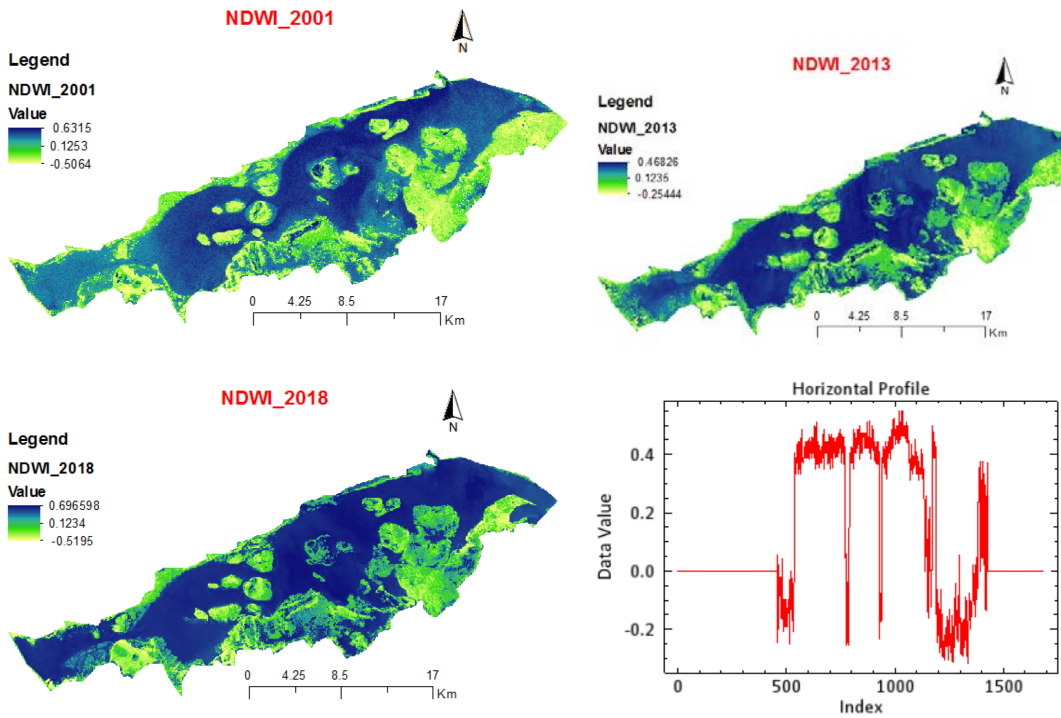


**Figure 4.** NDWI index of Burullus Lake in different years and spectral reflectance.

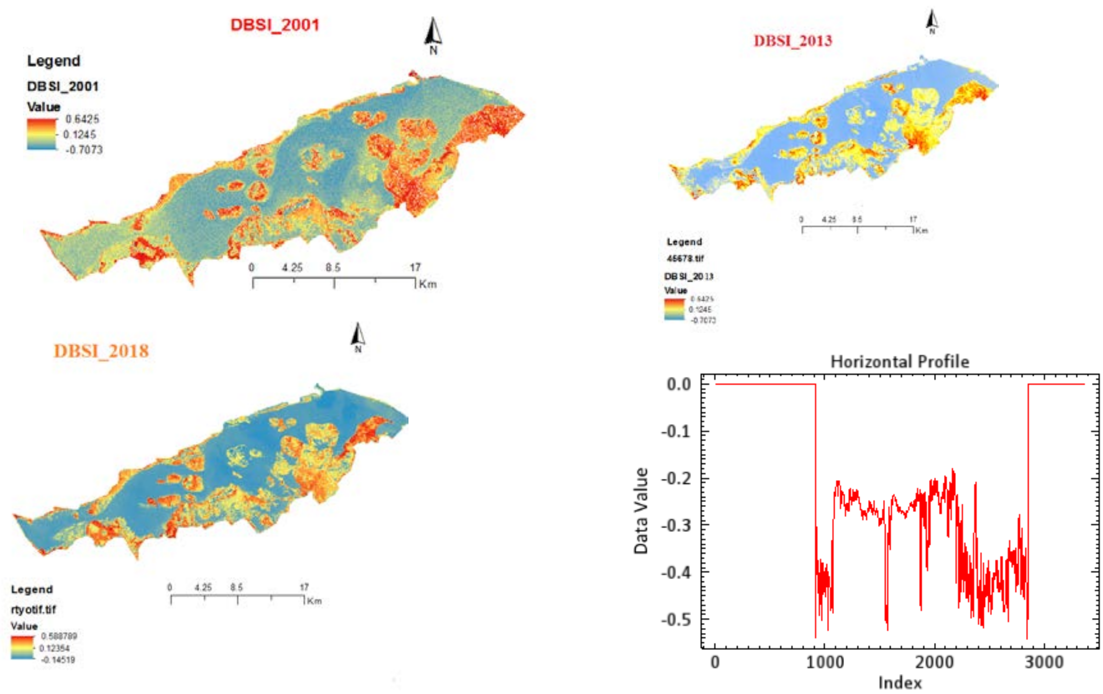


**Figure 5.** DBSI index of Burullus Lake in different years and spectral reflectance.

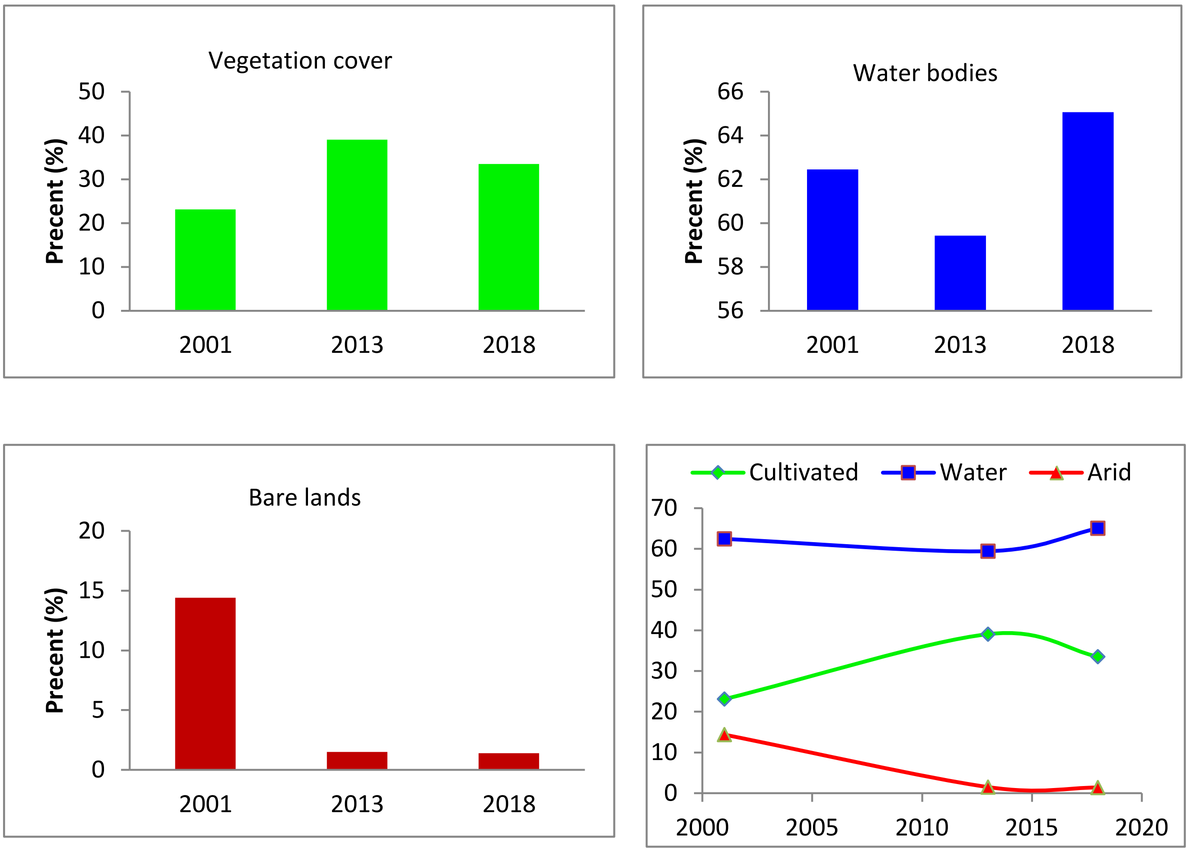


**Figure 6.** Percentage (%) of Burullus Lake environments.

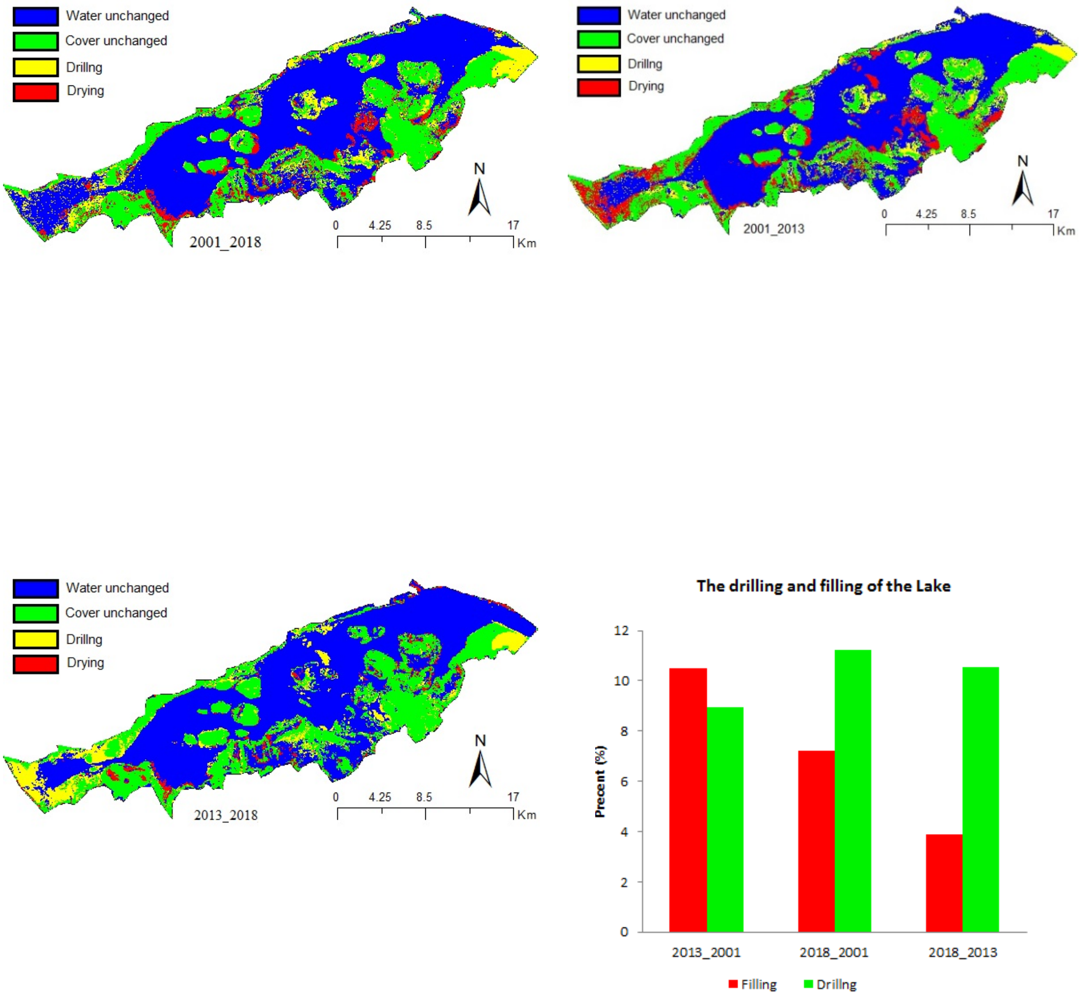


**Figure 7.** Drying and drilling of Burullus Lake during study period.

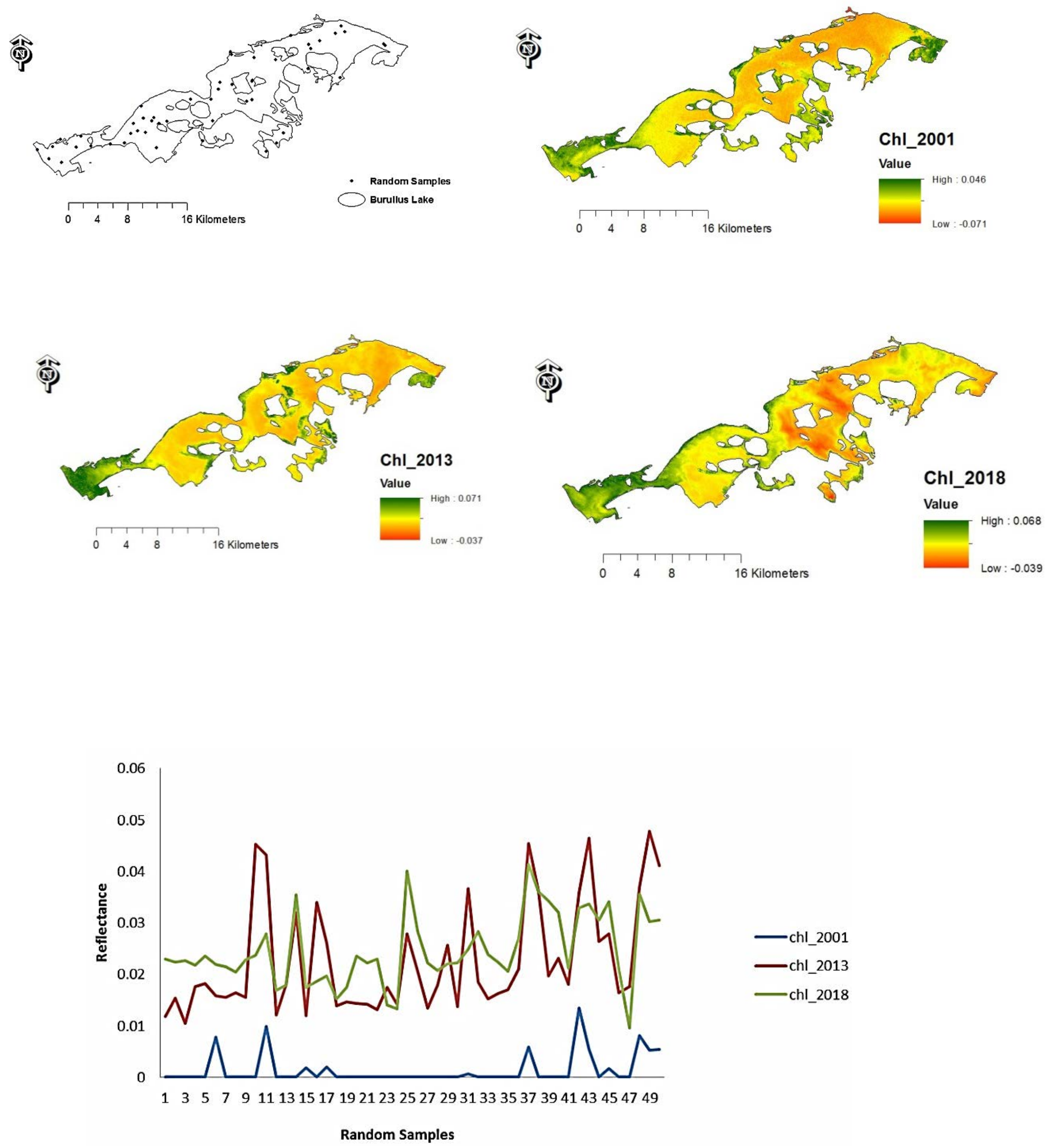


**Figure 8.** Extracted Chlorophyll maps according to equation of Brivio *et al*. [16]

# 4. Conclusions

Remote sensing and GIS techniques have been used effectively for studying the impact of anthropogenic activities on Burullus Lake environment. Three Landsat images were acquired in 2001, 2013 and 2018. NDVI, NDWI and DBSI have been selected using ERDAS Imagine and ArcGIS software showing the impact of human activities on the study area as a wetland protectorate. The bare areas have been gradually declined during the study period and the vegetation coverage increased by the same percentage. Thus, Burullus Lake environment has been affected by the impacts of human activities. Drying and drilling were calculated and the study has shown that increasing the water surface of the lake and drying processes are decreasing from 2013 to 2018. This is a good indicator of the attention of the decision makers by the lake. However, water bodies and vegetation cover in Burullus Lake need sustainable management to reduce negative human impact. The images showed high reflectance into last years as a proof of increasing drainage water in the area, so more efforts for decreasing these pollutants and remediate should be taken into considerations to protect the biodiversity of the lake.

# Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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