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Ecosystem Service Value Based on Land Use/Cover Dynamics and Socio-Economic, Burullus Lake, Egypt

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Abstract

Burullus Lake is an ecological system that supplies a variety of ecosystem services (ES) to the community. The value of these services depends on change in land use and land cover LU/LC and socioeconomic factors as fish production. Supervised classification was applied showing four classes; water, vegetation, fishfarm and services lands. Markov and CA-Markov were applied for LU/LC transition and prediction. Results reveal an increase in water bodies due to recent development in Burullus Lake. Removal the floating plants reflects the decrease in vegetation. Area of fishfarm was increased from 2009 to 2013 that increase the value of ecosystem services in the study area in this period. These changes in LU/LC had a positive impact on ESV due to the conversion among different classes. ESV varied significantly in Burullus Lake. Increased value of ecosystem provides higher opportunities for recreation and ecotourism. Fish production of Lake Burullus has increased from 2009 to 2018 with an increase of 18,000 ton by about 34%, and this increase in may be the result of adding additional areas to Lake Burullus during this period as a result of purification operations as a main factor. Also, the lowest parts of exploitation were observed at the central parts directed to the fish farms areas. While the most exploited areas are towards the eastern parts to the area of El-Boughaz. It is indicated more that areas of jetties sites and population centers are more exploited to the lakes shores. The present study suggests that governments should take awareness of ESV through studying some ecological conditions.

Introduction

Land, water, air, climate, and genetic resources must be appropriately utilized so that future generations can profit from them. Nature is necessary for both human existence and economic activity (Zingstra 2013). Natural capital, which includes natural resources, biodiversity, and ecosystem services, is the foundation of life on Earth and is critical to human survival (WWF 2020). When addressing the interaction of human and environmental activities, land use and land cover are dynamic changes that must be examined. Terrestrial and marine ecosystems, as well as their biodiversity, serve as the foundation for economic growth, sustainable development, and human well-being, with ecosystem services serving as an environmental imperative (Ecosyst. Restor. people, Nat. Clim. 2021). It is the life's pulsating heart. From an economic standpoint, the flow of ecosystem services may be viewed as the profits derived by civilization from natural capital (Gilvear et al. 2017). Maintaining a stock of natural capital provides for the sustainable delivery of future flows of ecosystem services, which aids in the survival of human well-being. Ecosystems provide a variety of services that benefit people, society, and the economy as a whole (Pascual et al. 2010). Water and wetlands provide several ecological services such as water provision, regulation, purification, and aquifer recharge. These services are critical for achieving water security goals and for water treatment for food security (Bongaarts 2019). Climate change (adaptation to climate and climate change mitigation), food security (providing crops and nurseries for fish farms), job security (maintenance of fish farms and soil quality for agriculture), and a variety of cultural benefits include knowledge (scientific and traditional), recreation, tourism, and the formation of cultural values, including identity and spirituality, all play important roles in food cycles (Sterrett 2011). Egyptian lakes are distinguished by a distinct and unique ecosystem, as they are an incubator for much aquatic life and fish wealth, as well as receiving huge flocks of waterfowl during their seasonal migrations, and if their fish production has declined, this is due to the severe pollution that has affected them, whether from industrial drainage, agricultural, and Egypt is distinguished by containing various types of lakes (N. F. Soliman and Yacout 2016). Salt lakes like Bardawil, Manzala, Burullus, Idku, and Mariout are among them, as are freshwater lakes like Nasser, Toshka, Qarun, and Wadi El Rayan, as well as industrial lakes like Al-Temsah and Port Fouad (Wed Abdel Latif and Busse 2012). A Naba lake may also be found in Wadi El-Natrun and Siwa in the Western Desert. Lake Burullus, one of the most significant lakes, is distinguished by an integrated ecosystem with distinct ecological traits and biological richness. On the lake, to a significant degree, either directly or indirectly. Lake Burullus is located to the northeast of Rashid Branch and spans roughly 70 Km in length and 6 to 17 Km in breadth (Hosam, Mohamad, and Mai 2017). Its present land size is around 70,000 acres. It is Egypt's second-largest natural lake. Lake Burullus is one of Egypt's oldest lakes, connected to the Mediterranean Sea by the Burullus Boughaz entrance and to the Nile by the Bermbal Canal, which was built in 1926 to provide the lake with ample Nile water and Nile fish. Lake Burullus, like the other northern lakes, faces numerous problems and threats that have resulted in an imbalance in its ecosystem, the most significant of which was the reduction of its area from 165,000 acres to less than 70,000 acres after nearly 60,000 acres were deducted and weeds and reeds were planted on approximately 25,000 acres (Younes and Nafea 2012). Acres and a decrease in water salinity as a result of the blockage of the Burullus sewage sludge, which connects it to the Mediterranean Sea and the Bermbal Canal, which resulted in the extinction of some types of fish and the spread of some exotic species, as well as the spread of reeds, which cover approximately

17% of the total water surface of the lake (Younes and Nafea 2012). The lake also faces a slew of other issues, such as shrinking area due to various encroachments. Addressing these issues and restoring the lake's functions as an integrated ecosystem necessitates the implementation of an action plan that includes the purification of the lake's current sulphur and the construction of a channel surrounding the lake to replenish the water and protect it from encroachment. It also necessitates the excavation of radial channels within the lake to reveal the vegetation cover (Romanelli, Cristina, Cooper, David, Campbell-Lendrum, Diarmid, Maiero, Marina, Karesh, William B., Hunter, Danny, Golden 2015). Researchers are studying the construction of new gases to replenish the lake's water in order to expand the lake's fishing areas. Lake Burullus is important for ecological, economic, and social reasons, including the protection of agricultural lands in the lake area, the protection of fish farms and fish production, the provision of job opportunities and investments in fishing and animal production units, and water purification, where the lake plays an important role in removing harmful substances from wastewater because aquatic plants absorb a portion of the pollutants (Kaleem and Bio Singou Sabi 2020). It is also a haven for migratory birds and aids in mitigating the effects of rising sea levels. Failure to maintain the lake will result in losses equal to the value of the expected damages if the lake's problems are not addressed. The study aimed to evaluate LU/LC change in Burullus Lake over four decades; 2009, 2013, 2018 and 2028, also to describe the impact of this change on ESV.

Materials And Methods

2.1. Study area

Burullus Lake is located in the central part of Nile Delta between the two Nile branches namely; Damietta and Rosetta. It is one of the most exposed lakes to different pressures as shown in Fig. 1. It is also consider the second largest lakes along the Egyptian coast of Mediterranean Sea (Hossen and Negm 2016). The amount of fish production in Burullus Lake valued by nearly 55000 tons/year equal to 40% from northern lakes productivity and 13.5% of the whole production of national income from fishing activitiy (M. R. Soliman, Ushijima, and El-Shinawy 2013). Negative anthropogenic activities affected badly on the lake’s biodiversity. The average water quality in front of drains in Burullus Lake is characterized by bad water quality (Lake 2019) and (Am et al. 2021).

2.1.1. Biodiversity in Lake Burullus

The biodiversity in Lake Burullus divides into three categorize as mentioned by (Hussien Shaltout 2010), which are producers, consumers and saprotrophs. Significant changes over the last decades were observed as a result of different spread land uses in the lakeshores. Where the aquaculture ponds and farms were increased, that impacted on the area of agricultural lands around the lake. The area of these ponds increased to nearly 33.660 hectares in 2011, where it was close to zero in 1980. This increase has an impact on the ecosystem service value especially on the biodiversity, fishing process and subsequently on food security and consequently on the local food security and livings (Zingstra 2013).

2.2. Recent development of Burullus Lake

The Egyptian government has started funding the current Burullus Lake development project in 2005. The project aims to produce a suitable environment for fish Reproduction, increasing the salinity of the lake’s water by developing saltwater inlet holes coming from the Mediterranean sea through the radial channels and the entrance to Burullus Boughaz, and developing the Bermbal Canal coming from the Rashid branch, Rotating the movement of water inside the lake, entering groups of various types of fish, whether marine fish or freshwater fish, providing a large space for free fishing by removing large quantities of aquatic plants, especially jungle linen, in addition to deepening works to increase the water level as shown in Fig. 2.

2.3. Data sources

2.3.1 Satellite data

Data of land use that are used in the present study are acquired from Landsat 5 Thematic Mapper (TM), Enhanced Thematic Mapper (ETM) and Operational Land Imager (OLI) during 2009, 2013 and 2018, respectively. Satellite images with a spatial resolution of 30 m in path 38 and row 177 were downloaded from USGS *(*https://glovis.usgs.gov*).* The single scene image covers the whole Lake, with average cloud coverage of less than 1% and good image quality.

2.3.2 Classification Spatial transition of land use and land cover (LU/LC)

Some image preprocessing was applied for image enhancement and reduces the effect of clouds and atmosphere variables using geometric correction, radiometric calibration, atmospheric correction, and terrain correction processing. According to previous studies and field survey, four classes were extracted from the study area; water, vegetation, fishfarm and services land using maximum likelihood classification by ENVI 5. The spatial transition of land use change represents the degree of land use type conversion to another type. This transition was applies using Geo-processing tools by ArcGIS 10.5.

2.3.3. Dynamic degree of Land use

The dynamic degree of land use defines the rate of land use change in the study area, which facilitates the comparison of local changes and the prediction of future trends. It includes single land use dynamic degree (R), which indicates the change in a specific land use type within a certain period, and comprehensive land use dynamic degree (L), which reflects the overall change in land use. A high dynamic degree shows an extreme change of land use (Yang et al. 2019). The weight of every land use type was selected according to development and it's important in the study area. The formulas are as follows:

$$L = 100 \times \sum_{i=1}^{n} A_i C_I \; \Delta L_{b-a} = L_b - L_a = 100 \times \left[\sum_{i=1}^{n} (A \times C_{ib}) - \sum_{i=1}^{n} (A \times C_{ia}) \right]$$

$$R = \frac{\Delta L_{b-a}}{\sum_{i=1}^{n} (A \times C_{ia})} = 100 \times \frac{\sum_{i=1}^{n} (A \times C_{ib}) - \sum_{i=1}^{n} (A \times C_{ia})}{\sum_{i=1}^{n} (A \times C_{ia})}$$

2.4. Simulation and prediction of LULC Using the CA–Markov Model

Markov and Cellular automata (CA) were applied in the present study for simulation and prediction of LU/LC with probability using Idrisi Selva 17.0. Using transition potential models as a foundation, LCM uses Markov Chain analysis to project the expected quantity of change and a competitive land allocation model to determine scenarios for a specified future date. Options exist to incorporate planning interventions such as incentives and constraints, proposed reserve areas and infrastructural changes.. It is important to note that CA–Markov model has been used recently in dynamic spatial phenomenon's simulation and future land use change prediction.

$$\mathrm{S}_{(t+1)} = (p_{ij} + S_{(t)}) \;\; P_{ij} = \begin{pmatrix} p_{11} & p_{12} & p_{1n} \\ p_{21} & p_{22} & p_{2n} \\ p_{n1} & p_{n2} & p_{nn} \end{pmatrix}$$

$$0 \le p_{11} \le 1 and \sum_{i=1}^{n} p_{ij} = 1, i, j = 1,2, \ldots\ldots, n)$$

Where, $S_{(t)}$ is the state of the system at time t, $S_{(t+1)}$ is the value and state of the system at a time (t + 1); P_{ij} is the transition probability matrix. The reliability of land use change modeling can be enhanced by joining two or more simulation methods to include the benefits of each model.

2.5. Assessment of the ecosystem service value

To obtain the ESV for each of the five land-cover categories, each category was compared with the 16 biomes identified according to Costanza *et al.* (Costanza et al. 1997), (Costanza et al. 2014) ES valuation model. The most representative biome for each category was used as the proxy for the category. Specifically, the lakes/rivers biome was used as a proxy for aquaculture ponds, cropland for farmland, forest for orchard/plant nurseries, urban for settlements, and estuaries for wetlands/tidal flats.

2.5.1. Ecosystem Service Values (ESV)

The ecosystem was altered as a result of change in LU/LC. For analyzing the impact of land cover changes, the ESV is determined; the ESV valuation method is still considered useful (Hu, Liu, and Cao 2008). The chief principle and the effective method ESV assessment were used by (Costanza et al. 1997). The valuations of ESV were calculated as follows:

$$ESV_f = \sum_i U_i \times VC_{if}$$

$$ESV_i = \sum_f U_i \times VC_{if}$$

$$ESV = \sum_f ESV_f = \sum_i ESV_i$$

Where, ESV_f is the value of ecosystem service function type "*f*"; U_i is the area for land use category "*i*"; VC_{if} is the value of coefficient of ecosystem service function type "*f*" for land use category "*i*"; ESV is the total ecosystem service value in the study area. Where: ESV is the total value of ecosystem services (USD); A_i is the average of land type (ha); VC_i refers to the ecosystem services of land type per unit area (USD·ha^{-1}·y^{-1}). Here, ESV unit area of wetlands ecosystem was determined. Ten ESFs were selected in the current study, as shown in Table 1, which are food production (FP), raw materials production (RMP), gas regulation (GR), climate regulation (CR), hydrological regulation (HR), waste treatment (WT), soil conservation (SC), water supply (WS), culture & regulation (C&R), and Habitat (H).

Table 1
Ecosystem services value of every function.

Service function	Fishfarm	Water bodies	Vegetation	Value ($/km^2)
FP	57.03	30.23	18.82	106.08
RMP	22.24	19.96	9.96	52.16
GR	41.06	29.09	46.38	116.53
CR	55.32	117.49	232.13	404.94
HR	43.92	1070.52	233.27	1347.71
WT	79.28	846.95	98.1	1024.33
SC	83.84	23.38	229.27	336.49
BC	58.17	195.62	257.22	511.01
LE	9.7	253.23	118.63	381.56
Total	450.56	2586.47	1243.78	4280.81

2.6. Remotely sensed indices

Three Landsat images were downloaded from (earthexplorer.USGS.gov) are representative to the studied years of 2009, 2013 and 2018, respectively. An image of 2009 is of Landsat TM, while the other two images are of Landsat OLI sensor. **Table (2)** discusses the acquisition, sensor type and resolution for studied images.

Table 2
Satellite, acquisition and resolution of each sensor for images.

Satellite	Sensor	Path/Row	Year	Resolution
Landsat 5	TM	177/38	2009	30 m
Landsat 8	OLI		2013	
Landsat 8	OLI		2018	

The images' pixels were converted from digital number into reflectance for further calculation of normalized different built-up index (NDBI) into Lake Burullus. Calculation of NDBI is occurred according to (Rasul et al. 2018), classes of NDBI are − 0.01–0.49 (minor built-up) and > 0.49 (major built-up) (Rasul et al. 2018); (Watik and Jaelani 2019).

2.7. Detection of exploitation degree in Lake Burullus

While the shoreline areas are important and sensitive for biological ecosystems, concerns were occurred to obtain anthropogenic impacts on coastal areas (El-Alfy et al. 2021) used similar methodologies according to proximity within different factors for assessing sensitivity to pollution in Burullus Lake within different distances. Here, the used factors for assessing the exploitation degrees are; Fish farms, Agricultural areas, urban areas (population centers), Digging processes, Jetties areas and industrial site. The Buffer that is being used of a 100meter outside the shoreline only as recommended by who used inside and outside buffer of 100m. Modified degrees were applied at different distances of 100, 500, 1000, 5000 and 10000 meters. While these categories recorded different indications to exploitations. The applied method is summarized as the chart and as applied in ArcGIS 10.5 **(Figure 3)**.

Results And Discussion

3.1. LU/LC of Burullus Lake

Based on supervised classification, four classes; Water, vegetation, fish farm and services lands were extracted from 2009, 20113, 2018 and 2028 as shown in Fig. 4. Water bodies were the dominant LU/LC in all periods of the study area. Water area was increased from 2009 to 2018. In 2009, LU/LC was water (20.32%), vegetation (26.14%), fish farm (47.31%) and services lands (6.23%). In 2013, water (23.37%), vegetation (22.39%), fish farm (48.96%) and services lands (5.28%). In 2018, water (43.9%), vegetation (25.46%), fish farm (26.06%) and services lands (4.39%). Finally, the predicted LU/LC in 2028 was water (26.77%), vegetation (21.99%), fish farm (46.38%) and services lands (4.84%) as shown in Table 2. It was showed that, water was increased due to recent development in Burullus Lake, however the predicted water area will be decreased in 2028 may be as a result of increasing of floating plants. On the other hand, the area of vegetation increased from 2013 to 2018 as a result of floating plants removal. Fishfarm increased from 2009 to 2013 but decreased from 2013 to 2018. Finally, services lands decreased due to great development in Burullus Lake.

Table 2
Areas and changes of different land use types in Burullus Lake.

	2009		**2013**		**2018**		**2028**	
Class	Area	Proportion	Area	Proportion	Area	Proportion	Area	Proportion
	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Water	172.9	20.32	198.86	23.37	373.57	43.90	227.7	26.77
Vegetation	222.4	26.14	190.5	22.39	218.18	25.64	187.04	21.99
Fishfarm	402.56	47.31	416.6	48.96	221.75	26.06	394.5	46.38
Services lands	53	6.23	44.9	5.28	37.36	4.39	41.2	4.84

3.2. Transition of LU/LC in Burullus Lake

Spatial transition of LU/LC in all periods of current study was presented as shown in Fig. 5. According to modeling of transition, about 168.41, 154.95, 170.41 and 32.37 Km^2 were constant for water, vegetation, fishfarm and services lands; respectively from 2009 to 2018 as shown in Table 3. It was showed that water loses about 5% of its area in the expense of other classes. Vegetation loses about 40.5 km^2 in the expense of fishfarm. On the other hand, fishfarm was the highest class that loses large area. It loses about 181.5 and 50.03 km^2 in the expense of water and vegetation; respectively. Conversion of vegetation to other classes leads to negative impact on the economy (Abd El-Hamid et al. 2020)

Table 3
Spatial transition of land use types from 2009 to 2018 in the study area.

2009–2018	Water	Vegetation	Fishfarm	Services lands
Water	168.4136465	22.10136498	181.5605735	1.421275028
Vegetation	0.766857434	154.953619	50.03472494	12.18369468
Fishfarm	3.710788577	40.51348979	170.4114222	6.950226638
Services lands	0.000587607	4.617199761	0.341648138	32.37022671

3.3. Land use dynamic

The comprehensive index of land use from 2009–2013, 2013–2018 and 22009 – 2018 was showed in Table 4. Results was 218.28, 209.57 and 190.52 from 2009–2013, 2013–2018 and 22009 – 2018; respectively. All data in the range of 100–400, representing that land use has been in a reasonable development stage; the comprehensive land use index has continued to decrease showing high development from 2009 to 2013. The degree of transformation in land use is less than zero. R values were – 0.039, -0.090 and – 0.145 for 2000, 2014 and 2019, respectively. According to(Lake 2019), due to the development and construction, agricultural lands can mainly increase the value of the environment. In general, urbanization or nature development are mainly responsible for transformations of agricultural land not agriculture sector.

Table 4
Comprehensive index, variation, and change rate of Land use dynamic.

	2009–2013	2013–2018	2009–2018
Services lands	24.92	21.11	17.56
Vegetation	78.41	67.17	76.93
Fishfarm	94.62	97.92	52.12
Water	20.32	23.37	43.90
Change	**2009–2013**	**2013–2018**	**2009–2018**
L	218.28	209.57	190.52
ΔL	-8.70	-19.05	-27.76
R	-0.039	-0.090	-0.145

3.4. Ecosystem service value (ESV)

Based on land use data, the ESV was presented as shown in Table 5. The total ESV in 2009, 2013, 2018 and 2028 are 12015634.36, 3452161.628, 3484443.935 and 3466212.684 $km^{-2}y^{-1}$ respectively. Results showed that the total ESV has increased year by year, however it will be decreased in 2028 as a result of human activities in the study area. It was shown that ESV of agriculture and grass and woodlands has increased from 2005 to 2018. Results showed that the value of the ecosystem in the study area is very suitable for sustainable development. Vegetation is an essential source for market products. The effect of changes in ES supply between study periods on benefits to users. Spatial distribution of ESV in 2009 and 2018 was presented as

shown in Figs. 6 and 7. ESV reached to 2.207752 and 4.380.932 $km^{-2}y^{-1}$ in 2009 and 2018. It was showed that ESV was high in 2018 than 2009. High rate of ESV was attributed to recent development in the lake.

Table 5
Ecosystem services value ($km^{-2}y^{-1}$) of LU/LC in Burullus Lake.

Function	2009	2013	2018	2028
FP	297751.7088	85496.2368	86296.08	85844.1792
RMP	146405.8176	42038.8736	42432.16	42209.9584
GR	327083.3958	93918.5188	94797.155	94300.7372
CR	1136609.888	326365.4424	329418.69	327693.6456
HR	3782833.291	1086200.352	1096362.085	1090620.84
WT	2875150.904	825569.0068	833292.455	828928.8092
SC	944480.3214	271197.4804	273734.615	272301.1676
BC	1434333.529	411853.6196	415706.635	413529.7324
LE	1070985.502	307522.0976	310399.06	308773.6144
Total	12015634.36	3452161.628	3484443.935	3466212.684

3.5. Fish production in Burullus Lake

The Egyptian lakes, including Lake Burullus, are of great economic importance at the national level, as their diversified fish production is of particular importance to the local population for its contribution to meeting their fish food needs, as well as providing many job opportunities and direct and indirect incomes related to fishing operations. Data from the Public Authority for Fish Resources Development 2018 indicated that the fish production of Lake Burullus during the period 2009–2018 ranged between a minimum estimated at 46,000 tons in 2011 and a maximum of about 71,000 tons in 2018, with an average of nearly 60,000 tons as shown in Fig. 8. The fish production of Lake Burullus has developed during the same period with an increase of 18,000 by about 34%, and this increase in fish production may be the result of adding additional areas to Lake Burullus during this period as a result of purification operations as a main factor. Which led to an increase in the water area and the ease of flow and circulation of water currents as a result of the work of the radial channels from the Burullus gas that connects Lake Burullus in the Mediterranean Sea and the removal of some sediments and silting that were blocking the water from contacting each other, especially in the eastern sector of the lake, and fish production may have increased as a result of relying on Some of the modern means and tools that fishermen resort to increase their fish production and reduce the effort and shorten the time needed for fishing. Also, the control of some islands that were under the grip of a few influential fishermen has decreased as a result of opening channels in them and the cleansing work that included deepening and removing aquatic plants that hinder fishing operations. This provided the opportunity for many fishing methods to work instead of being limited to a few crafts or one craft before disinfection. The data also indicate an increase in fish production revenues as a result of the increase in production during the study period, which ranged from a minimum of about 496 million Egyptian pounds in 2011. And a maximum of about 1.850 billion Egyptian pounds in 2018, with an average of about 987 million Egyptian pounds. The current disinfection should be developed and improved by rationalizing fishing operations, reducing sources of pollution as much as possible, and maintaining a balanced ecosystem between aquatic, plant and fish life.

3.6. Labor as an Ecosystem service

Fisheries play, either directly or indirectly, an essential role in the livelihoods of many people in coastal and inland fisheries around the world. Lakes are an important source of human labor and income, as they usually provide the conditions of having paid work. Labor in capture fisheries is not limited to work in primary fish production, there are people engaged in other ancillary activities, providing necessary support to the primary activities, such as processing, boat construction and maintenance, net and gear making, ice production and supply, transportation, manufacturing of fish-processing equipment, packaging, marketing and

distribution. As well as fisheries management personnel. In Burullus Lake there are no official data on the estimated number of persons involved in these other activities, the average number of licensed fishermen in Lake Burullus during the period 2009–2018 is estimated to be about 16,600, Some estimates indicate that for each person engaged in capture fisheries production, there are about four productive jobs in auxiliary activities, including post-harvest1, for the estimated number of fish workers becomes 83,000 workers, and if we take into account that each person supports his family with an average of 3 people, then the number of fishermen and those who provide services and goods to him becomes They provide the means of subsistence for an estimated 332,000 people, representing about 9.1% of the population of Kafr El-Sheikh Governorate, which numbers about 3.6 million people (FAO 1999 Press Releases n.d.).

3.7. Excavation and backfilling of Burullus Lake

The NDBI map also indicates similar results as indication to this exploitation. From NDBI, it is clear that change analysis of built up coverage give an increase of 0.81 km^2 between 2009 and 2018, may attributed to dryness process in to the lake or from building small areas as shown in Fig. 9. (Medina, Blanco, and Candido 2020) discussed similar case as changes may occur as a result to land reclamations that have been representing a challenge to lakes monitoring programs. In Lake Burullus, the built-up activities were more appear at the northeastern side and El-Boughaz area, may attributed to building a belt of cornice. (El-Amier et al. 2021) explained the change of shoreline areas to the lake and showed shrunk and shoreline changes that may be attributed to backfill and sedimentation processes.

3.7. The exploitation of Burullus Lake

The exploitation is defined as anthropogenic physical modification of the natural environment (Mattison 2003 and 2004). Where, the increase of jetties and building are indicate different degrees of exploitation in the studied area. The inventory of different acivities in the drawed buffer at the shoreline of Lake Burullus is as **Figure (10).** According to **Figure (11 from A-g)**, it is indicate no to very strong indication. Jetties were distributed nearby the eastern part and southwestern parts nearby El-Shaklouba village and El-Hox area. Fish farms covered the southern part parallel to shoreline and a central part of lakeshore northern part. The population centers are highly distributed at the eastern parts (Baltim and El-Borg cities) and the southwestern part (El-Shaklouba village). Also agricultural areas were having two parts east and west sides. The coastal road covered parallel to the north lake shore side and passed to the northeastern side of lake. Only an industrial site lies at this buffer which is concentrated at the southeastern side to lake (at Baltim city). Digging processes is occurred at El-Boughaz area and at Brinbal canal (a fresh water canal). The highest areas of exploitation from different factors ranged between low to high as appeared in the final exploitation map (Fig. 12). The lowest parts of exploitation are appeared at the central parts directed to the fish farms areas. While the most exploited areas are towards the eastern parts to the area of El-Boughaz. It is indicated more that areas of jetties sites and population centers are more exploited to the lakes shores.

Conclusion

This study aimed to quantify ecosystem services value (ESV) and their benefits to the society in Burullus Lake, where there has been considerable LU/LC change from 2009 to 2018. The study captured rapid LU/LC transition over a relatively short time-period; this revealed a significant increase in water and fishfarm from 2009 to 2018 as a result of restoration activities. A higher ESV of was observed in Burullus Lake. The total ESV increased from 2009 to 2018. Water body contributed a lot to the ecosystem service function, the key factor in improving the regional ecological environment and the ecosystem service function. The effects of LU/LC changes on the specific ecosystem services are equally significant. Water supply, food production, nutrient cycle maintenance and gas regulation were the four major ecological functions that affected the total ESV in Burullus Lake. Therefore, we advocate that when protecting natural ecosystems in the future land use management in Burullus Lake should be prioritized.

Declarations

-Ethical Approval: Ok

-Consent to Participate: Ok

-Consent to Publish: Not applicable.

Code availability (software application or custom code): Not applicable.

-Authors Contributions:

Hazem .T. Abd El-Hamid: suggest the idea of the paper, write 30% of the paper, revise the paper, and submit it to the journal

Fawzi Zarzoura: made the introduction section and modify the language.

Muhammad A. El-Alfy: made the part ofexploitation for Burullus Lake, write 20% of the paper and revise the paper.

Mohamed M. Toubar: wrote the part of fish production

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-Competing Interests: The authors declare no competing interests.

-Availability of data and materials: The datasets supporting the conclusions of this article are included within the article.

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Figures

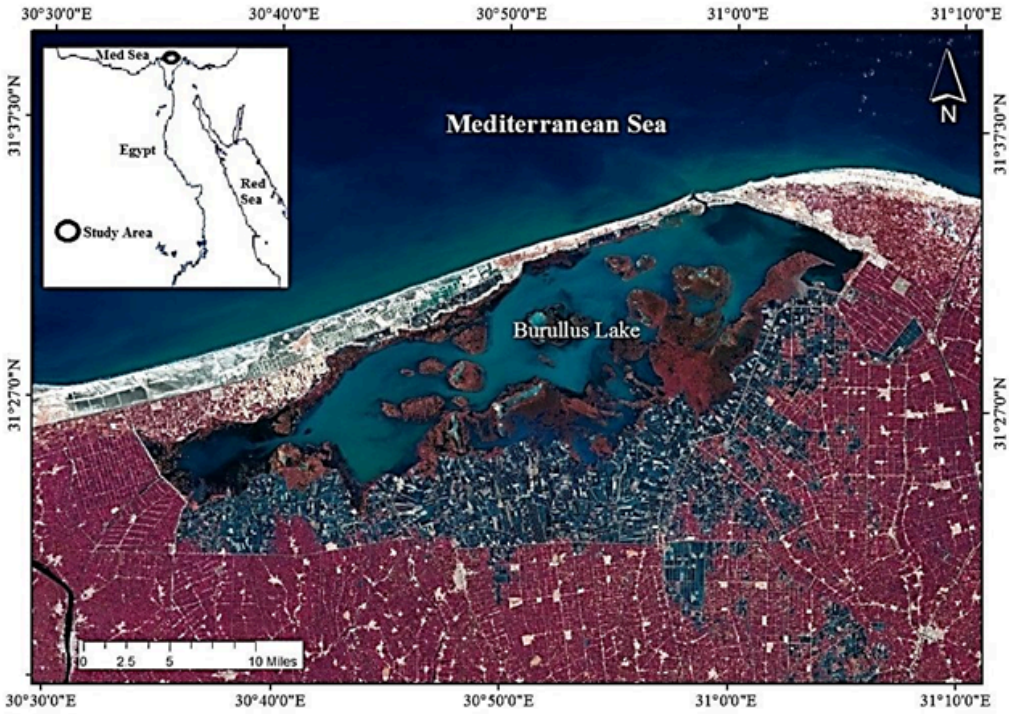


Figure 1

Study area shows Burullus Lake.



Figure 2

Recent development showing Governmental activities of Burullus Lake.

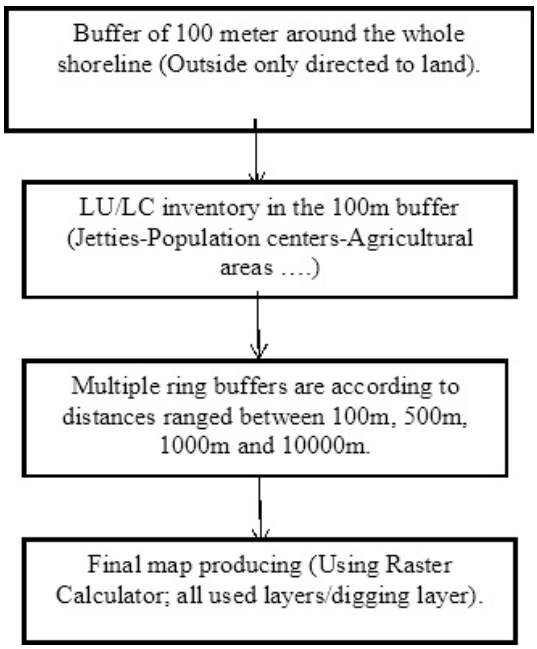


Figure 3

Chart indicates different processes for producing an exploitation map at El-Burullus shoreline

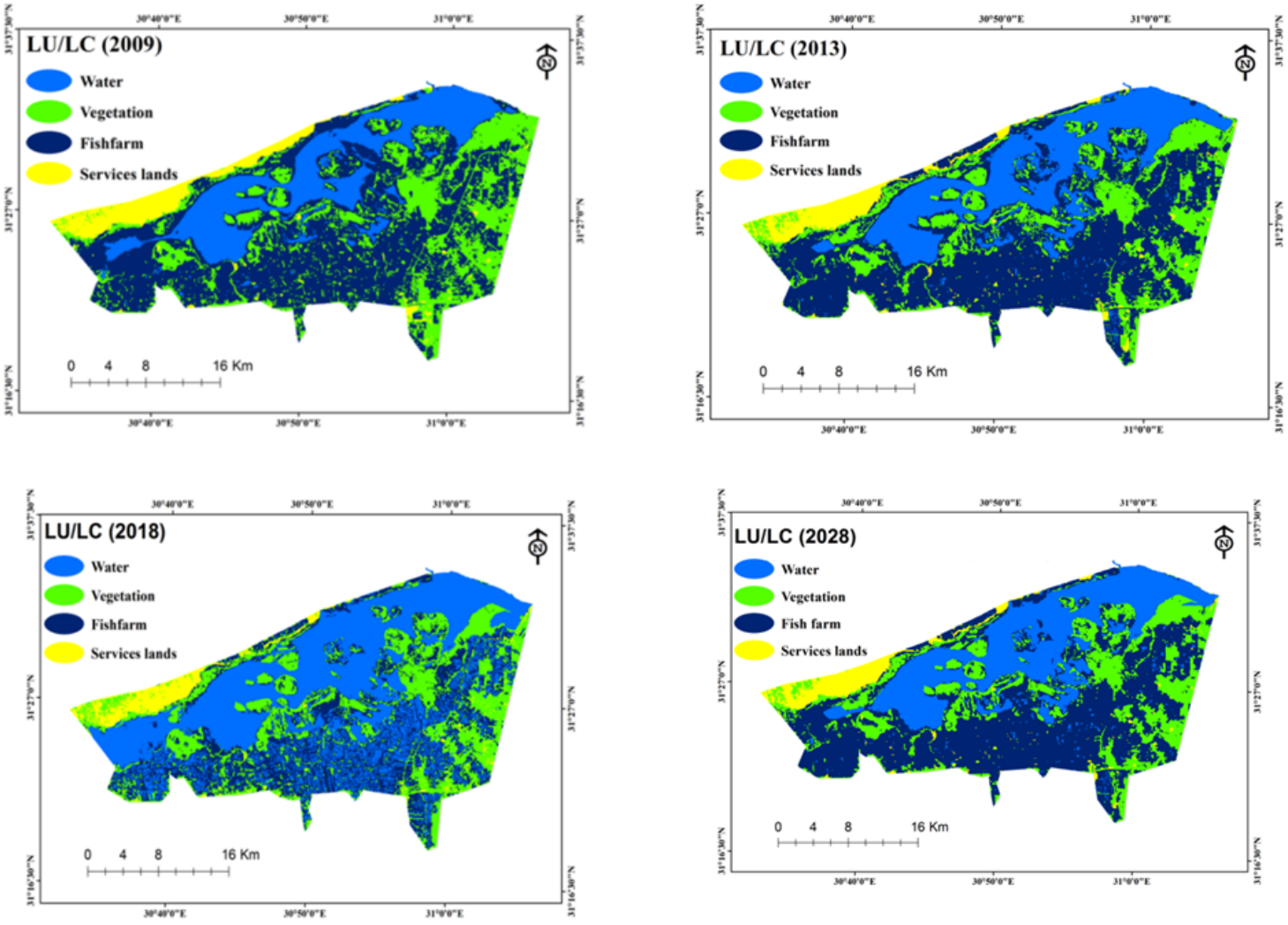


Figure 4

Distribution of land use types in Burullus Lake during 2009, 2013, 2018 and 2028.

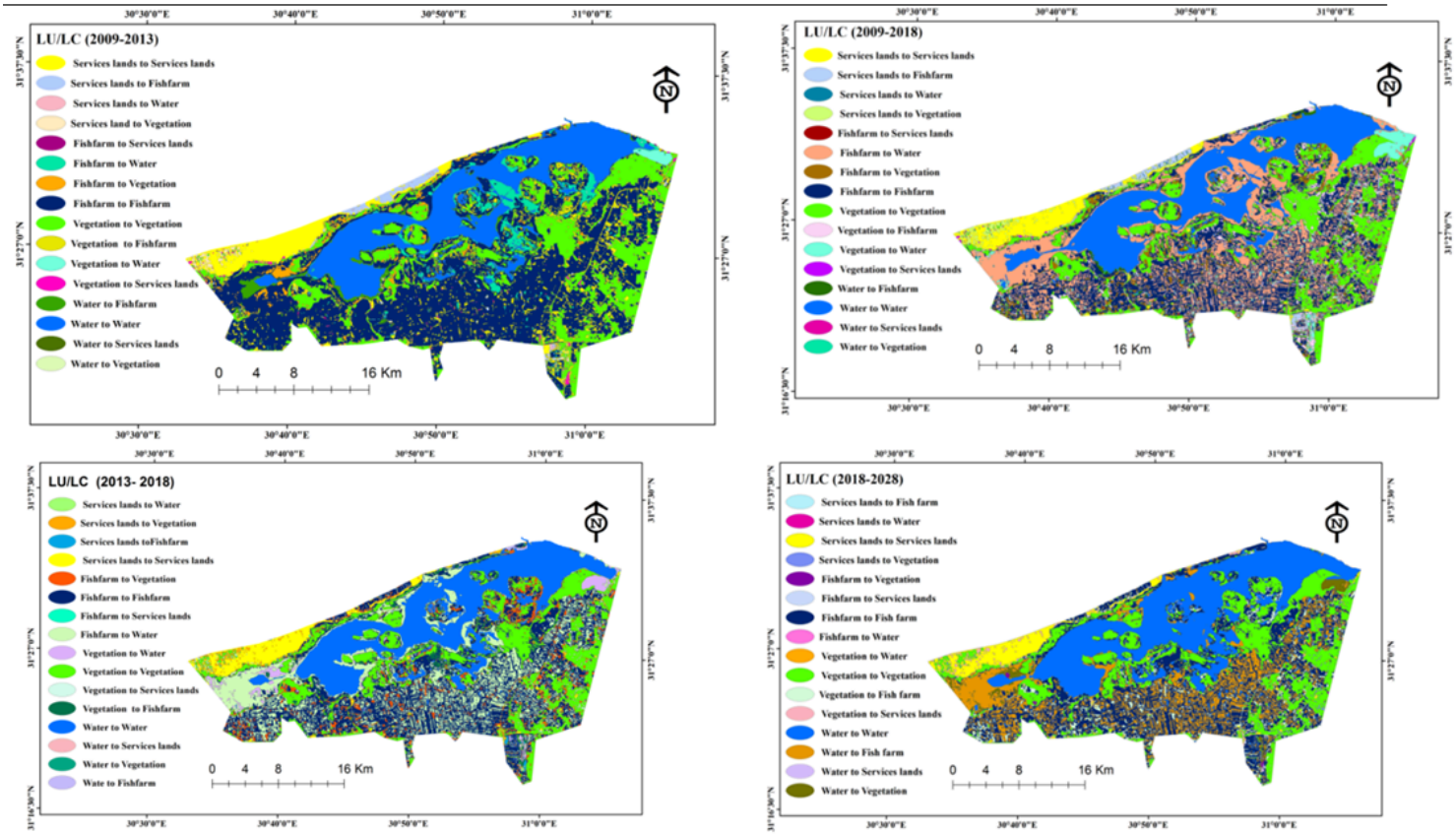


Figure 5

Transition maps of LU/LC in Burullus Lake.

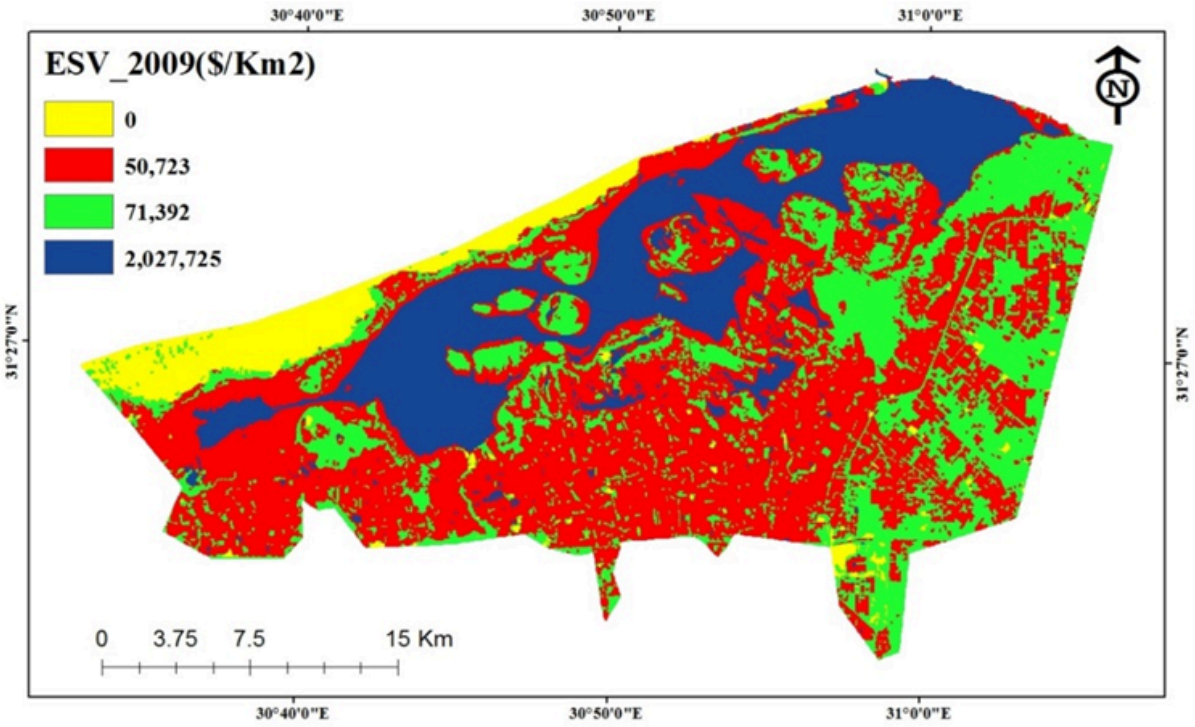


Figure 6

Ecosystem service value (ESV) of LU/LC in 2009.

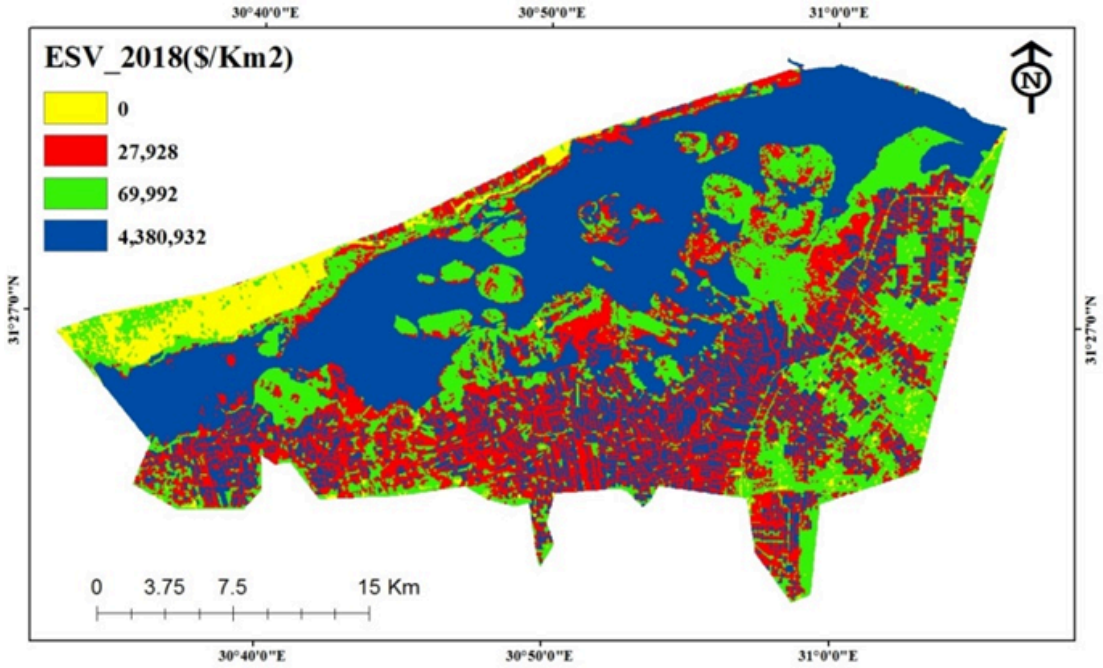


Figure 7

Ecosystem service value (ESV) of LU/LC in 2018.

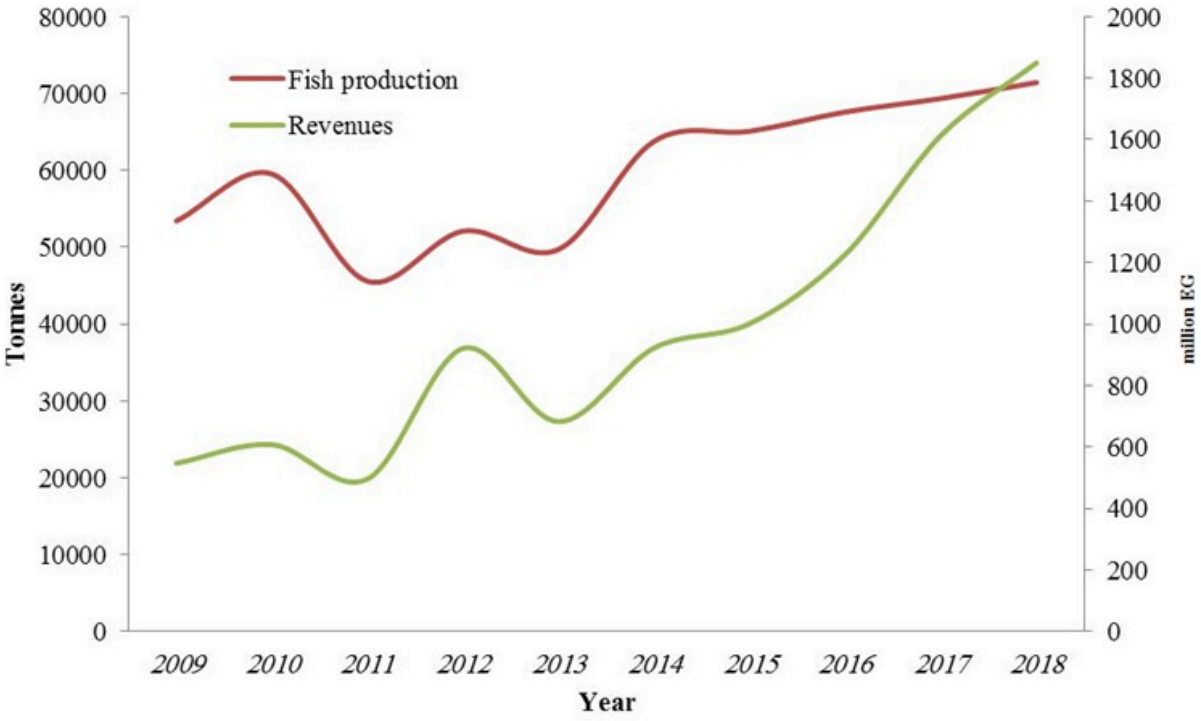


Figure 8

Annual fish production of Burullus Lake.

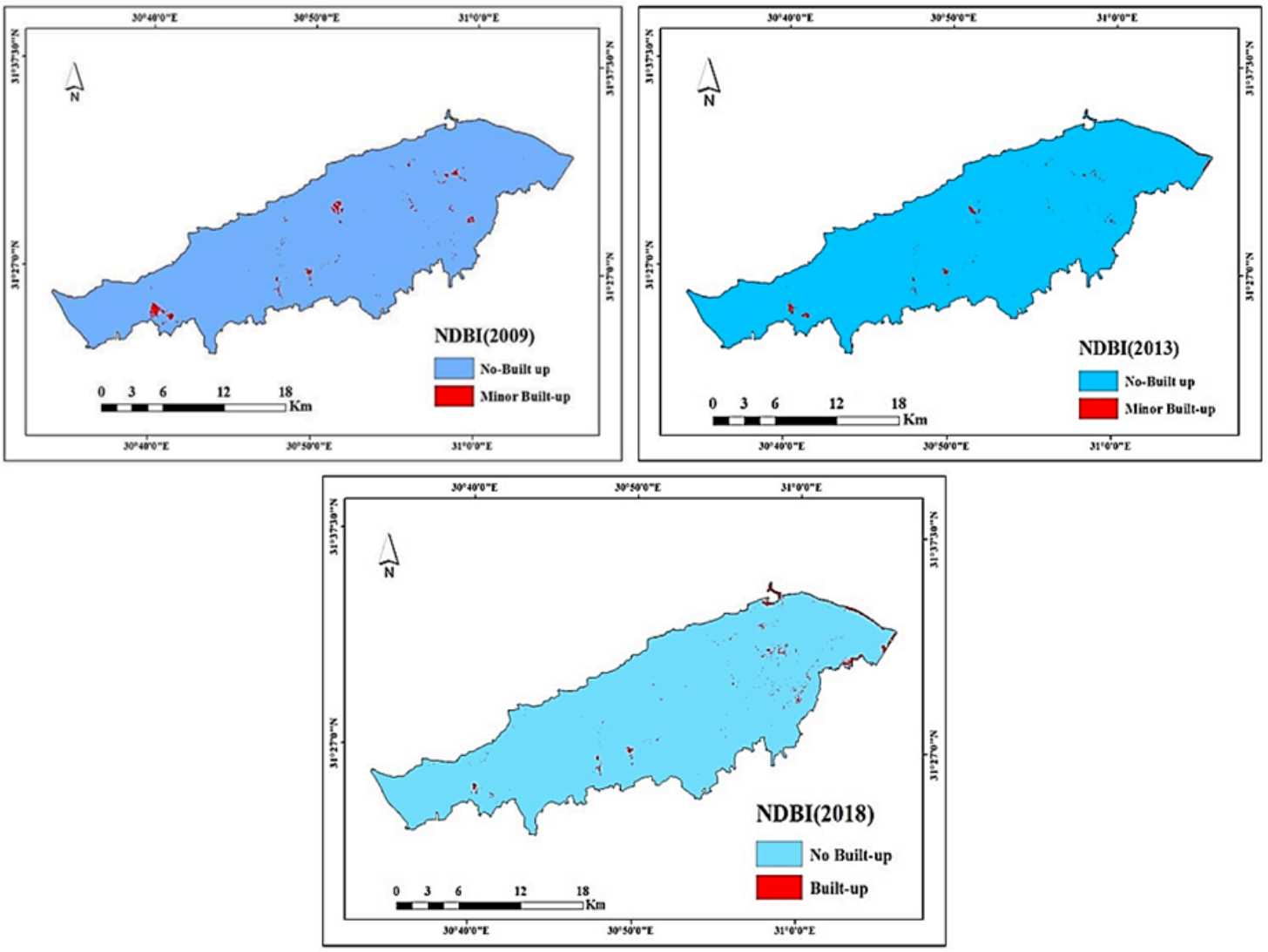


Figure 9

NDBI in Lake Burullus at three different years (2009, 2013 and 2018).

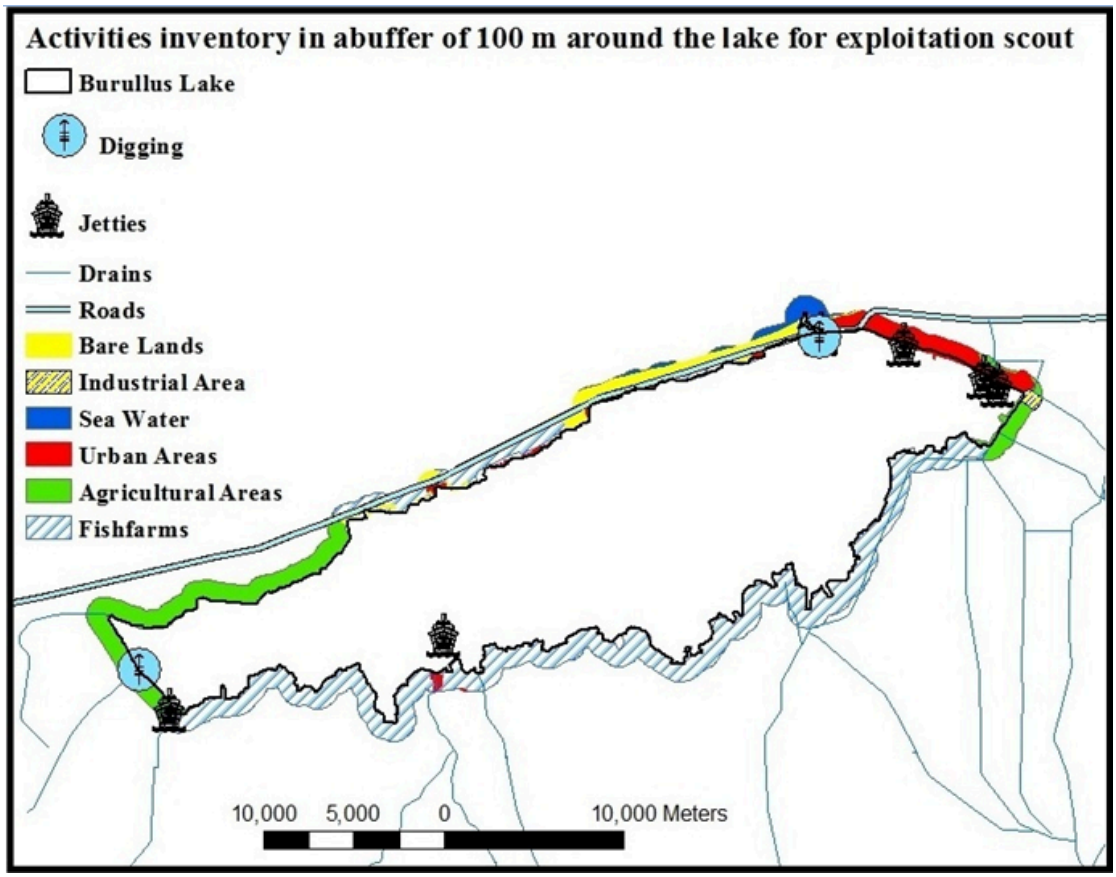


Figure 10

Map indicates different usages in a buffer outside the lake of about 100m.

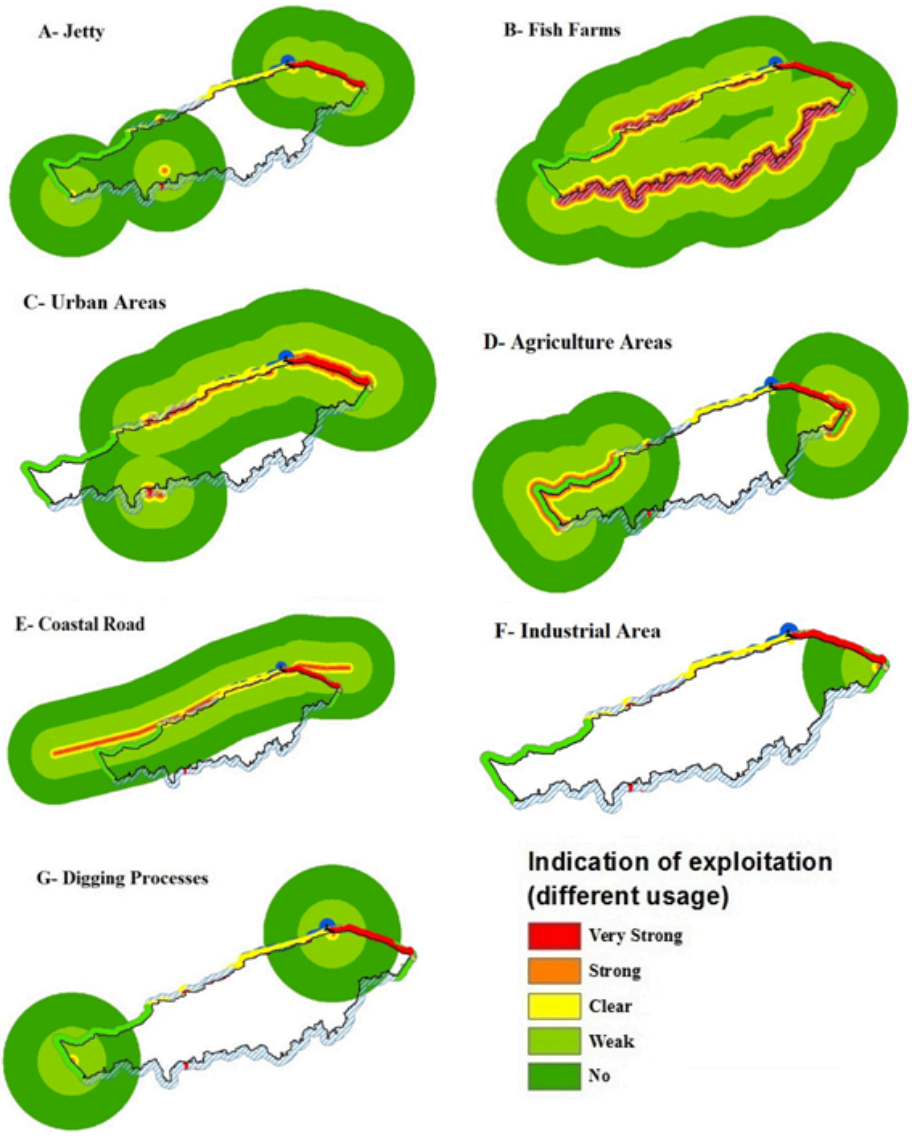


Figure 11

(A-g): Degree of indication around Burullus Lake.

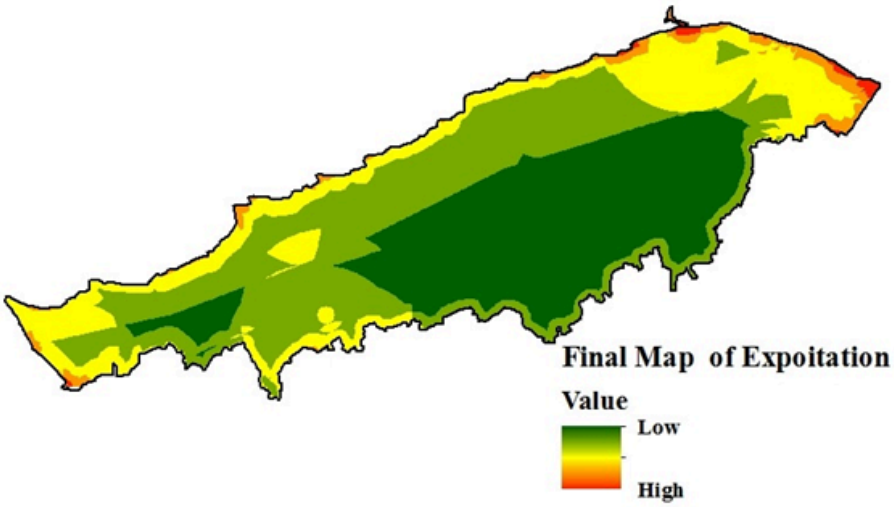


Figure 12

Final exploitation map at the shoreline of Lake Burullus