Remote Sensing and Sustainable Agricultural Development in Nile Delta Region

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Key words: Remote Sensing, agricultural, Sustainable Development

SUMMARY

Coastal areas characterized by a low and flat surface and light slope, especially in estuaries, this is one of the most serious problems facing Egypt because of its negative effect on sustainable agricultural development (Kawy and Darwish, 2014). Sustainable development aims to improve the quality of people's lives and preserves the rights of future generations through many goals (Saad *et al.*, 2019). Remote sensing techniques used to monitor change detection such as Land use changes, coastal changes and urban creep while urban growth causes pressure on land resources, leading to agricultural land degradation and widening the gap between population growth and agricultural land (Haboudane *et al.*, 2004). This research aims to study sustainable agricultural development for Kafr El-Sheikh Governorate using remote sensing and GIS. Kafr El-Sheikh Governorate located on the north of Egypt between the two branches of the Nile River and is bordered to the north by the Mediterranean Sea with a length of 111 km (Abdelsalam, 2018).

Based on the study and analysis of the results of previous vegetation indices, these seven indices were grouped by layer staking to produce a new visual consisting of seven bands each band represents one of the seven indices. In general, the results showed that during the period 1984 – 2018 there were significant changes in the area of agricultural land, the total added area of agricultural land is 331 km^2, as a result of the agricultural reclamation expansion. The study area lacks the infrastructure supporting the agricultural education and research because of poor coordination and absence of direct farmers' involvement.

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1. INTRODUCTION

Nile Delta region is the most affected by the climate changes causing rising sea level, which have a significant effect on increasing land's erosion and salinity. Rising sea level causes underground water salinity high concentration resulting in low productivity and a change in the land use pattern especially after the construction of the High Dam in 1964 which caused discharge discontinuity of Nile deposits. Erosion exposed to coastal areas increases with the increase of average global temperature. According to the United States of America report, the northern coasts of Egypt are categorized to need effective shore protection efforts (Abo El-Magd, 2016).

Kafr El-Sheikh governorate has an important economic role as it contains many investment ingredients such as international coastal road, which connects North Africa and Asia, large areas of reclaimable agricultural lands, natural gas discoveries in the Brolos region. The area of Kafr El-Sheikh extends between two circles having latitudes of 31 37′and 31 ° N, and longitudes of 30 ° 20′ and 31 ° 20′. Kafr El-Sheikh (Figure 1) is one of the leading agricultural governorates where more than 36569 thousand Feddans are cultivated after adding newly reclaimed lands (Abo El-Magd, 2016). The area of Kafr El-Sheikh is about 3748 km^2, representing 28.1% of the total area of the Delta region. Kafr El-Sheikh is divided administratively to ten centres, as presented in Figure 1: Kafr El-Sheikh, Brolos, Bella, Desouk, Sidi Salem, Fouh, Kaleen, Metoubas, Hamoul, Riyadh (Abdelsalam, 2018).

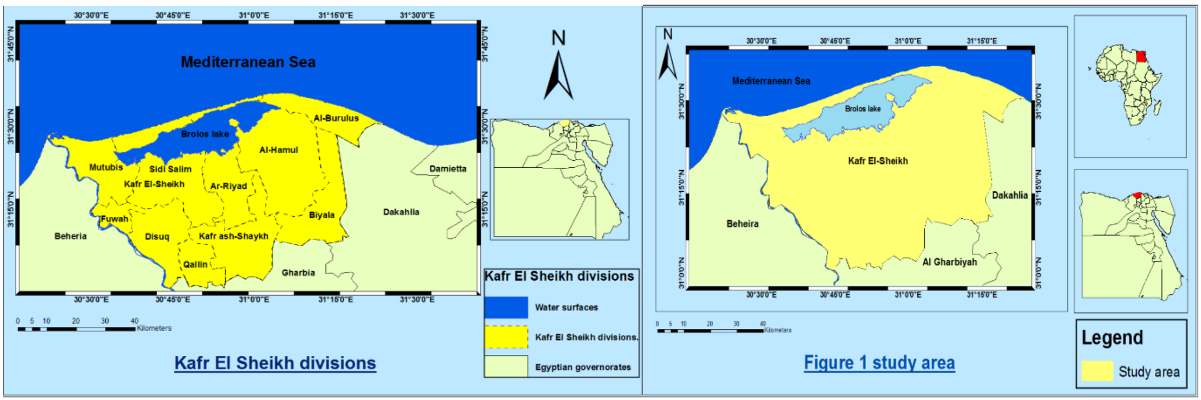

Fig. 1 Study area

2. CLIMATE CHARACTERISTICS

Climate is one of the factors that affect economic development aiming to study the climate elements: Temperature, Wind, Rain and Relative humidity we found the following:

2.1 Temperature:

Tables 1 and 2 show the summary of the climate characteristics. It should be noted that it is important to study the temperature as one of the climate elements where, it has a considerable role in determining the economic activities especially the agricultural one (Bannari *et al.*, 1995). At the study area found that northern parts are more affected by the Mediterranean Sea and Lake Brolos than the southern regions where the thermal range decreases because of land and sea breeze phenomenon during the day and night periods, as well the existence of water surfaces that contribute to non-huge variance between the maximum and minimum temperature degree. Studying the average temperature degrees through the years from 2010 to 2017 we found that the varied temperature degrees allow optimal sustainable agricultural exploitation throughout the four seasons due to the air depressions absence during the period from May to early September.

Table 1: Climate observations

Month	T	TM	Tm	slp	H	PP	VV	V	VM
2017									
1	13.4	17.7	10.1	1019.8	72.2	12.7	9.5	7.6	13.5
2	14.6	18.8	11	1021	72.4	6.61	9.7	6	13.3
3	17.4	21.4	14.1	1014.8	71.1	0	9.7	8.4	14.2
4	19.3	23.6	15.7	1015.7	70	4.06	9.8	8.5	13.4
5	22.9	27.6	19.2	1013.8	70.1	0	9.8	8.3	14
6	25.9	29.9	22.3	1011.8	71.3	0	9.9	8.2	14.7
2016									
1	13.7	18	10.4	1020.9	73.4	49.79	9.4	8.8	14.9
2	16.8	21.6	13.3	1019.8	73	79.76	9.5	8.2	13.7
3	17.8	22.3	14.6	1015.3	69.4	2.54	9.9	9.2	15.1
4	21.1	26.5	17.1	1013.5	70.6	1.02	9.7	7.8	13.6
5	23.1	27.9	19.5	1013.7	65.6	0	10	9.6	15.1
6	26.9	31.2	22.9	1010.7	68.4	0	10	8.4	13.2
2015									
mean	21.4	25.4	18.4			203.48		7.2	
2010									
mean	22.2	26.9	18.7			50.04		8.3	

Where, T: Average Temperature (°C), TM: Maximum temperature (°C), Tm: Minimum temperature (°C), SLP: Atmospheric pressure at sea level (hPa), H: Average relative humidity (%), PP: Total rainfall and / or snowmelt (mm), VV: Average visibility (Km), V: Average wind speed (Km/h), VM: Maximum sustained wind speed (Km/h) and VG: Maximum speed of wind (Km/h).

Table 2: Summary weather of stations observations (Figure 2)

station	Temp	Winter			spring			summer			autumn		
		12	1	2	3	4	5	6	7	8	9	10	11
Baltem	max	19	17.4	17.9	19.9	22.5	25.5	28.5	29.3	29.7	28	26.8	23.3
	min	12.8	11.2	11.6	13.1	14.9	17.7	21.2	22.9	23.6	22.2	20	16.9
	rain	46.6	46.5	18.8	18.6	7.3	1.8	---	---	---	1.3	11.5	22.5
	Humidity %	71	72	68	65	67	67	69	73	72	70	68	70
Sakha	max	21.4	17.4	20.6	22	27	30.9	33.1	33.7	33.6	31.9	29.7	25.7
	min	8.4	6.4	6.5	8	10.8	14.1	17.2	19.1	18.6	17.7	15.5	12.6
	Rain mm	13.6	17	12.2	6	5	3	---	---	0.9	0.7	7.8	14.9
	Humidity %	70	69	67	63	57	54	57	61	63	64	65	67

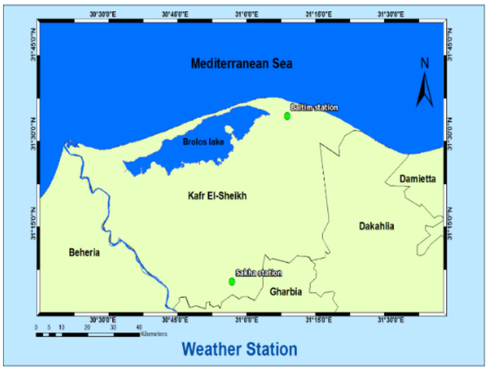

Fig. 2 Weather stations

2.2 Wind:

The wind is known as horizontal air, as presented in Figure 3, which transports heat, moisture, and pollutants from one place to another and continuously redistributes them. Wind also causes soil erosion in the newly reclaimed land that is prone to severe winds which form sand dunes covering the plants. Wind speed increases transpiration and evaporation. The wind has a direct negative impact on achieving sustainable agricultural development in the study area especially fruit, cotton and wheat crops. Wind dangers can be faced by windbreaks or planting a palm tree (Kauth and Thomas, 1976).

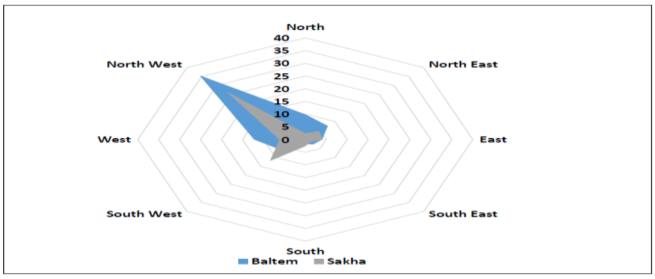

Fig. 3 Wind rose

2.3 Rain:

The amount of rain falling on the northern parts of the study area is used to grow crops that depend on rainwater only especially in the northern area of Brolos centre. In the northern Mediterranean region, rainfall is associated with winter depressions. The amount of rainfall controls agricultural crops growth and productivity.

2.4 Relative humidity:

Humidity clearly affects plants growth and productivity. The lower the humidity, the higher the temperature and the higher the evaporation rate which affects the seeds life in crops such as vegetables and fruits. The higher the temperature degree the lower relative humidity, so at Sakha station, the relative humidity rises in winter. As Baltim station located next to the Mediterranean Sea, so the relative humidity in summer is higher than other seasons because of the high-temperature degrees which cause raising the evaporation rate.

2.5 Water Resources:

Irrigation sources vary in the governorate where it contains main canals with a length of 1537.4 km serving an area of 4593 acres beside the underground water.

Sustainable agricultural development depends on a regular agricultural drainage system. The agricultural drainage network in the study area consists of main deep and sub drains with a total length of 1205km that collects agricultural wastewater and direct it to major drainage areas in the north of the government to pour into Lake Brolos. There are areas of 45931 acres with no drainage. There are some drainage problems such as no canals cleansing and low pump efficiency.

2.6 Soil:

Soil capacity and suitability for agricultural production vary, so the soil should be well studied for good utilization in reclamation projects and the possibility to adjust crop structure to suit soil characteristics. Conducting laboratory experiments of soil samples collected from the field, Table 3, whether natural features such as textures and bulk density or chemical properties like soil salinity, acidity and calcium carbonate, organic materials, and cation exchange capacity (Abo El-Magd, 2016).

Table 3: Soil texture

Texture	Area	Percentage
	Km^2	%
Clay	2966	90.23
Sand	321.2	9.77
summation	3287.2	100

Applying the modern American classification system to the study area sectors to the level under the group depending on the morphological characterization of soil sectors and natural and chemical analyzes shows in Table 4 that the study area falls under three major design levels as in the table below based on stories index, 1978, the land is classified according to its production capacity to six degrees and each type is given a value that expresses the soil efficiency coefficient (Abdelsalam, 2018).

Table 4: Classification of lands

Degree of land	Area	percentage
	Km^2	%
Second	1192.0	36.3
Third	1768.0	53.8
Fourth	238.0	7.2
Fifth	54.0	1.6
Sixth	35.2	1.1
summation	3287.2	100

The percentage of workers in agricultural activity 46.4%, then the commercial activity by about 10%, then workers in construction and industry 12.3%, and finally the workers in transport and communications 5.8% of the total number of workers in the governorate. The agriculture activity is the main at governorate as it includes about 564 thousand Feddans, which represents about 64.5% of the total area.

Table 5: The population values from 1984 to 2018

	1986		1996		2006		2018	
	value	%	value	value	value	%	value	%
Kafr El-Sheikh	359765	19.89	420409	639276	639276	18.81	639276	17.75
Brolos	101491	5.61	138164	190596	190596	6.79	190596	7.66
Bella	173005	9.56	204233	304867	304867	8.92	304867	8.62
Desouk	328018	18.13	383442	560206	560206	16.74	560206	14.75
Sidi Salem	225342	12.46	278295	448032	448032	12.26	448032	15.38
Fouh	101786	5.63	120806	183716	183716	5.26	183716	5.57
Kaleen	147242	8.14	174019	271465	271465	7.77	271465	8.23
Metoubas	139217	7.96	185523	309482	309482	8.73	309482	9.78
Hamoul	143503	7.93	198296	296407	296407	9.52	296407	5.67
Riyadh	89852	4.97	120472	190596	190596	5.2	190596	6.58
sum	1809221	100	2223659	3445213	3445213	100	3445213	100

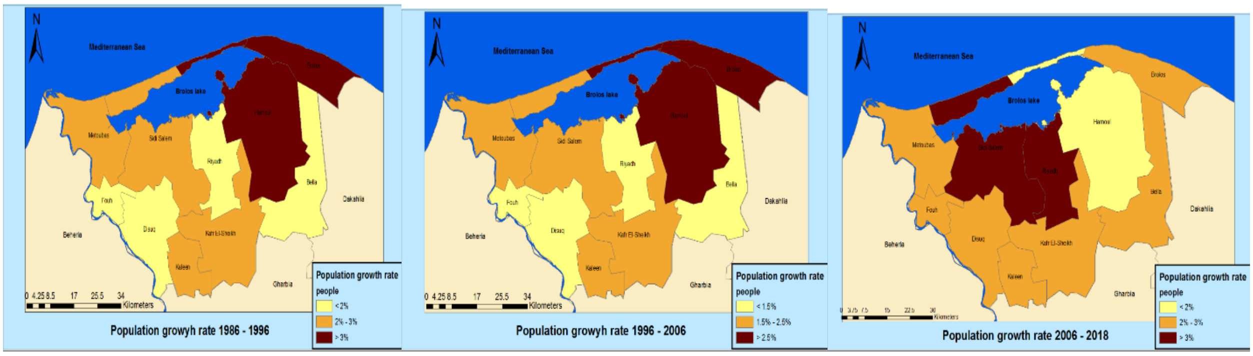

Fig. 4 Population growth

Through the production capacity analysis of the study area found that the third-degree lands prevail in the study area where it occupies 53.8% of the total area followed by the second degree by 36.3% then the fourth-degree lands by 7.2% while there is no first-class soil in the study area. Sustainable development doesn’t depend only on studying the environmental situation, but we must examine the human element as it is the basis for planning sustainable development. In developing countries, rapid population growth represents a massive burden on agricultural lands and there is no way to achieve sustainable development unless the pressure of the population on resources, mainly agricultural, is reduced. The society has risen at government centres, as presented in Table 5 and Figure 4, during the last three decades starting from1986 (1.809 million) to 2006 (2.62 million) which causes a significant challenge for sustainable development.

3. METHODOLOGY FOR MONITORING THE AGRICULTURAL AREAS

Remote sensing and GIS techniques are applications used to study land cover where each region on Earth has a unique shape and characteristics (Mouat et al., 1993; Foody, 2002). Studying the urban growth during the period (1984 - 2018), it was divided into three phases, from the year (1984-2000) the urban addition increased by the end of the period to 33.5 km^2, from the year (2000- 2010) increased by the end of the period to reach 64.7 km^2, from the year (2010 – 2018) increased by the end of the period to reach 60.9 km^2.

3.1 Vegetation indices (VI)

3.1.1 Normalized Difference Vegetation Index (NDVI)

NDVI is used in dense vegetation areas to separate soil and vegetation and is also used to indicate the distribution of plants and their degree of greenness. It can be calculated by the following equation (Bannari *et al.*, 1995):

$$NDVI = \frac{NIR - Red}{NIR + Red} \qquad Where\ NIR(\ Near\ infra - red) \qquad (1)$$

Figure 5 illudtrates the NDVI of study area.

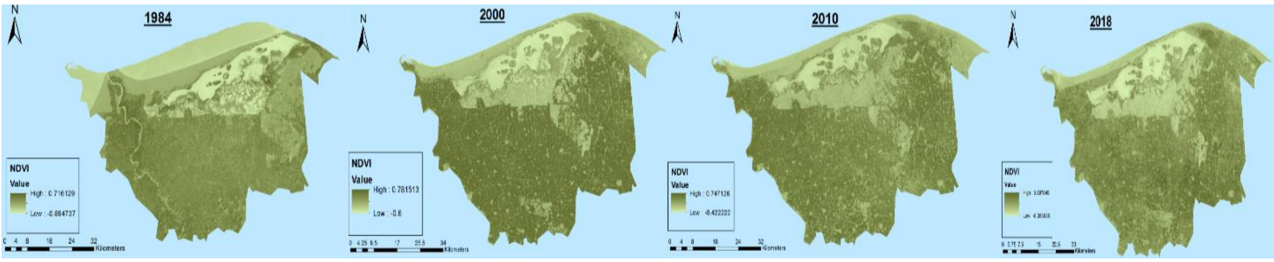

Fig. 5 NDVI from 1984 to 2018

3.1.2 Green Vegetation Index (GVI)

It is one of the most important indicators that show the vegetation cover, which shows the spatial distribution of plants and separates the reflection of the vegetation from the other reflections. GVI very clear in the infrared range. It can be calculated by equations 2 and 3 (Kauth and Thomas, 1976), and GVI of study area was presented in Figure 6.

LANDSAT 7:

$$(GVI) = (-0.2848 * TM_1) + (-0.2435 * TM_2) + (-0.5436 * TM_3) + (0.7243 * TM_4) + (0.0840 * TM_5) - (1.18 * TM_7) \quad (2)$$

LANDSAT 8:

$$(GVI) = (-0.2941 * \text{Band2}) + (-0.243 * \text{Band3}) + (-0.5424 * \text{Band4}) + (0.7276 * \text{Band5}) + (0.0713 * \text{Band6}) - (0.1608 * \text{Band7}) \quad (3)$$

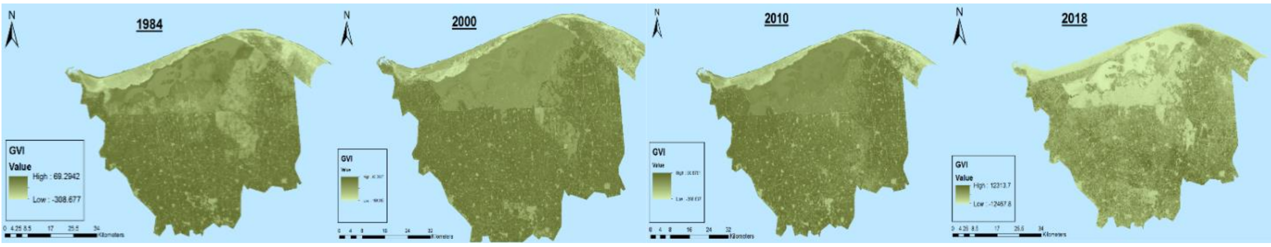

Fig. 6 GVI from 1984 to 2018

3.1.3 Modified Soil Adjusted Vegetation Index 2 (MSAVI2)

MSAVI2 is a simple version of the MSAVI Index, it is presented in Figure 7 for the current study, a modified plant-soil index seeks to address some of the NDVI limits when applied to areas with a high degree of the exposed soil surface, and was developed by Qi *et al.* (1994).

$$MSAVI2 = \frac{2NIR + 1 - \sqrt{(2NIR + 1)^2 - 8(NIR - Red)}}{2} \qquad (4)$$

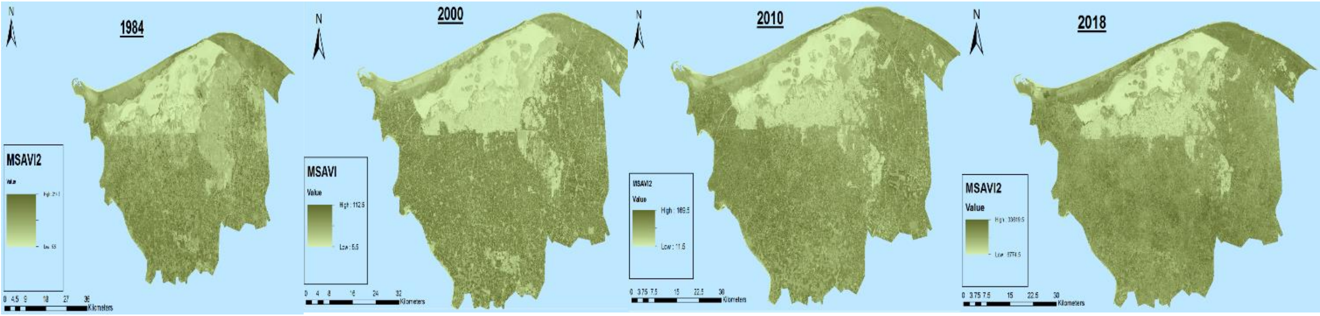

Fig. 7 MSAVI2 from 1984 to 2018

3.1.4 Normalized Difference Built-up Index (NDBI)

NDBI was originally developed to monitor the spatial distribution and urban growth, but was found to be useful in separating arid soils from vegetation (Abd-El Monsef and Smith, 2017):

$$NDBI_{OLI} = \frac{(PCA_{Band6,7} + PCA_{Band10,11}) - OLI\ Band_5}{(PCA_{Band6,7} + PCA_{Band10,11}) + OLI\ Band_5} \qquad (5)$$

$Where\ PCA: Principal\ Compoents\ Analysis\ \ and\ OLI: Operational\ Land\ Imager$

the NDBI of the current case study was shown in Figure 8.

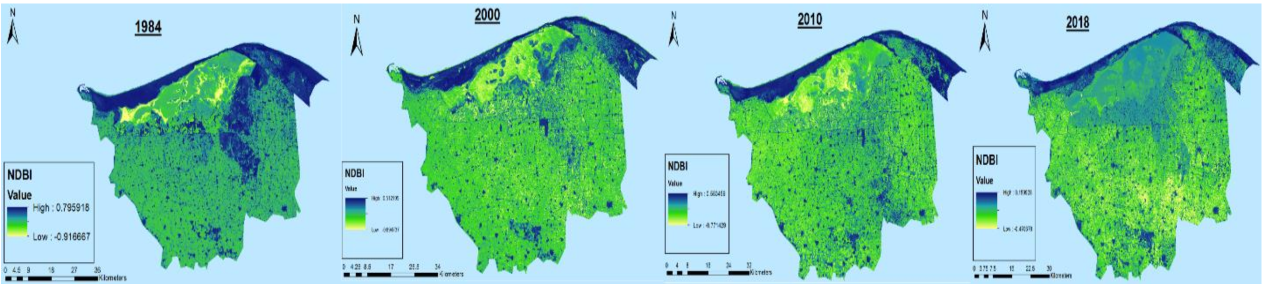

Fig. 8 NDBI from 1984 to 2018

3.1.5 Normalized Difference Water Index (NDWI)

It is a derivative of near-infrared NIR channels, while NIR reflection is influenced by differences caused by composition; Figure 9 demonstrates the NDWI of study area.

$$NDWI = \frac{Green - NIR}{Green + NIR} \qquad (6)$$

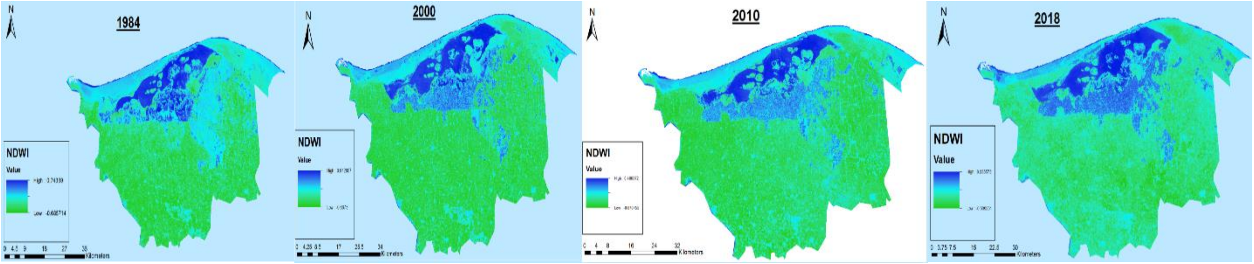

Fig. 9 NDWI from 1984 to 2018

3.1.6 Renormalized Difference Vegetation Index (RDVI)

Figure 10 presents RDVI of the study area; the modified greening index is one of the improved and modified evidence developed to combine the advantages of the DVI vegetation guide and the NDVI guide, respectively (Haboudane *et al.*, 2004).

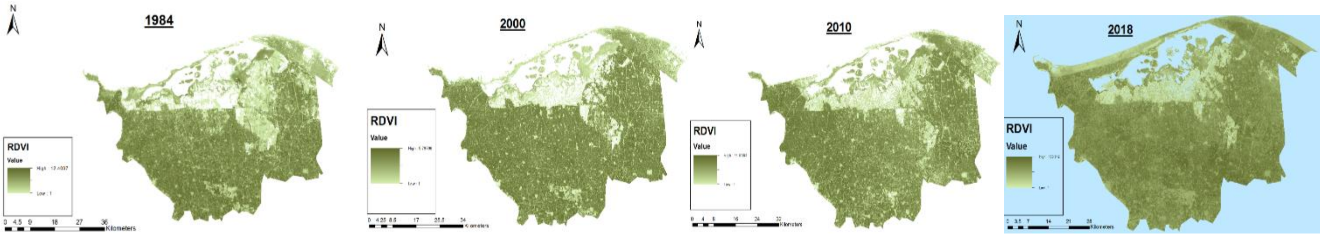

Fig. 10 RDVI from 1984 to 2018

$$RDVI = \frac{(NIR - Red\ 1)}{\sqrt{NIR - Red}} \qquad (7)$$

3.1.7 Transformed Difference Vegetation Index (TDVI):

Figure 11 presents TDVI of the study case; it is useful for monitoring vegetation in urban areas and evaluating the potential of this index by comparing it with the soil-adjusted vegetation index and green index (Huete, 1988; Bannari *et al.*, 1995)

$$TDVI = \sqrt{0.5 + \frac{(NIR - Red)}{(NIR + Red)}} \qquad (8)$$

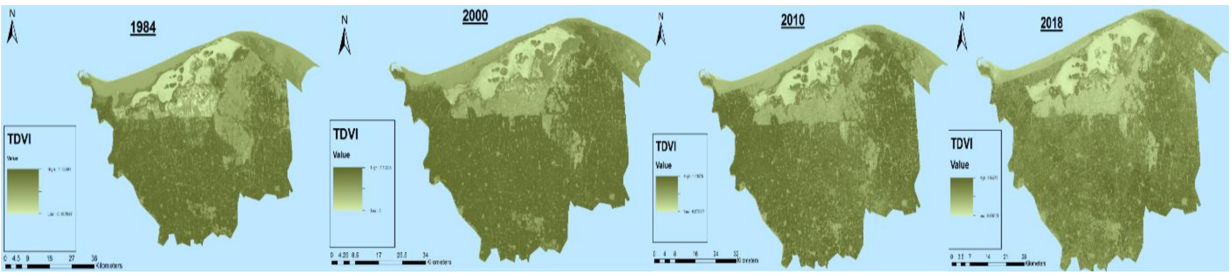

Fig. 11 TDVI from 1984 to 2018

Finally, the supervised classification of study area and land use are presented in Figures 12 and 13, respectively.

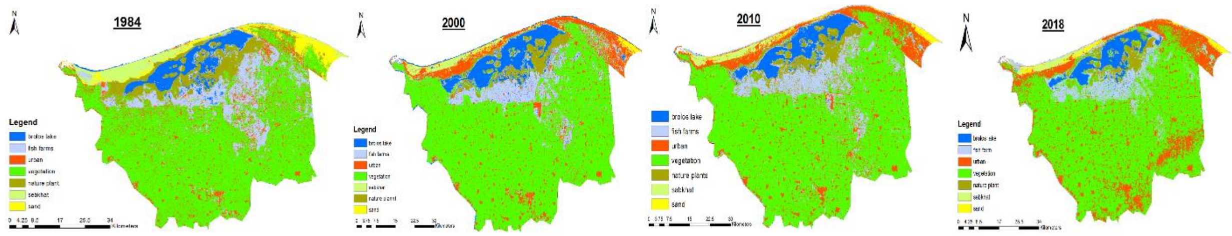

Fig. 12 Supervised Classification from 1984 to 2018

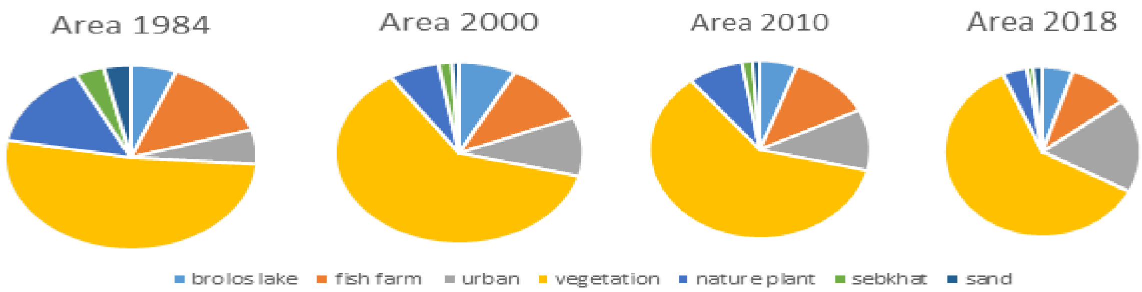

Fig.13 Area of land use/land cover changes from 1984 to 2018

4. ACCURACY ASSESSMENT

To ensure the accuracy of the supervised classification assessment process we must take into consideration: Classification errors itself, Interpretation errors, and ground data collection are presented in Table 6. All of the above factors, Figures 5-13, affect the assessment process. The accuracy assessment process passes through several phases, starting with the establishment of the error matrix, Confusion Matrix, followed by a set of statistical analyzes that evaluate the classification accuracy (Lu and Weng, 2007; Campbell and Wynne, 2011). The overall classification assessment is one of the most important statistical analyzes as it is an indicator of the different classification methods accuracy.

$$K = \frac{Observed\ accuracy - chance\ agreement}{1 - chance\ agreement} \quad (9)$$

Table 6: Accuracy assessment

	Agricultural land	Urban land	Brolos lake	Fish pond	Over all	K
VI	100	95	100	82	94	0.90
SC	100	97	100	95	98	0.97
VI=vegetation indices; SC= Supervised Classification						

It is clear from the results of the study that there is a change in the area of agricultural land during the different three phases, the increase in the area of agricultural land reached 368 km^2 during the first period 1984-2000 m, the area of agricultural land saw a notable decrease through the second period 2000-2010 by 44.43km^2. The increasing rate was not the same during the first, and the last period 2010-2018, the total area added for agricultural land was 6.8 km^2. The sustainable development methodology has been adopted in planning for the future and even the existing projects, see Figure 14 and Table 7. Global interest in sustainable development is due to its advantages as follow (Ristić et al., 2017):- Economic dimension: Employ available resources to raise the standard of living people and reduce energy consumption and natural resources in general; the human and social dimension: Sustainable development seeks to stabilize population growth and stop indiscriminate migration by developing education and health services and maximizing popular participation in development planning (Abdelsalam, 2018); and the environmental dimension: Optimal use of agricultural lands, water resources and using clean technologies consuming less energy (Abo El-Magd, 2016). Sustainable agricultural development is important in the context of global sustainable development (Saad *et al.*, 2019). The future objectives of sustainable agricultural development are among the major issues of the national economy, given the strategic importance of food and natural resources for human survival and progress.

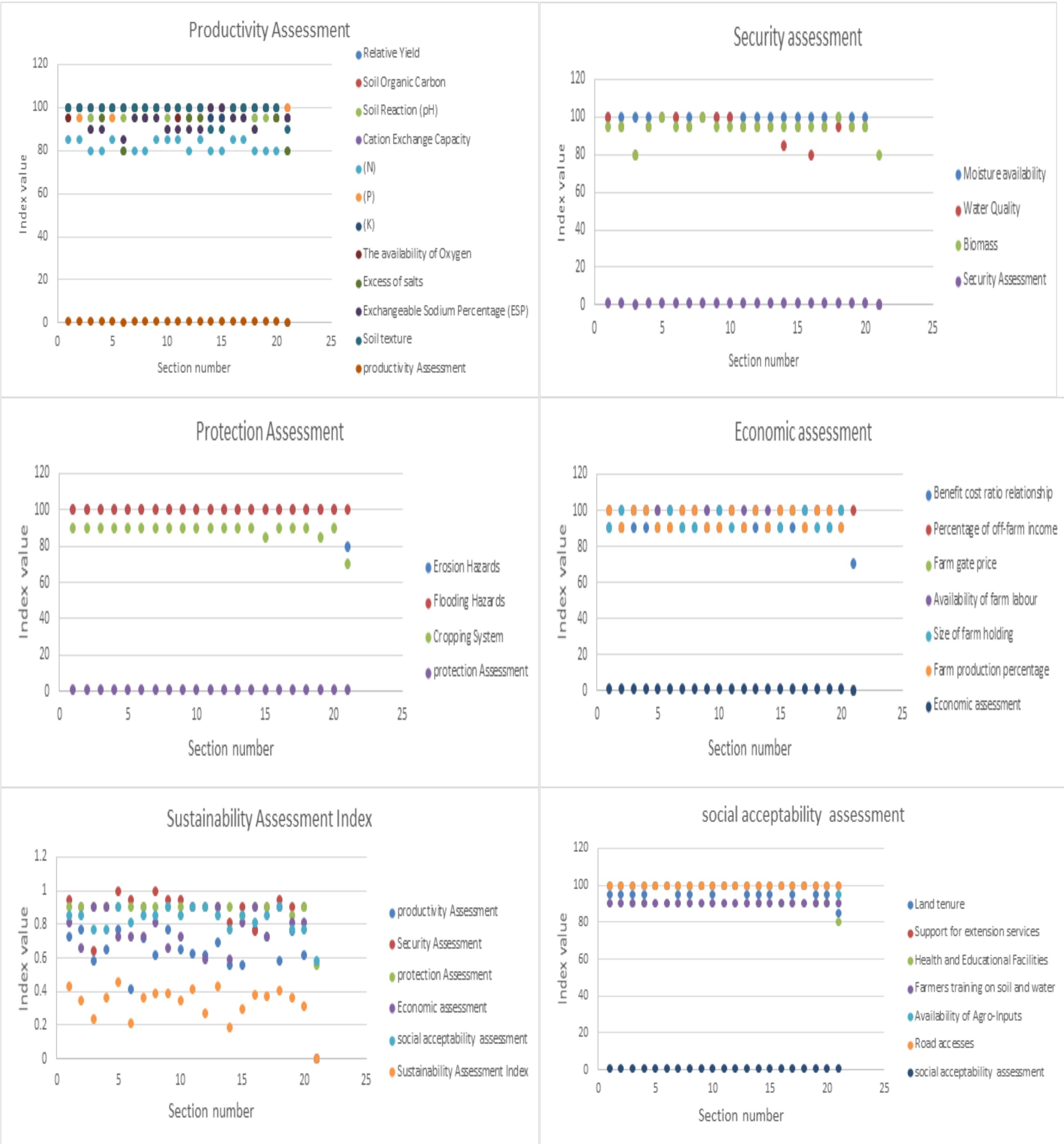

Fig. 14 Sustainability assessment index

Table 7: Sustainability categories

Class	Description of sustainability status of land use & management	Value
I	High	0.6-1.0
II	Above the threshold	0.3-0.6
III	Below the threshold	0.1-0.3
IV	Do not meet	0-0.1

Based on the international framework for sustainable land management to identify the current conditions of sustainability, from the study of the results of the model of sustainable land management, the study area has been classified into three categories of sustainability, medium-sustainable land (category II), low-sustainable land (category 3) and unsustainable land (category 4) and land management practices that do not meet sustainability requirements Sustainable development of the agricultural sector in the study area is affected by several constraints obtained from the current study, where the infrastructure supporting agricultural education, research and extension was ineffective due to poor coordination and lack of direct participation by farmers.

CONCLUSION

The poor coordination and the absence of direct farmers' involvement are considered to be a problem needing quick intervention and a future government strategy. Farmers prefer to obtain their needs from the private sector because of the high-interest rate in the Central Bank and Bank for Development and Agricultural Credit. The study area can be classified into three sustainability categories; The second category is medium sustainable land which reflects land management practices that slightly exceeds the minimum sustainability. The third category is poor sustainable lands which reflect land practices that are slightly less than the minimum sustainability. The fourth category is unsustainable lands which reflect land management practices that do not meet sustainability requirements.

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