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Monitoring soil productivity using Remote sensing and GIS techniques in El- Qaliobia Governorate, Egypt

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SOIL PRODUCTIVITY refers to the capability of soil to sustain crop production, as determined by its complete range of physical, chemical, and biological attributes. The present study aimed to assess and monitoring the productivity of soils in El-Qaliobia Governorate, Egypt, which encompasses an area of 1022 km^2. To determine the major physiographic units in the area, ENVI software 5.3 was used to process the "Landsat Enhanced Thematic Mapper Plus (ETM+) and Landsat Operational Land Imager (OLI) " images and digital elevation model. The study area is located in lower Egypt, north of Cairo, in the Nile Delta region, which was analyzed using multi-temporal Landsat imagery (2005 and 2022) and Digital Elevation Models. Results showed that the vegetation areas were decreased from 70% to 63 % during the period from 2005 to 2022 while the urban areas were increased from 23.9 % to 30.8 %. The main landform units over the area were delineated using Satellite images and the Digital Elevation Model (DEM). Out of twenty-nine soil profiles, thirteen were selected to represent different map units. Morphological descriptions were conducted as well as soil samples for physical and chemical analysis. soil samples were analyzed to classify soil productivity using the Requier Land Productivity Index (RLPI). The spatial analyst function within ArcGIS 10.8 was employed for the purpose of approximating the assessment of the moisture content rating, drainage condition, effective soil depth, texture/structure, soluble salt concentration, organic matter content, Cation exchange capacity, and mineral reserve. The results illustrated that approximately 38.3 % and 23.0 % of the entire expanse is comprised of good classes (II) and average classes (III), while Class IV and V accounts for a mere 35.8% and 2.9 % of the total area in 2005, then Approximately 25.5 % and 12.9 % of the entire expanse is comprised of good classes (II) and average classes (III), while Class IV and V accounts for a mere 35.8 % and 25.8% of the total area in 2022.

Keywords: Soil productivity, Remote sensing, GIS, Change detection, RLPI, El-Qaliobia Governorate.

1. Introduction

Soil productivity refers to the potential of soil to yield crops due to the efficient utilization of production factors related to its fertility (Sokolowski, et al. 2020 and Mueller, et al., 2010). The productivity of soil can be impacted both positively and negatively by human activity, as noted by Rashed et al. (2021). The examination of effect of land productivity has been conducted through the utilization of a metric that measures the aptitude of land for agricultural purposes (Zuo et al., 2019 and Farag et al., 2022). This capacity is determined by the soil's ability to produce a specific crop yield or other plants under specified management practices. However, the overall productivity of a land is influenced by various factors, such as climate, parent material,

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topography, as well as physical and chemical soil properties. By evaluating land productivity, agricultural practices can be enhanced to preserve the soil's ability to produce diverse commodities (Field, 2017). The Nile Delta stands as one of the most ancient and extensively cultivated regions worldwide. Its population density is remarkably high, reaching up to 1700 inhabitants per square kilometer, owing to its fertile and low-lying floodplains surrounded by barren deserts. Various factors, including physico-socio-economic, institutional, and organizational elements, significantly impact agricultural productivity, such as droughts and climatic conditions and land productivity across different categories (Mansour et al, 2017). change detection" refers to the technique of comparing two or more photographs captured at various times in order to find differences in the structure and/or attributes of objects and events on Earth. Understanding the evolution of different natural or human-related phenomena throughout time and the relationships between them can be based on change detection (Parelius, 2023). Egypt has backed development initiatives to boost the productivity of the existing agricultural land and broaden agricultural regions. Therefore, it is imperative to evaluate how the land has changed in terms of cover as well as its suitability and aptitude for sustainable land use planning. One of the most important ecological issues that should be of worldwide concern is changes in land use and cover, or LULC (Halmy et al., 2015). In order to assess the change detection of land use/land cover across numerous areas, a number of research investigations were conducted in Egypt (Abd El-Kawy and Darwish, 2019; Elimy et al., 2020; Radwan, 2019; Yousif and Ahmed, 2019; Yousif and Ahmed, 2024). The enhancement of land productivity can be achieved through the utilization of advanced environmentally sustainable soil management techniques by farmers. The refinement of agricultural practices through the evaluation and observation of land productivity contributes to the preservation of soil capacity for the production of food, fiber, and commodity goods (Osuji and Henri-Ukoha, 2017). The present investigation endeavors to create a physiographic soil map of the examined region utilizing remote sensing techniques, evaluate and monitoring soil productivity in the period between 2005 and 2022, and generate a soil productivity maps for the study area.

2. Materials and Methods

2.1. Study area

El-Qaliobia Governorate located between longitudes 30° 15′ 0″ and 30° 30′ 0″ N and latitude 31° 03′ 30″ and 31° 34′ 30″ E. It covers an area 1022 km^2. It includes several districts, including the Kafr Shukr district, Banha, Qalyub, Al-Qanater Al-Khairiya, Toukh, Al-Khanka and Shebeen Al-Qanater (Fig.1).

2.2. Climate

The climate of the studied area can be characterized as a typical desert climate, where arid conditions prevail. Long hot summer months with no rainfall, and mild winters with very low or no rainfall are the norm. According to the Egyptian Meteorological Authority's Climatologically Normal for Egypt report (2020), this is the case. Additionally, referring to the keys to soil taxonomy (USDA, 2022), it can be inferred that the soil temperature regime of the area is Thermic, with the soil moisture regime has been identified as Aridic.

2.3. Geology and Geomorphology

The geographical composition of the region in question is attributed to the late Pleistocene period, characterized by the presence of prenile deposits, sand dunes, sea and water, Tertiary Alkali Olivine Basalt, Wadi deposits, and Nile silt. The geological units of interest were procured from the geological map of Egypt, which was produced by CONCO (1987) and has a scale of 1: 500,000. Qaliobia Governorate is home to seven distinct geomorphologic formations, namely the Decantation basin, Islands, Levees, Overflow basin, Overflow mantle, River terraces, and Turtle backs.

2.4. Landform mapping

Digital image processing was conducted on a single "Landsat Enhanced Thematic Mapper Plus (ETM+) and Landsat Operational Land Imager (OLI) "satellite image (path 176, row 39) with a spatial resolution of 30 meters that was obtained from the Geologic Survey archive of the United States Geological Survey (USGS) in the year 2005 and 2022 as shown in (Fig.2). This image was enhanced using the ENVI 5.3 software, and a carefully chosen combination of bands (4, 3, and 2) was selected in accordance with the recommendations of Lillesand and Kiefer (2015) as shown in (Table 1). The digital elevation model (DEM) of the study area (Fig.3) was extracted from the shuttle Radar Topography Mission (SRTM). Collection of data sources includes topographic map of Qaliobia Governorate, Egypt (scale 1:100000). ArcGIS 10.8 was the main GIS platform used in this study. GIS tool is applied to manage soil databases developed for the study area, mapping soil variables and modeling. Physiographic map of the study area has been produced using physiographic analysis, then map legend was established according to Zink and Valenzuala (1990).

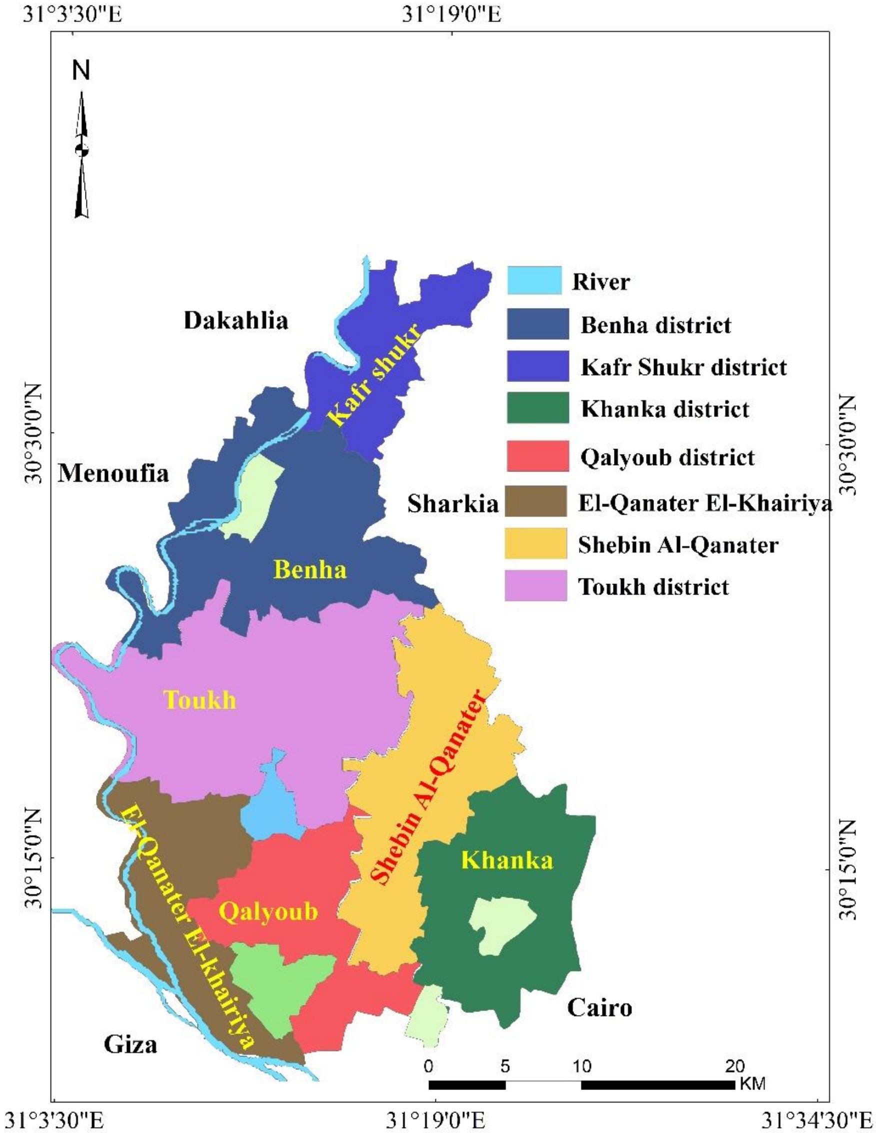

Fig. 1. Location of the studied area.

2.5. Change detection

To determine the changes in land cover within the research area. The changes in the studied area between the designated time periods of 2005–2022 were ascertained by comparing each pair of the final raster images obtained from the vegetation index. Changes in the two designated land cover categories (vegetation and urban) were identified for the classified maps in order to evaluate the growth of vegetation within the studied area during the previous seventeen years.

2.6. Field work and laboratory analysis

In the study area, an extensive soil survey was conducted with considerable detail. The survey involved excavation of a total of twenty-nine profile pits, and the morphological characteristics of the soil were delineated based on the guidelines of the Food and Agriculture Organization (FAO, 2006). Subsequently, samples were collected for analytical purposes. The particle size distribution of the soil was determined in accordance with the regulations of the US Department of Agriculture (USDA, 2004). Additionally, the electric conductivity (EC) of soil paste extract, soluble cations and anions, organic matter, pH, exchangeable sodium percentage, as well as available N, P, and K nutrients and cation exchange capacity (CEC).

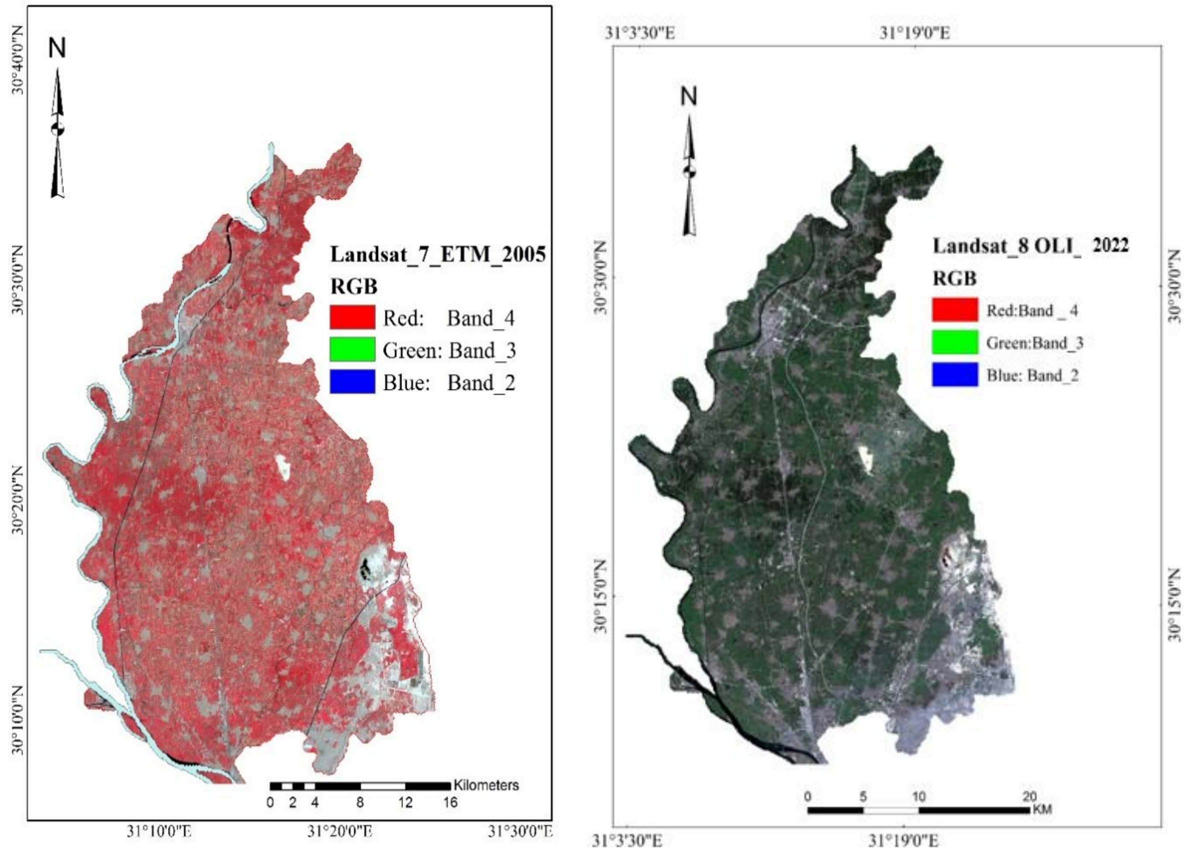

Fig. 2. Enhanced Landsat ETM+ and OLI satellite images.

Table 1. Remote sensing data of the study area.

Source	Sensor type	Identifier
Landsat-7	ETM (Enhanced Thematic Mapper)	LE07_L1TP_176039_20050517_20200914_02_T1
Landsat-8	OLI / TIRS “Operational Land Imager /Thermal Infrared Sensor”	LC08_L1TP_176039_20211215_20211223_01_T1
DEM	SRTM 1 Arc (30x30 meter)	SRTM1N29E030V3

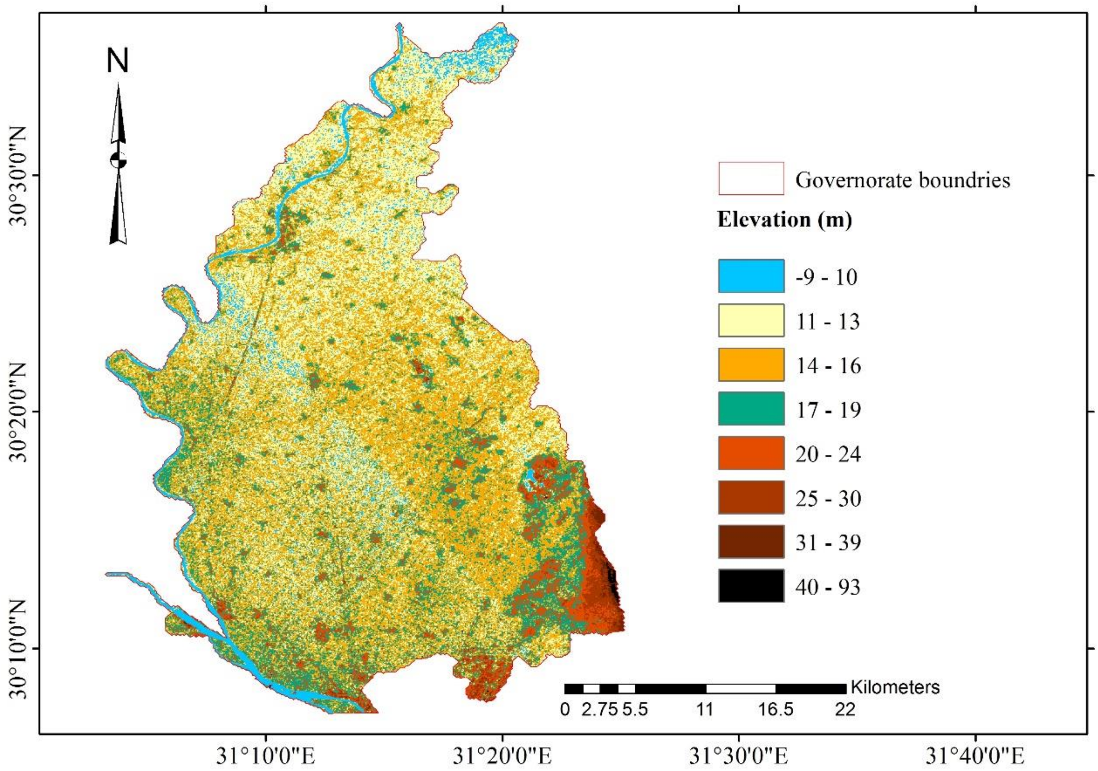

Fig. 3. Digital Elevation Model (DEM) of studied area.

2.6. Soil productivity index

The Riquier Land Productivity Index (RLPI) was estimated for the different mapping units in the study area using model produced by Riquier etal. (1970) modified by Raji (2000) as:

$$PI = \left(\frac{H}{100} \times \frac{D}{100} \times \frac{P}{100} \times \frac{T}{100} \times \frac{S}{100} \times \frac{O}{100} \times \frac{A}{100} \times \frac{M}{100}\right) \times 100$$

where RLPI is the Riquier Land Productivity Index, H is the moisture availability, D is the drainage, P is effective depth, T is the texture/structure, S is the soluble salt concentration, O is the organic matter, A is the mineral exchange capacity/nature of clay and M is the mineral reserves are used in soil factor analysis. Each factor is rated on a scale from 0 to 100, the actual percentages being multiplied by each other. The resultant is the index of productivity (between 0 and 100). The rating of the productivity and potentiality of the soils was done according to the grading system in Table 1. The various diagnostic elements pertaining to each thematic layer were carefully evaluated and subsequently attributed with values for the purpose of factor rating modified by (Mansour et al. 2017).

Table 2. Grades and classes of the calculated soil productivity index (PI).

PI (%)	Grade	Class
65 – 100	I	Excellent
35 – 64	II	Good
20 – 34	III	Average
8 – 19	IV	Low
0 – 7	V	Extremely low

Riquier et al. (1970) and Sanchez et al (1982). modified by Raji (2000)

3. Results

3.1. Change detection

The results of change detection for vegetation land cover and urbanization were achieved as illustrated in Figure 4 and Table 3. The spatial distribution of vegetation cover illustrated that vegetated areas represented 70.0 % with an area of (715.3 Km^2) and 63.0 % with an area (644.1 km^2), for 2005 and 2022, respectively. The spatial distribution of urban illustrated that urbanization areas represented 23.9 % with an area of (245.0 Km^2) and 30.8 % with an area (315.0 km^2), for 2005 and 2022, respectively.

3.2. Physiographic units

The identification of the landform units was conducted through an analysis of the landscape, which was extracted from satellite imagery, with the aid of Digital Elevation Model (DEM). The resulting geomorphology map depicts three primary landscapes. Table 4 shows the physiographic units over the studied area and (Fig. 5) shows the locations of twenty-nine the studied soil profiles on mapping units.

3.2.1. Soils of the basin

Basin containing Levees (L1 and L2), Overflow mantle (OM1 and OM2) and Overflow basins (OB1 and OB2), Decantation basin (DB1 and DB2) and Turtle backs (TB). The soils in this landform were classified into Typic Torrifluvents and Typic Torripsamments. The pH values ranged from (7.2 to 8.2). The electrical conductivity (EC) values range from 1.8 to 8.6 dS/m, while the $CaCO_3$ content ranges from 0.2% to 5.5%. The organic matter content ranges from 0.1 to 1.8%. Exchangeable sodium percent ranges from 2.18 to 17.7 %.

3.2.2. Soils of the river terraces River terraces with the highest and lowest river terraces (T1 and T2). The soils in this landform were classified into Typic Torrifluvents. The pH values of the soil are (8.0 and 8.2). The electrical conductivity (EC) values range from 1.1 to 2.7 dS/m, while the $CaCO_3$ content ranges from 0.3% to 1.8%. The organic matter content ranges from 0.1 to 0.9%. Exchangeable sodium percent ranges from 3.1 to 37.2 %.

3.2.3. Soils of islands

Islands including recent island and sub-recent island (I1 and SI1). The soils in this landform were classified as Typic Torripsamments. The pH values of the soil are (7.0 and 7.9). The electrical conductivity (EC) values range from 0.4 to 5.7 dS/m, while the $CaCO_3$ content ranges from 0.1% to 0.6%. The organic matter content ranges from 0.1 to 0.5%. Exchangeable sodium percent ranges from 8.4 to 9.8 %.

Table 3. Land use/Land cover area from 2005 to 2022.

Year	Area	Urban	Vegetation	Water	Bare land	Total
2005	km^2	245.0	715.3	27.2	34.5	1022
	%	23.9	70.0	2.7	3.4	100
2022	km^2	315.0	644.1	28.1	35.6	1022
	%	30.8	63.0	2.7	3.5	100

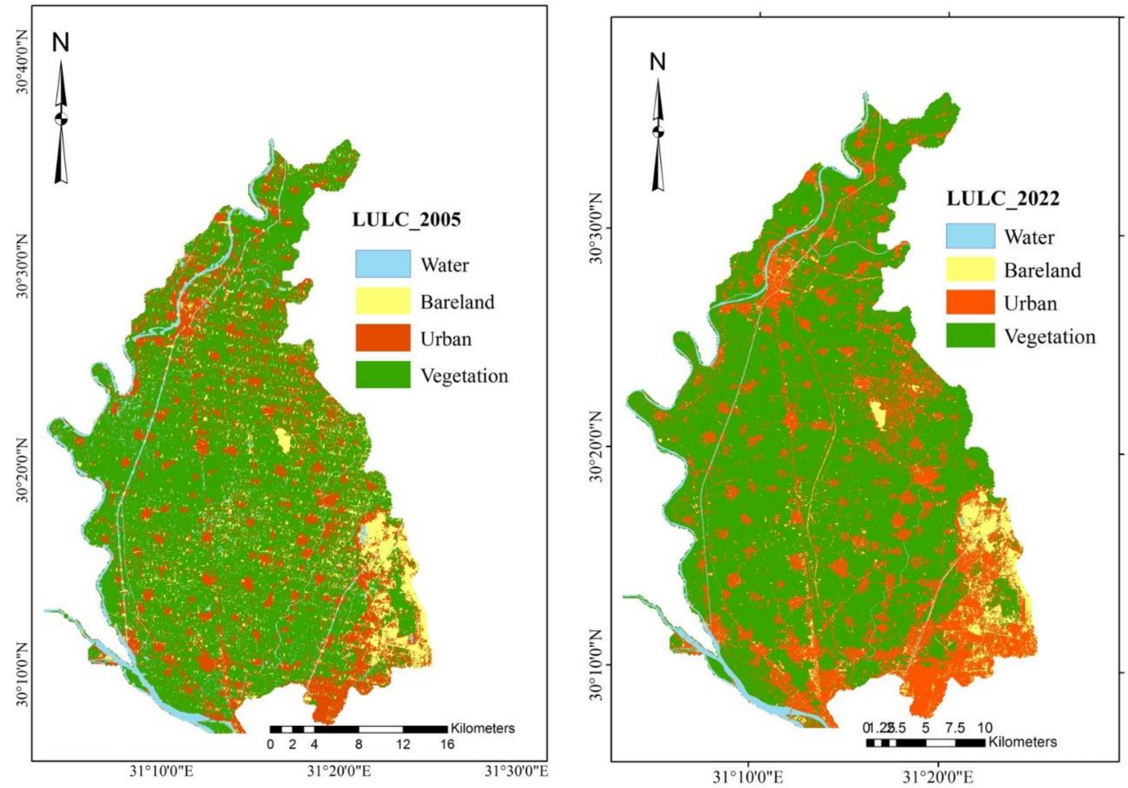

Fig. 4. LULC of the studied area (2005 – 2022).

Table 4. Physiographic legend and areas of the different mapping units.

Landscape	Relief	Lithology/origin	Land form	Mapping unit	Area Km²	% of the total area
Alluvial plain	River Terraces	Sequence of river terraces	The Highest river terraces	T1	189.02	18.5
			The lowest river terraces	T2	63.3	6.2
	Basin	Levees	Recent sand deposits	L1	11.02	1.15
			Sub-recent sand deposits	L2	5.28	0.52
		Overflow mantle	Relatively high parts	OM1	54.91	5.4
			Relatively low parts	OM2	60.13	5.9
		Overflow basin	Relatively high parts	OB1	124.57	12.2
			Relatively low parts	OB2	122.71	12.03
		Decantation basin	Relatively high parts	DB1	101.01	9.9
			Relatively low parts	DB2	226.5	22.2
		Turtle backs	Isolated hills (complex)	TB	11.01	1.08
	Nile deposits	Islands	Recent islands	I1	4.53	0.4
			Sub-recent islands	SI1	13.21	1.28
Total					1022	100

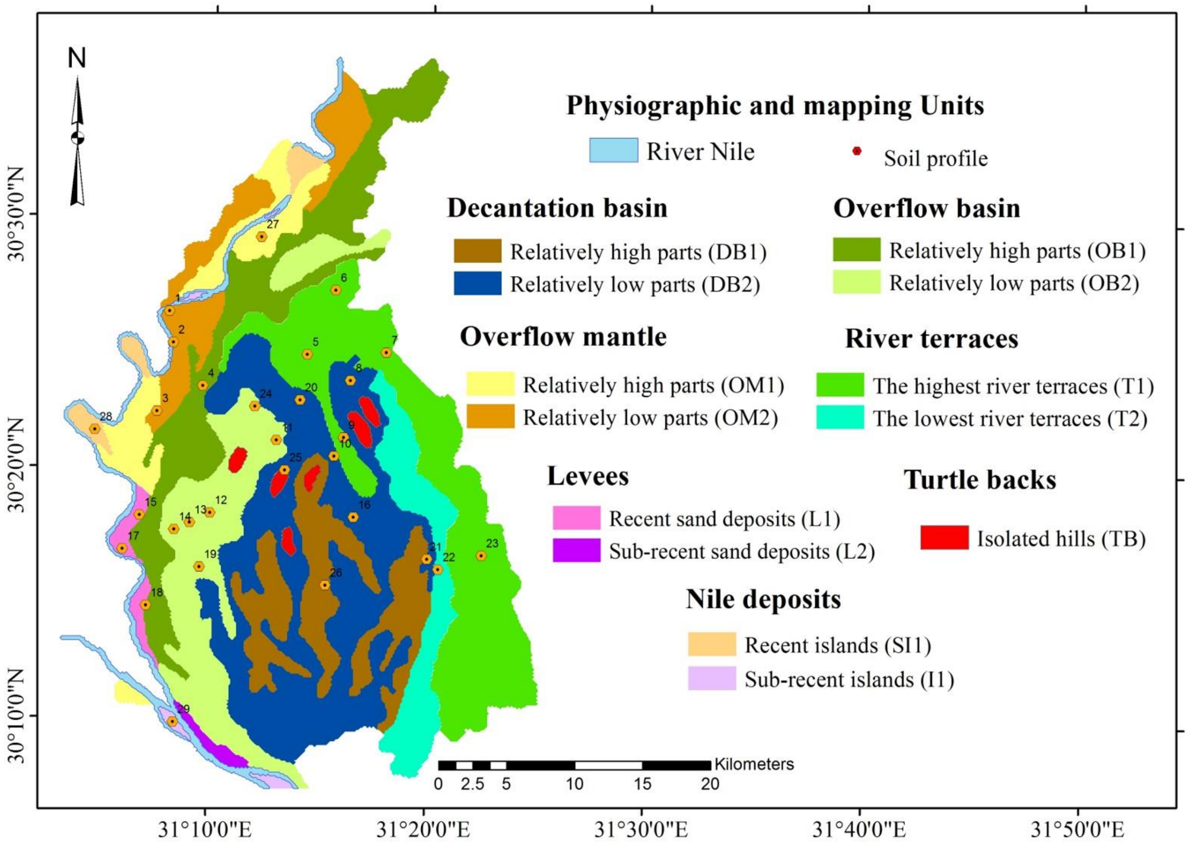

Fig. 5. The main physiographic units and location of soil profiles in the studied area, modified after Abd El-Kawy and Darwish., (2019).

3.3. Soil productivity assessment

The productivity of soil refers to its ability to generate a designated plant or series of plants in specific management frameworks. According to Riquier et al. (1970), this productivity is defined as the initial soil capacity to yield a particular crop per hectare per year. In contrast, soil potential productivity represents the maximum productivity achievable with all feasible enhancements. Therefore, this potentiality reflects the future capability of the soil, considering both physical and chemical characteristics that may be altered by conservation practices or improvements, as well as those characteristics that cannot currently be modified with modern technology (Riquier et al., 1970). Using the ArcGS 10.8 program, modeling was done to calculate soil productivity in 2005 and 2022 and then extracting productivity maps over the two years.as shown in (Fig. 6).

The results illustrated the changes of soil productivity index during 2005 and 2022 in the different landforms in (Tables 5 to 11) and (Fig. 5). Soil productivity index in the studied area between Grade II to Grade V. In L1, L2, OM1, OM2, OB1 and OB2 the productivity index was good class in 2005 with 38.3 % of the studied area while units of L1, OM1, OM2 and OB1 were good class in 2022 with 25.5 % of the studied area. In DB2 the productivity index was average class in 2005 with 23 % of the studied area while units of L2 and OB2 were good class in 2022 with 12.9 % of the studied area. In DB1, T1 and T2 the productivity index was low class in 2005 with 35.8 % of the studied area while units of DB1, T1 and T2 were low class in 2022 with 35.8 % of the studied area. In TB, I1 and SI1 the productivity index was extremely low class in 2005 with 2.9 % of the studied area while units of TB, DB2, I1 and SI1 were low class in 2022 with 25.8 % of the studied area as shown in (Fig. 6).

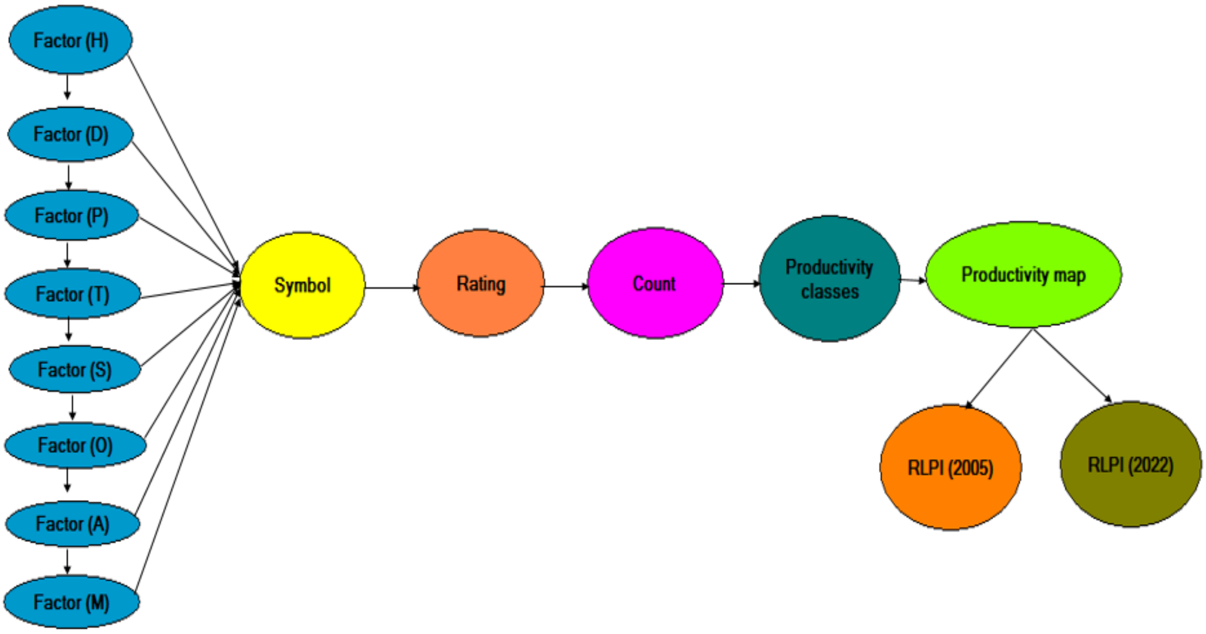

Fig. 6. Flowchart of the designed soil productivity model.

4. Discussion

The most widely used, well-liked, effective, and dynamic methods in soil productivity studies to evaluate the suitability of significant and important crops in many countries are remote sensing, geographic information systems, and simulation models (Yousif ., 2023; Yousif et al., 2020; Yousif and Ahmed 2019; Abd El-kawy and Darwish, 2019; Abd El-kawy and Ali., 2012; Abd El-kawy et al., 2023). In the current work, we used remote sensing, GIS, and urban vegetation cover change detection in the El-Qaliobia Governorate of Egypt. It is suggested that the utilized method be suitable for analogous studies carried out in other areas (Yousif and Ahmed., 2024; Mansour et al., 2017; Zayed et al., 2021; Abd El-kawy et al., 2023). Thirsteen sites were selected in the studied area as shown in (Tables 5 to 11). The sites selection depends mainly upon previous study carried out by Rashad W., (2005) and Shawaky. H., (2005). while the current study select the same sites to make the comparison as well as the monitoring of productivity more realistic. The soil characteristics of previous and current studies were grouped and recalculated to meet the requirements of Riquier's productivity model as shown in (Tables 5 to 8). Productivity rating were calculated depending on the aforementioned recalculated soil characteristics by the aid of (Riquier., 1970 modified after Mansour., 2017) resulting soil productivity index and grades as shown in (Table 9 and 10).

Previous soil productivity assessment in the alluvial plain

All mapping units which represent the basin soils (L1, L2, OM1, OM2 and OB1) have been classified as grade II except the decantation basin soils DB1 which have been classified as grade IV and DB2 have been classified as grade III, Turtle backs (TB) have been classified as grade V. All mapping units which represent the river terraces soils (T1 and T2) have been classified as grade IV while the islands soils have been classified as grade V as shown in (Table 9).

Current soil productivity assessment in the alluvial plain

All mapping units which represent of the basin soils (L1, OM1, OM2, OB1 and OB2) have been classified as grade II except the decantation basin soils DB1 have been classified as grade IV and DB2 have been classified as grade V, Turtle backs (TB) have been classified as grade V. All mapping units which represent of the river terraces soils (T1 and T2) have been classified as grade IV while the islands soils have been classified as grade V as shown in (Table 10).

Actual soil productivity map

The objective of the current study is the interpretative classification of soil productivity to different categories, each of which corresponding to a certain level of detail. At each level the interpretation differs in precision, objectives, requirements and assumptions. These successive steps may help the user in a better understanding of the system. Soil productivity interpretation shows that, the groupings are distinguished in precise numerical units. Classifications, which meet soil productivity requirements would be taken the highest grades. On the contrary would be the lowest ones. Intermediate grades would be occurred in between. Soil characteristics relevant to productivity are shown in (Table 7 and 8) while assessment of soil productivity could be obtained by matching soil characteristics with its counterpart of the Riquier's model rating as shown in (Table 9 and 10).

Soil productivity improvement

Soil productivity can be enhanced through the following practices in the studied area. (a) use of appropriate crop production technologies and related resource management systems that involve the composition, structure, and function of entire ecosystems, (b) Tillage to reduce organic matter degradation and compaction, (c) Reducing crusting, especially in fine textured soils, improving aggregation, preventing erosion and compaction, (d) The drainage can be improved by adding organic matter or by adding materials such as lime or gypsum, (e) reduce salt loading and concentration of salt in water supplies and control by leaching soil, adding gypsum and installing adequate drains.

Table 5. Values of the factors of land productivity of the studied soils of the investigated area in 2005.

Mapping Units	Profile No.	(H)	(D)	(P)	(T)	(S)	(O)	(A)	(M)
L1	15	*	Well	150	clay	1.55	5.3	37.5	Reserves large
L2	17	*	Good	100	clay	0.78	2.88	35.9	Reserves large
OM1	27	*	Well	150	clay	2.41	9.5	42.3	Reserves large
OM2	2	*	Well	150	clay	1.75	10.3	40.6	Reserves large
OB1	4	*	Well	150	clay	1.42	8.73	46.3	Reserves large
OB2	14	**	Well	150	Silty clay	1.11	7.3	26.1	Minerals derived from sands
DB1	26	*	Well	150	Sandy loam	1.64	9.5	8.1	Minerals derived from sands
DB2	21	*	Good	70	Clay	4.5	6.7	43.8	Reserves large
TB	25	**	Well	150	Sandy	2.4	5.4	24.1	Minerals derived from sands
T1	23	**	Good	70	Sandy loam	0.72	8.7	17.8	Minerals derived from sands
T2	22	**	Good	70	Sandy loam	1.93	8.9	12.7	Minerals derived from sands
I1	28	**	Good	100	Sandy	2.6	7.9	28.09	Minerals derived from sands
SI1	29	**	Good	100	Sandy	3.0	6.1	23.51	Minerals derived from sands

*Rooting zone above wilting point and below field capacity for most of the year

**Rooting zone below wilting point for 3 to 5 months of the year

(**H:** moisture content, **D:** drainage condition, **P:** effective soil depth, **T:** texture/structure, **S:** soluble salt concentration, **O:** organic matter content, **A:** Cation exchange capacity and **M:** mineral reserve)

Table 6. Values of the factors of land productivity of the studied soils of the investigated area in 2022.

Mapping Units	Profile No.	(H)	(D)	(P)	(T)	(S)	(O)	(A)	(M)
L1	15	*	Well	130	clay	2.75	4.5	38.5	Reserves large
L2	17	*	Good	65	clay	2.59	2.3	39.0	Reserves large
OM1	27	*	Well	110	clay	8.61	8.2	43.0	Reserves large
OM2	2	*	Well	140	clay	2.86	9.5	41.0	Reserves large
OB1	4	*	Well	110	clay	3.22	8.0	45.2	Reserves large
OB2	14	**	Well	140	Silty clay	5.48	6.8	25.4	Minerals derived from sands
DB1	26	*	Well	120	Sandy loam	3.63	8.7	9.2	Minerals derived from sands
DB2	21	*	Good	50	Sandy loam	5.5	5.9	45.0	Minerals derived from sands
TB	25	**	Well	120	Sandy	2.29	4.8	22.2	Minerals derived from sands
T1	23	**	Good	140	Sandy loam	2.27	7.5	16.6	Minerals derived from sands
T2	22	**	Good	130	Sandy loam	1.57	7.8	13.5	Minerals derived from sands
I1	28	**	Good	60	Sandy	4.82	6.5	21.2	Minerals derived from sands
SI1	29	**	G0ood	80	Sandy	5.72	5.5	22.8	Minerals derived from sands

*Rooting zone above wilting point and below field capacity for most of the year

**Rooting zone below wilting point for 3 to 5 months of the year

(**H:** moisture content, **D:** drainage condition, **P:** effective soil depth, **T:** texture/structure, **S:** soluble salt concentration, **O:** organic matter content, **A:** Cation exchange capacity and **M:** mineral reserve)

Table 7. Soil characteristics of the investigated area in 2005.

Mapping Units	Profile No.	(H)	(D)	(P)	(T)	(S)	(O)	(A)	(M)
L1	15	H5	D4	P6	T5b	S1	O1	A2	M3
L2	17	H5	D3	P5	T5b	S1	O1	A2	M3
OM1	27	H5	D4	P6	T5b	S1	O1	A3	M3
OM2	2	H5	D4	P6	T5b	S1	O2	A3	M3
OB1	4	H5	D4	P6	T5b	S1	O1	A3	M3
OB2	14	H4	D4	P6	T7	S1	O1	A3	M2a
DB1	26	H4	D4	P6	T2b	S1	O1	A1	M2a
DB2	21	H5	D3	P4	T5b	S2	O1	A3	M3
TB	25	H3	D4	P6	T2a	S1	O1	A2	M2a
T1	23	H4	D3	P4	T2b	S1	O1	A1	M2a
T2	22	H4	D3	P4	T2b	S1	O1	A1	M2a
I1	28	H3	D3	P4	T2a	S1	O1	A1	M2a
SI1	29	H3	D3	P4	T2a	S1	O1	A1	M2a

Table 8. Soil characteristics of the investigated area in 2022.

Mapping Units	Profile No.	(H)	(D)	(P)	(T)	(S)	(O)	(A)	(M)
L1	15	H5	D4	P6	T5b	S1	O1	A2	M3
L2	17	H5	D3	P4	T5b	S1	O1	A2	M3
OM1	27	H5	D4	P5	T5b	S3	O1	A3	M3
OM2	2	H5	D4	P6	T5b	S1	O1	A3	M3
OB1	4	H5	D4	P4	T5b	S2	O1	A3	M3
OB2	14	H4	D4	P6	T7	S2	O1	A2	M2a
DB1	26	H4	D4	P6	T2b	S2	O1	A1	M2a
DB2	21	H4	D2	P3	T2b	S2	O1	A3	M2a
TB	25	H3	D4	P6	T2a	S1	O1	A2	M2a
T1	23	H4	D4	P6	T2b	S1	O1	A1	M2a
T2	22	H4	D4	P6	T2b	S1	O1	A1	M2a
I1	28	H3	D3	P4	T2a	S2	O1	A2	M2a
SI1	29	H3	D3	P4	T2a	S2	O1	A2	M2a

Table 9. Assessment of Requier land productivity index of the study area in 2005.

Mapping Units	Profile No.	(H)	(D)	(P)	(T)	(S)	(O)	(A)	(M)	Riquire Productvity index (RPI)	Grade
L1	15	100	100	100	80	100	70	95	95	50.5	II
L2	17	100	100	80	80	100	70	95	95	40.4	II
OM1	27	100	100	100	80	100	70	100	100	56.0	II
OM2	2	100	100	100	80	100	80	100	100	64.0	II
OB1	4	100	100	100	80	100	70	100	100	56.0	II
OB2	14	80	100	100	100	100	70	100	90	50.4	II
DB1	26	80	100	100	30	100	70	90	90	13.6	IV
DB2	21	100	100	80	80	90	70	100	100	40.3	III
TB	25	70	100	100	10	100	85	95	85	4.8	V
T1	23	80	100	80	30	100	70	90	90	10.9	IV
T2	22	80	100	80	30	100	70	90	90	10.9	IV
I1	28	70	100	90	10	100	85	90	85	4.1	V
SI1	29	70	100	90	10	100	85	90	85	4.1	V

Table 10. Assessment of Requier land productivity index of the study area in 2022.

Mapping Units	Profile No.	(H)	(D)	(P)	(T)	(S)	(O)	(A)	(M)	Riquire Productvity index (RPI)	Grade
L1	15	100	100	100	80	100	70	95	95	50.5	II
L2	17	100	80	80	80	100	70	95	95	32.3	III
OM1	27	100	100	100	80	80	70	100	95	42.6	II
OM2	2	100	100	100	80	100	70	100	95	53.2	II
OB1	4	100	100	80	80	90	70	100	95	38.3	II
OB2	14	80	100	100	100	70	70	95	90	33.5	III
DB1	26	80	100	100	30	70	70	90	90	9.5	IV
DB2	21	80	40	50	30	70	70	95	90	2.0	V
TB	25	70	100	100	10	100	85	95	85	4.5	V
T1	23	80	100	100	30	100	70	90	90	13.6	IV
T2	22	80	100	100	30	100	70	90	90	13.6	IV
I1	28	70	90	80	10	70	85	95	85	2.4	V
SI1	29	70	90	80	10	70	85	95	85	2.4	V

Table 11. Distribution of Requier land productivity index of the studied area during the period 2005-2022.

Class	Grade	PI (%)	2005			2022		
			Mapping units	Area km^2	%	Mapping units	Area km^2	%
Excellent	I	100 - 65	-	-	-	-	-	-
Good	II	64 - 35	L1, L2, OM1, OM2, OB1 and OB2	378.6	38.3	L1, OM1, OM2 and OB1	250.6	25.5
Average	III	34 - 20	DB2	226.5	23.0	L2 and OB2	127.9	12.9
Low	IV	19 – 8	DB1, T1and T2	353.4	35.8	DB1, T1and T2	353.4	35.8
Extremely low	V	7 - 0	TB, I1 and SI1	29.0	2.9	TB, DB2, I1 and SI1	255.5	25.8

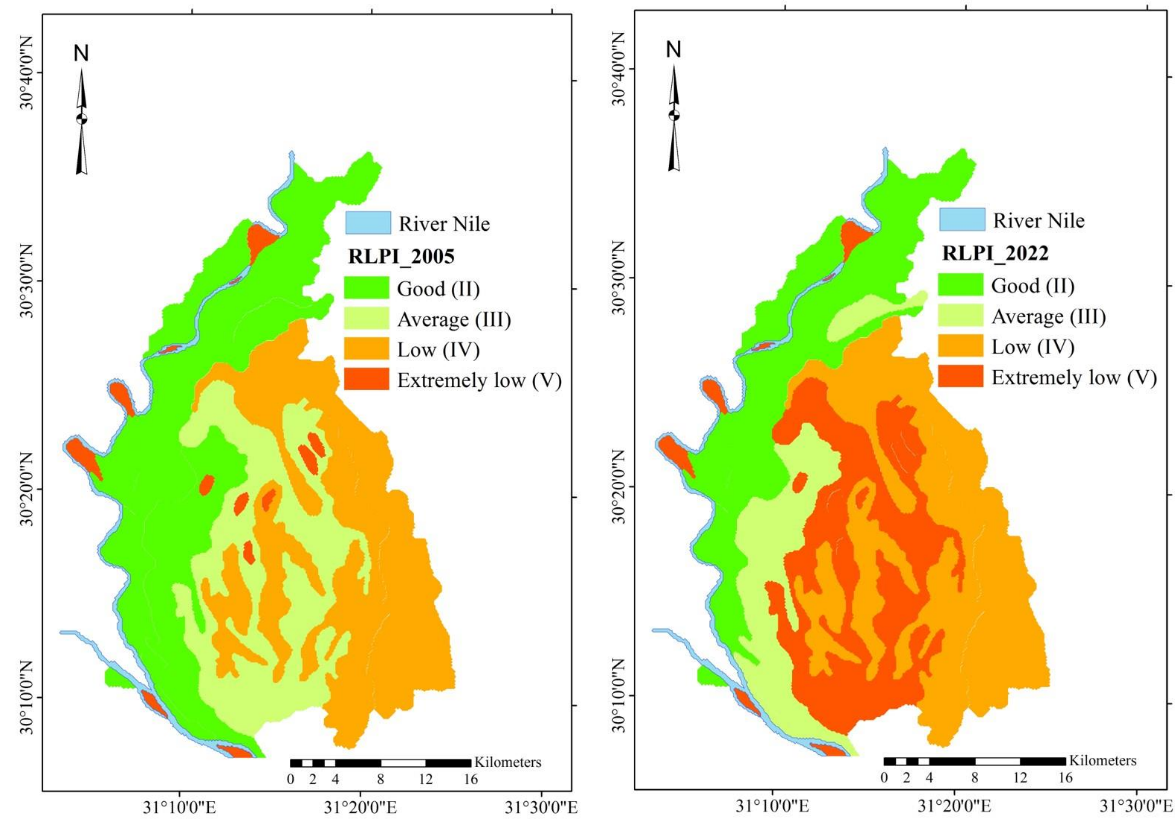

Fig. 7. Soil productivity map of the studied area for the year 2005 – 2022.

5. Conclusion

More than half of the El-Qaliobia Governorate is estimated to have poor to extremely poor productive attributes based on indicators of change in soil productivity. Some of the substandard soils have remediable limitations like salinity and cation exchange capacity, but some have irreversible limitations like soil depth and soil texture. This conclusion is drawn from monitoring changes in the physical characteristics of the land between 2005 and 2022. More precise data regarding the kinds and geographical distribution of changes in land use and cover, along with the extent of degradation, could be obtained by combining remote sensing data with GIS tools.

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