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Utilizing Sustainable Land Management Model for Sustainability Index Assessment in El-Minufiya Governorate, Egypt

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ABSTRACT

This study aims to assess Sustainable Land Management Index (SLMI) for the soils in El-Minufiya Governorate through five indices (productivity index, security index, protection index, economic viability index and social acceptability index). The studied area, lies between latitudes 31° 5' and 31° 25' N and longitudes 30° 10' and 30° 40' E, and occupied 217160 hectares. The two Nile branches (Rosetta and Damietta branches) pass the Governorate. Thus, the land use in rural areas of the Governorate is mainly agriculture. The area included two landscapes; Flood plain and Aeolian plain. Soils in the investigated area were classified under one soil order, Entisols and classified as Typic Torrifluvents, Vertic Torrifluvents and Typic Torripsamments. Fifteen soil profiles were dug to represent El-Minufiya Governorate soils. An SLMI model was designed using the spatial geoprocessing tools of ArcGIS by integration between biophysical, socioeconomic and environmental factors for soils of each mapping unit. Four SLMI classes were outlined; the overflow mantles, overflow basins mapping units (Class I) representing 24.1 % (52333 ha) of the total area, the river levees, decantation basins, high river terraces, moderate river terraces and low river terraces mapping units (Class II) covering 48.3% (104991 ha) of the total area, turtle backs mapping unit (Class III) occupying 0.3% (642 ha) of total area and Class (IV) that not meeting sustainability found in sand sheets mapping unit occupying 16.7% (36255 ha) of the total area.

Keywords: El-Minufiya Governorate, SLMI, Nile Delta and ArcGIS.

INTRODUCTION

Agriculture is the most important sector for sustainable growth in Africa (World Bank, 2007), agricultural land is a complex system that combines social economy and natural ecology to provide adequate outputs, and the role of agriculture is crop yield (Andzo-Bika and Kamitewoko, 2004; Li and Yan, 2012; Kokoye *et al*., 2013; Kumhálová and Moudr, 2014; Verburg, 2015; DeClerck, 2016; Rashed, 2016; Rasmussen, 2018 and Scown *et al*., 2019). Agriculture has significant negative effects on land, biodiversity, water, and the global climate (McLaughlin and Mineau, 1995; Carpenter, 1998; Foley *et al*., 2005 and Vermeulen *et al*., 2012). Soil security, is concerned with the main-tenancy and improvement of the global soil resource to produce food and fiber (Bouma and McBratney, 2013 and McBratney *et al*., 2014), sustainable agriculture raises food production for peoples and animals (Faroque, 2013), and is one of the most important strategies to overcome world hunger (Saeed *et al*., 2018). Land assessment is a tool that can be used to provide data for the creation of sustainable agriculture (George, 2015 and UNEP, 2015).

The concept of sustainability indicates a relationship between suitability and various degradation processes (Sonter *et al*. 2017 and Tóth and Hermann 2018), the main element of sustainability is the proper land use planning of nature resources (Abu-Sirhan *et al*. 2015). Sustainable development is what meets the needs of today's society (Blanco *et al*., 2001; Trinder and Milne, 2002 and Trinder, 2008). It refers to practices that meet current and future societal needs for food, ecosystem services and human health (USAID, 1988; Tilman *et al*., 2002 and Lichtfouse *et al*., 2009). It focuses on production that renews resources; Egypt has sustainability constraints such as salinity and alkalinity, lack of infrastructure and credit utilization (Mohamed *et al*., 2014). The global population is rise to 9.8 billion in 2050 (Searchinger, *et al*., 2018). The impact of the increase in population leads to increasing pressure on soils already populated (Darwish *et al*., 2006 and CAPMAS, 2009). Egypt is the most populous country in the Arab world (FAO, 2015), and must combat sustainability constraints that hinder agricultural development (Nawar, 2009; El-Bastawesy *et al*., 2013; Ali and Shalaby, 2013 and Abdel Kawy and Darwish, 2014). Egypt Nile Delta has very limited area of fertile soils which threatening by urban sprawl (Abowaly *et al*., 2018). Sustainable land management (SLM) is necessary to narrow the gap between planning practices and requires integration of technologies and policies (Milesi-Ferretti and Razin, 1996; Dumanski, 1997; Gliessman, 1998 and Antonson, 2009), SLM is complex and including biophysical, socio-economic and environmental (Hurni, 1997; Gliessman, 1998; El-Baroudy 2016 and Moghanm etal., 2018). SLM measures are widely promoted to decrease erosion and increase crop yield (Wickama *et al*., 2014). Five Indicators (productivity, security, economic viability and social acceptability) are used under Egyptian conditions for agricultural sustainability (Smith and Dumanski, 1993 and Dumanski, 1997; Hurni, 2000; Eswaran *et al*., 2000; Nawar, 2009 and El-Bastawesy *et al*., 2013). Evaluation of soil productivity for a long term has been a major hotspot in soil science (El-Baroudy, 2015).

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Remote sensing (RS) gives an accurate picture of the agricultural sector with high revisit frequency (Zhongxin *et al*., 2004). It measures many physical aspects and can play a role in assessing sustainability (Becker, 1997 and Shanmugapriya *et al*., 2019). RS data are used for estimating biophysical parameters, cropping systems analysis, and land-use & land-cover estimations during different times (Rao *et al*., 1996 and Panigrahy *et al*., 2006). It provides a wealth of environmental over a range of spatial and temporal scales (Foody, 2003). Geographic Information System (GIS) is an organized collection of computer hardware, software, spatial and non-spatial data (Rajitha *et al*., 2006 and Quan Bin *et al*., 2007). These techniques have many fold applications in agriculture such as crop production, soil moisture estimation, soil fertility evaluation, crop stress detection, detection of diseases, drought and flood condition monitoring, weather forecasting, precision agriculture economic growth and sustainability evaluation (Shanmugapriya *et al*., 2019).

The main objective of the current work is to evaluate Sustainable Land Management Index (SLMI) in El-Minufiya Governorate, Egypt; through five indices (productivity index, security index, protection index, economic viability index and social acceptability index) using GIS and remote sensing data.

MATERIALS AND METHODS

Location of the study area

El-Minufiya Governorate, central Delta is located between the two branches (Rosetta and Damietta), It is one of the oldest governorates of Egypt, latitudes 31° 5' and 31° 25' N, and longitudes 30° 10' and 30° 40' E (Fig. 1). The area of El-Minufiya is about 217160 ha. The study area is under arid conditions**,** with hot arid summer and little rain winter, with average temperature of 15.0 to 27.2 °C. Average monthly relative humidity ranges from 51%. The capital of the Minufiya is Shebin El-kom City, which comprises departments of major government administration, also has El-Minufiya University. The land use in rural areas of the Governorate is mainly agriculture. The elevation of the study area varied from 0 to 20 m above the mean sea level (a.m.s.l.).

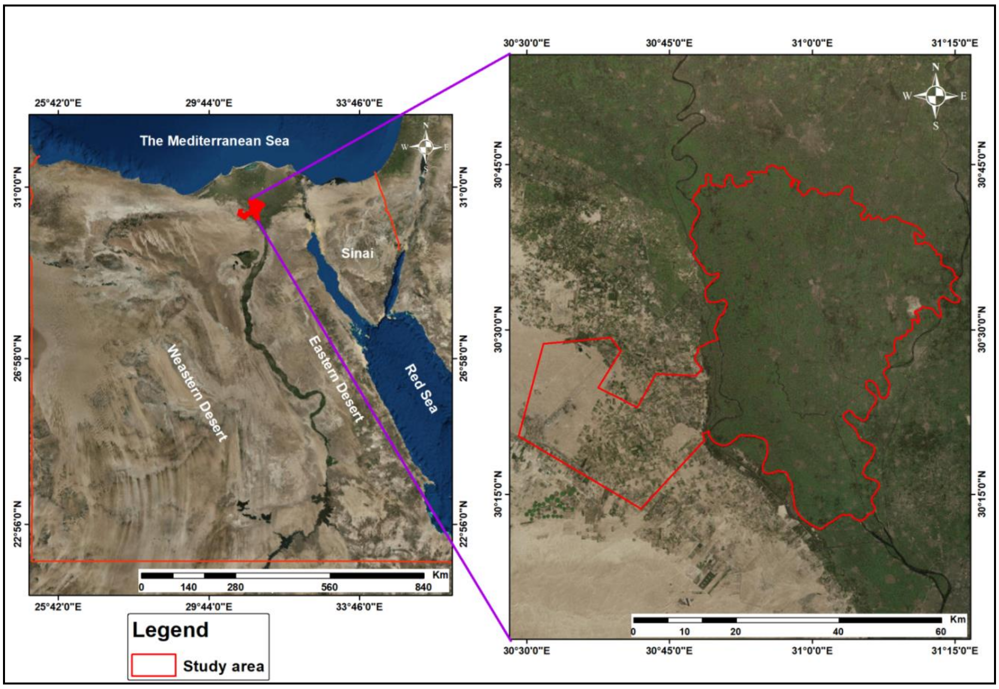

Fig. 1. Location map of the study area.

Hydrology

The two Nile branches (Rosetta and Damietta branches) pass the governorate of El-Minufiya. Three main canals are passing through the governorate: El-Minufiya Rayyah canal, Nagayel Canal and Darwa Canal. According to ESIAF (2010) the fresh water bodies and irrigation canals have relatively good water quality. The depth of groundwater table in El-Minufiya Governorate is generally in the range of 3-5 meters. The groundwater aquifers that yield major groundwater supplies in the Nile Delta, have depths ranging from 100 to 900 meters and salinity of 300 to 600 mgL^{-}.

Geomorphology and geology of the study area.

There are three major geomorphic units in middle of Nile Delta, namely: young deltaic plain, old deltaic plain, young Aeolian plain (EI-Fayoumy, 1968). Land of El-Minufiya Governorate belongs to the late Pleistocene era which is represented by the deposits of the Neonile which lowering its course at a rate of 1m/1000 years (Hagag, 1994 and Said, 1993). The middle Nile delta area according to (CONOCO, 1987) is characterized by the following geological units:

-Neonile deposits: clay, silt, very fine-grained sand, fragments of vegetal matter, Nile silt deposits: fine grained sediments (silt and clay) deposited from suspension on a flood plain by floodwater, Prenile deposits: medium-coarse grained sand, a few clay intercalations and Protonile deposits: soft clay, shale, siltstone, streaks of very fine sandstone and thin limestone.

Soil surveys and laboratory analyses

Soil surveys and laboratory analyses were conducted, and socio-economic data were generated. Ground Position System (GPS) was used to locate the site of each profile (latitude and longitude). Fifteen soil profiles were made to represent the study area (Fig.1). Soil samples were taken from the profiles and analyzed from main properties (USDA, 2004 and Bandyopadhyay, 2007). Water samples were collected from irrigation, drainage and the water table from the soil profile locations. Detailed socio-economic data about the studied area were collected through field questionnaires.

Satellite Data:

Digital image processing of Base map satellite images in 2019 was executed using ENVI 5.2 and the Arc-GIS 10.3 software. The digital image processing included bad lines manipulation by filling gaps module designed using IDL language, data calibration to radiance according to Lillesand and Kiefer (2007).

Assessment of Sustainable land management Index (SLMI)

Sustainability potential of the representative soil profiles were assessed by applying the international model for evaluating sustainable land management index (SLMI) established by Smith and Dumanski (1993). The system suggests calculation of a SLMI considering five indices as determining land Sustainability factors. They are: productivity index (AI), security index (BI), protection index (CI), economic viability index (DI), and social acceptability index (EI). The resultant is the index of SLMI (between 0 and 1.0). The obtained multiplication results, which reflect the degree of the agricultural sustainability, are divided into four sustainability classes according to Smith and Dumanski (1993) as shown in Table 1.

Table 1. Class and rating limit of Sustainable Land Management index (SLMI).

Rating	Sustainability status	Class
0.6-1.0	Land management practices meet sustainability requirements	I
0.3-0.6	Land management practices are marginally above the threshold for sustainability	II
0.1-0.3	Land management practices are marginally below the threshold for sustainability	III
0.0-0.1	Land management practices don't, meet sustainability requirements	IV

RESULTS AND DISCUSSION

Geomorphologic features.

The geomorphologic map of the studied area is produced based on integration of topographic map, aspect map, Digital Elevation Model (DEM) and field work observations and remote sensing data. Figure 2 shows that two main landscapes could be identified in the investigated area include:

1- Flood plain with eight mapping units; river levees (L) (1935 ha., 0.9%), overflow mantles (O) (7821 ha., 3.6%), overflow basins (B1) (44512 ha., 20.5%), decantation basins (B2) (19625 ha., 9.0%), high river terraces (R1) (31830 ha., 14.6%), moderate river terraces (R2) (32685 ha., 15.1%), low river terraces (R3) (18916 ha., 8.7%) and turtle backs (T) (642 ha., 0.3%). The landscape of Flood plain was represented by 13 soil profiles.
2- Aeolian plain containing two mapping units; hummock areas (H) (18483 ha., 8.50%) is out of soil profiles and sand sheets (S) (36255 ha., 16.70%), is represented by 2 soil profiles.

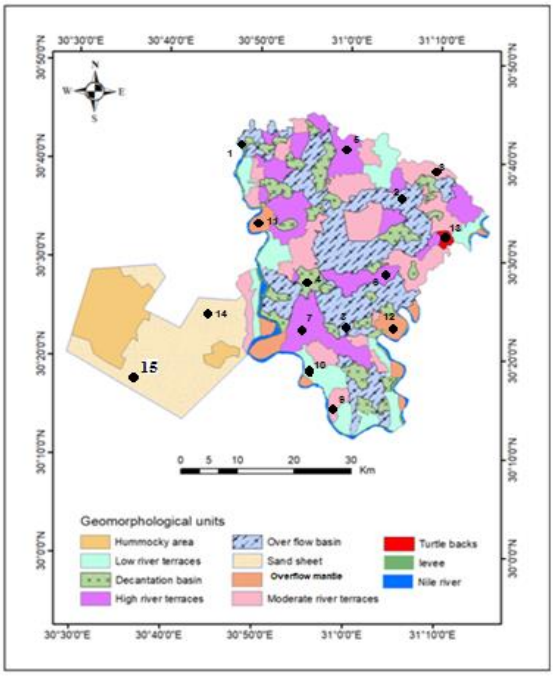

Fig. 2. Geomorpholog of El-Minufiya Governorate and profiles location.

Soil mapping and classification

The soil classification due to the Soil Taxonomy Bases (USDA, 2014) of the American Soil Survey Staff is applied up to the sub great group for mapping unit, and to family level for the profile description. Soils in the study area are classified under one soil order, Entisols. The soils were classified as Typic Torrifluvents, Vertic Torrifluvents and Typic Torripsamments.

Model of Sustainable land management index (SLMI).

The SLMI model is established by Smith and Dumanski (1993). It was designed using the spatial geoprocessing tools of ArcGIS 10.3 (Figure 3). It is aimed at assimilating the five indicators of sustainable land management (productivity, security, protection, economic viability and social acceptability). Its sustainability indicators were formulated and evaluated for soils of each mapping unit. Equations for each indicator are according to Smith and Dumanski (1993):- explain the mechanism of SLMI model:

1-Indices (indicators) include productivity (AI), security (BI), protection (CI), economic viability (DI), social acceptability (EI) all of which are used as diagnostic criteria.

2- Indicators are expressed as an index numbers. Each represents a particular expression (such as: texture, water quality, erosion hazards, benefit-coast ratio, land tenure and other expressions). The indicator is expressed in terms of its normal expression (such as amount or content numerals "e.g. soil EC) or in terms of non-numeral descriptive words (such as soil texture). Thus the resultant multiplication gives a number which amounts up to 100. Each of such (scores expressing each indicator) is divided by 100, then all similarly divided indicators belonging to a particular indicator are combined in a multiple multiplication equation to get the "indicators Index", which is a number of up to 1.00. The special Tables are used for the transformations.

3-Calculating the mean weighted value of each determined property.

4-Calculating a series of values for criteria was resulted in five datasets for each input criteria.

5-Calculataing the Productivity Index (AI) according to the following equation (Eq. 1):

Productivity Index (AI) = A/100 × B/100 × C/100 × D/100 × E/100 × F/100 × G/100 × H/100 × I/100 × J/100 × K/100…………..Eq. (1)

Where, A: relative crop yield %, B: organic carbon %, C: soil pH, D: cation exchange capacity, E: available nitrogen, F is available phosphorus, G is available potassium, H: soil depth "indicator for soil oxygen", I: Soil salinity, J: soil sodicity and K: Texture.

6-Calculataing the Security Index (BI) according to the following equation (Eq. 2):

Security Index (BI) = A/100 × B/100 × C/100…………Eq. (2)

Where, A: moisture availability, B: water quality, and C: production of crop residue biomass.

7-Calculataing the Protection Index (CI) according to the following equation (Eq. 3):

Protection Index (CI) = A/100 × B/100 × C/100………Eq. (3)

Where, A: erosion hazards, B: flood hazards and C: cropping system.

8-Calculataing the Economic Viability Index (DI) according to the following equation (Eq. 4):

Economic Viability Index (DI) = A/100 × B/100 × C/100 × D/100 × E/100 × F/100 ×G/100………Eq. (4)

Where, A:benefit/cost ratio, B: percentage of off-farm income, C: farm-gate price, D: farm labor availability, E is farm-size, F: farm-credit availability, and G: percentage of farm-produce sold in market.

9-Calculataing of the Social Acceptability Index (EI) according to the following equation (Eq. 5):

Social acceptability Index (EI) = A/100 × B/100 × C/100 × D/100 × E/100 × F/100 × G/100……………….Eq. (5)

Where, A: Land tenure, B: support for extension services, C: health and educational facilities, D: percentage of subsidy for conservation packages, E: training of farmers on soil and water conservation, F: availability of agro-inputs within 5-10 km range, and G: village road access to main road.

10-After preparation, the spatial analysis function in ArcGIS 10.3 was used to create thematic layers of the most constraining factors.

11-SLMI was calculated for the different mapping units according to the following equation (Eq. 6):

Sustainable Land Management index (SLMI) = AI×BI×CI×DI×EI……………………Eq.(6)

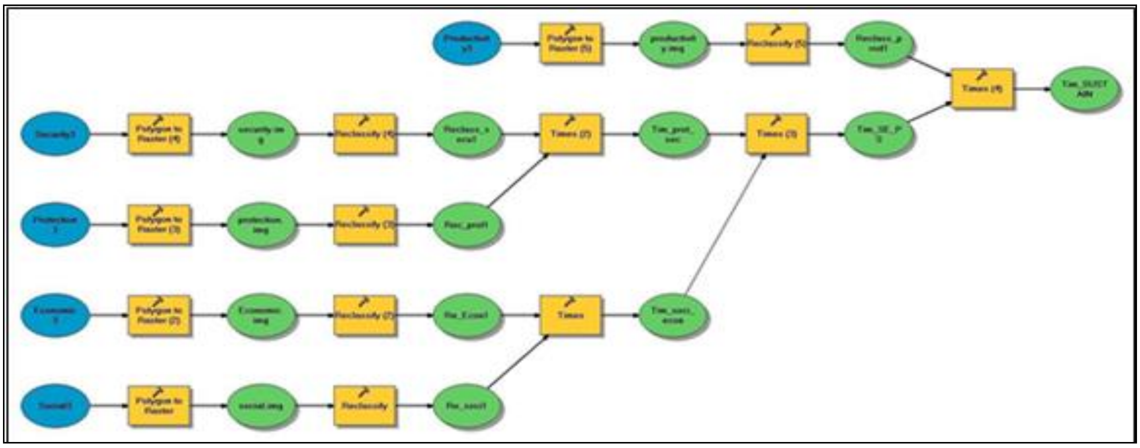

Fig. 3. Model of the Sustainable Land Management Index (SLMI).

Assessment of productivity index (AI).

Productivity is the quantity of yield from agricultural operations (Moghanm, 2015). Table 2 shows characteristics of the productivity indicators on mapping unit level. The parametric evaluation system of the index is given in Table 3. Each indicator has a scale of 0.0 to 1.0. The resultant index of productivity lies between 0.32 and 1.00. Figure 4 shows that, soil productivity index in the flood plain (L, O, B1, B2, R1, R2, and R3 mapping units) except for T mapping unit are of high productivity index ranging between 0.6 and 1.0 and representing (class I). The Aeolian plain (S mapping unit) and T mapping unit of the flood plain are of moderate productivity index ranging between 0.3–0.6 and representing (class II). The main reasons for a decrease in soil productivity index are salinity values, cation exchange capacity CEC as well as the decrease of relative yield, available nutrients and adequate management observed during the several visits made during survey.

Table 2. Productivity characteristics of the studied soil mapping units.

Mapping unit	Relative yield % (A)	Nutrient availability						Oxygen availability (Depth to water table (cm) (H)	Salinity EC (dS/m) (I)	Sodicity ESP (J)	Texture (K)
		Organic matter g/kg (B)	pH 1:2.5 (C)	CEC cmolc/kg soil (D)	N mg/kg (E)	P mg/kg (F)	K mg/kg (G)				
L	0.96	20.43	7.23	50.35	90.33	14.05	281.91	100	5.72	10.12	Silty clay
O	0.95	18.02	7.57	54.12	96.71	15.52	319.22	120	1.67	6.67	Clay
B1	0.92	15.56	7.76	45.53	67.00	11.73	255.06	70	4.76	8.56	Clay
B2	0.90	11.62	7.57	42.65	54.87	7.54	235.60	110	0.88	2.74	Silty clay loam
R1	0.90	10.75	7.66	49.31	87.35	10.08	152.54	100	11.05	9.28	Clay
R2	0.88	13.18	7.42	38.03	80.70	15.17	170.60	115	7.54	11.37	Clay loam
R3	0.93	9.65	7.68	43.50	76.62	10.56	145.13	120	2.61	5.93	Clay loam
T	0.77	3.43	7.92	13.74	28.20	4.19	96.28	150	3.36	7.85	Sand
S	0.68	2.08	7.85	11.64	21.38	5.72	80.83	150	21.56	13.01	Sand

Table 3. Assessment of Productivity Index of the study area.

Mapping unit	Relative yield % (A)	Nutrient availability						Oxygen availability (Depth to water table (cm) (H)	Salinity EC (dS/m) (I)	Sodicity ESP (J)	Texture (K)	Productivity Index (AI)
		Organic matter g/kg (B)	pH 1:2.5 (C)	CEC cmolc/kg soil (D)	N mg/kg (E)	P mg/kg (F)	K mg/kg (G)					
L	100	100	100	100	100	100	100	100	95	95	95	0.86
O	100	100	100	100	100	100	100	100	100	100	100	1.00
B1	100	100	100	100	95	100	100	95	95	100	100	0.86
B2	100	100	100	100	95	95	95	100	100	100	95	0.86
R1	90	95	100	100	100	100	95	100	90	100	100	0.73
R2	90	100	100	100	100	100	95	100	95	95	95	0.73
R3	100	90	100	100	100	100	95	100	100	100	95	0.81
T	90	90	100	95	85	90	95	100	100	100	90	0.50
S	80	90	100	90	85	90	90	100	85	95	90	0.32

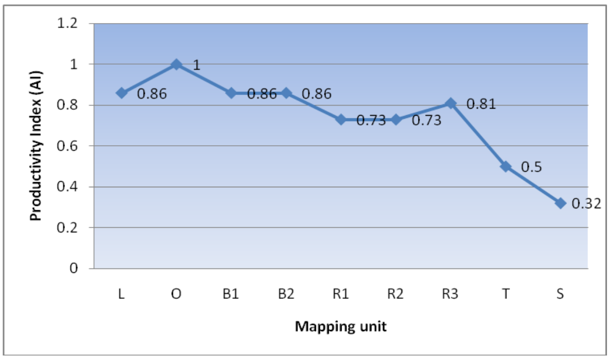

Fig. 4. Productivity Index in El-Minufiya Governorate.

Assessment of Security and protection indices (BI and CI).

Table 4 shows characteristics of the security and protection indicators on mapping unit level. The parametric evaluation system of the two indices was given in Table 5.Each indicator has a scale of 0.0 to 1.0. Figures 5 and 6 show that, security and protection practices in the flood plain (L, O, B1, B2, R1, R2, R3 and T mapping units) meet the requirements of sustainability ranging between 0.64 and 1.00 and representing (class I).

Table 4. Security and protection characteristics of the studied soil mapping units.

Mapping Unit	a- Security			b- Protection		
	Moisture availability day/year (A)	Water quality dS/m (B)	Biomass % (C)	Erosion hazards Observed (A)	Flooding hazards observed (B)	Cropping system observed in the field (C)
L	365	0.88	> 50 % > 3 years	No evidence	No flooding	Double cropping with hedge row
O	365	0.47	> 50 % > 3 years	No evidence	No flooding	Double cropping with hedge row
B1	365	0.66	> 50 % > 3 years	No evidence	No flooding	Double cropping with hedge row
B2	365	0.58	> 50 % > 3 years	No evidence	No flooding	Double cropping with hedge row
R1	365	0.86	> 50 % > 3 years	No evidence	No flooding	Double cropping with hedge row
R2	365	1.04	> 50 % > 3 years	No evidence	No flooding	Double cropping with hedge row
R3	365	0.70	> 50 % > 3 years	No evidence	No flooding	Double cropping with hedge row
T	220	0.53	< 50 % > 3 years	No evidence	No flooding	Double cropping without hedge row
S	200	1.23	< 50 % > 3 years	5 cm ripples (by wind)	No flooding	Mono cropping without hedge row

Table 5. Assessment of security and protection Indexes of the study area.

Mapping Unit	a- Security			Security Index (BI)	b- Protection			Protection Index (CI)
	Moisture availability day/year (A)	Water quality dS/m (B)	Biomass % (C)		Erosion hazards Observed (A)	Flooding hazards observed (B)	Cropping system observed in the field (C)	
L	100	90	100	0.90	100	100	100	1.00
O	100	100	100	1.00	100	100	100	1.00
B1	100	100	100	1.00	100	100	100	1.00
B2	100	100	100	1.00	100	100	100	1.00
R1	100	90	100	0.90	100	100	100	1.00
R2	100	90	100	0.90	100	100	100	1.00
R3	100	100	100	1.00	100	100	100	1.00
T	80	100	80	0.64	100	100	80	0.80
S	70	90	80	0.50	70	100	70	0.50

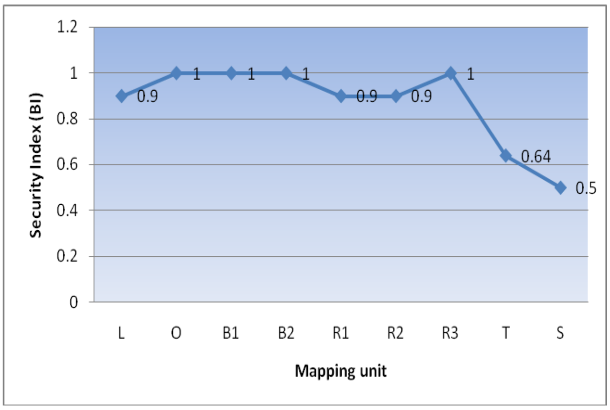

Fig. 5. Security Index in El-Minufiya Governorate.

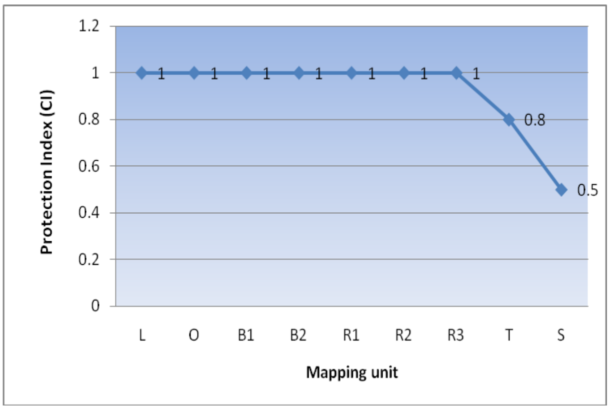

Fig. 6. Protection Index in El-Minufiya Governorate.

On the other side, security and protection indices of the Aeolian plain (S mapping unit) are marginally above the sustainability threshold where their indices are 0.50 (class II). This may be due to moisture and biomass stress, erosion hazard and the unsuitable cropping system.

Assessment of economic viability index (DI).

Table 6 shows characteristics of the economic viability indicators on mapping unit level. The parametric evaluation system of the index was given in Table 7. Each indicator has a scale of 0.0 to 1.0. Figure 7 shows that, the economic viability index ranged from 0.47 to 0.90. Economic viability practices in all flood plain mapping units except for T mapping unit meet the requirements of sustainability ranging between 0.60 and 1.00 and representing (class I). On the other hand, economic viability index of the Aeolian plain (S mapping unit) and T mapping unit of the flood plain are marginally above the threshold of sustainability ranging between 0.30 and 0.60 (class II), that may be due to suffering from lack of markets, however there is a very big difference between farm gate price and the nearest main mark*et al*so benefit cost ratio is difference.

Tables 6. Economic viability characteristics of the studied mapping units.

Mapping unit	Benefit cost ratio (A)	Percentage of off-farm income % (B)	Difference between farm gate price and nearest main market price% (C)	Availability of farm labour man/feddan (D)	Size of farm holding (ha) (E)	Percentages of available farm credit % (F)	Percentage of farm produce sold in market % (G)
L	1.86	53.61	13.4	2	0.33.	80.0	100.0
O	1.94	45.26	22.5	3	0.50	70.0	90.0
B1	1.90	22.50	17.4	4	1.27	90.0	80.0
B2	1.82	40.03	52.5	2	0.35	100.0	100.0
R1	1.78	35.34	9.3	4	0.16	45.0	75.0
R2	1.90	59.50	15.1	3	1.67	80.0	95.0
R3	1.87	36.71	18.7	3	0.52	55.0	85.0
T	1.53	20.62	10.3	2	0.20	20.0	80.0
S	1.28	36.00	16.8	4	2.76	20.0	75.0

Table 7. Assessment of economic viability Index of the study area.

Mapping unit	Benefit cost ratio (A)	Percentage of off-farm income % (B)	Difference between farm gate price and nearest main market price% (C)	Availability of farm labour man/feddan (D)	Size of farm holding (ha) (E)	Percentages of available farm credit % (F)	Percentage of farm produce sold in market % (G)	Economic Viability Index (DI)
L	100	100	100	90	80	100	100	0.72
O	100	100	90	100	90	100	100	0.81
B1	100	90	90	100	100	100	100	0.81
B2	100	100	80	90	80	100	100	0.58
R1	100	100	100	100	80	90	100	0.72
R2	100	100	90	100	100	100	100	0.90
R3	100	100	90	100	90	100	100	0.81
T	90	90	100	90	80	80	100	0.47
S	80	100	90	100	100	80	100	0.58

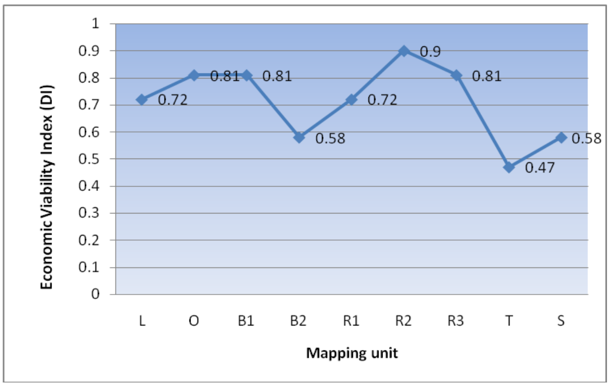

Fig. 7. Economic Viability Index in El-Minufiya Governorate.

Assessment of social acceptability index (EI).

Table 8 shows characteristics of the social acceptability indicators on mapping unit level. The parametric evaluation system of the index was given in Table 9. Each of these seven indicators is on a scale from 0.0 to 1.0. Figure 8 shows that, the social acceptability index in the flood plain is higher, where it realized the value of 1.00, meeting the sustainability requirements (class I). The social acceptability index in the Aeolian plain is marginally above the threshold of sustainability (class II), where their social acceptability index is 0.37.

Table 8. Social acceptability characteristics of the studied soil mapping units.

Mapping Unit	Land Tenure (A)	Support for extension Service (B)	Health and educational facilities in village (C)	Percentage of subsidy for conservation packages (D)	Training of farmers on soil and water conservation (E)	Availability of agro-input within 5-10 km range (F)	Village road access to main road (G)
L	Full ownership	Moderate support	Adequate	57.0	Somewhat sufficient training	Available	Full access
O	Full ownership	Full support	Adequate	71.0	Somewhat sufficient training	Available	Full access
B1	Full ownership	Full support	Adequate	36.0	Sufficient training	Available	Full access
B2	Full ownership	Full support	Adequate	45.0	Somewhat sufficient training	Available	Full access
R1	Full ownership	Full support	Adequate	52.0	Somewhat sufficient training	Available	Full access
R2	Full ownership	Moderate support	Adequate	65.0	Sufficient training	Available	Full access
R3	Full ownership	Moderate support	Adequate	50.0	Somewhat sufficient training	Available	Full access
T	Full ownership	Full support	Adequate	43.0	Somewhat sufficient training	Available	Full access
S	Full ownership	Low support	Shortage	27.0	No training	Not available	Limited access

Table 9. Assessment of social acceptability Index of the study area.

Mapping Unit	Land Tenure (A)	Support for extension Service (B)	Health and educational facilities in village (C)	Percentage of subsidy for conservation packages (D)	Training of farmers on soil and water conservation (E)	Availability of agro-input within 5-10 km range (F)	Village road access to main road (G)	Social Acceptability Index (EI)
L	100	90	100	100	100	100	100	0.90
O	100	100	100	100	100	100	100	1.00
B1	100	100	100	90	100	100	100	0.90
B2	100	100	100	90	100	100	100	0.90
R1	100	100	100	100	100	100	100	1.00
R2	100	90	100	100	100	100	100	0.90
R3	100	90	100	90	100	100	100	0.81
T	100	100	100	90	100	100	100	0.90
S	100	80	90	90	80	80	90	0.37

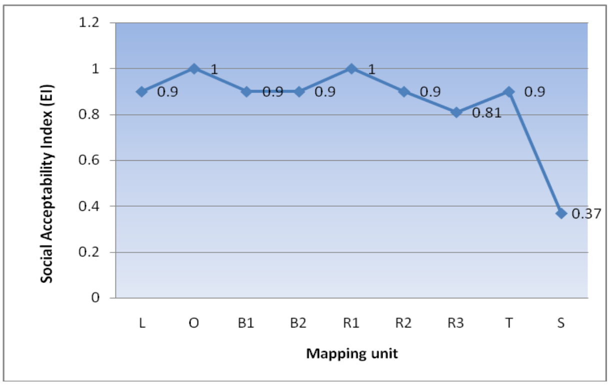

Fig. 8. Social acceptability index in El-Minufiya Governorate.

The low score value of the social acceptability index is mainly due to the shortage in health and educational facilities in the villages and lack of training allocated for the land users on soil and water conservation.

Overall sustainable land management assessment.

The study is based on SLM model and the SLM indices (productivity, security, protection, economic viability and social acceptability). Mathematical formula expressing SLMI as a resultant of the various criteria as shown in equation (6). Each index is valued on a scale from 0.0 to 1.0. Thus, the 5 indices are multiplied by one-another. The resultant index of SLM also lying between 0.0 and 1.0. Tables 10 and 11 show values of the factors of SLMI, parametric evaluation system and distribution of sustainable land management index of the study area.

Table 10. Sustainability evaluation on the studied soil mapping units.

Mapping unit	Five indices					Overall Sustainable Land Management Index (SLMI) and class	
	Productivity Index (A)	Security Index (B)	Protection Index (C)	Economic Viability Index (D)	Social acceptability Index (E)	Index	Class
L	0.86	0.90	1.00	0.72	0.90	0.50	II
O	1.00	1.00	1.00	0.81	1.00	0.81	I
B1	0.86	1.00	1.00	0.81	0.90	0.63	I
B2	0.86	1.00	1.00	0.58	0.90	0.49	II
R1	0.73	0.90	1.00	0.72	1.00	0.47	II
R2	0.73	0.90	1.00	0.90	0.90	0.53	II
R3	0.81	1.00	1.00	0.81	0.81	0.53	II
T	0.50	0.64	0.80	0.47	0.90	0.11	III
S	0.32	0.50	0.50	0.58	0.37	0.02	IV

Table 11. Distribution of SLMI in the study area.

Sustainable Land Management Index (SLMI) Rating	Class	Mapping unit	Area (ha)	Area %
0.6-1.0	I	O and B1	52333.0	24.1
0.3-0.6	II	L, B2, R1, R2 and R3	104991.0	48.3
0.1-0.3	III	T	642.0	0.3
0.0-0.1	IV	S	36255.0	16.7

Figure 9 shows that, sustainable land management in the investigated area fall into four sustainability classes, which assess the degree of agriculture sustainability. Class I, II and III exist in the flood plain soils, while class IV exists in the Aeolian plain.

Most of El-Minufiya area 72.4% (157324 ha) consists of excellent and good classes (I and II) in terms of land management practices amply meeting sustainability requirements: L, O, B1, B2, R1, R2 and R3 mapping units of flood plain. A portion of 0.3% (642 ha) of study area has average class (III) in terms of land management practices markedly short of meeting sustainability requirements: T mapping unit of flood plain. The remaining 16.7% (36255 ha) has extremely low sustainability (IV) in terms land management practices and does not meet sustainability: S mapping unit of aeolian plain. Sustainable land management classes of the area vary from "I" to "IV" due to different limiting factors. The limiting factors are soil texture, organic matter, cation exchange capacity, nutrients content and relative yield. Map of sustainable land management index is shown in Figure 10 using GIS.

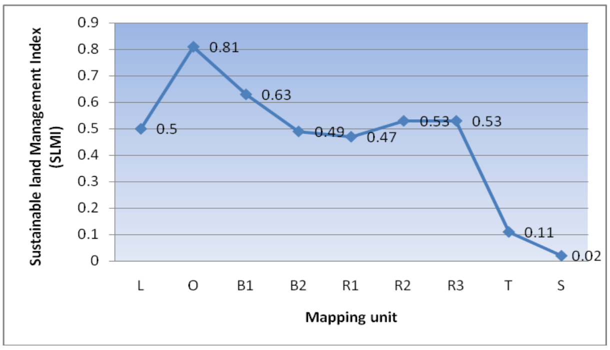

Fig. 9. Sustainable Land Management Index (SLMI) in El-Minufiya Governorate.

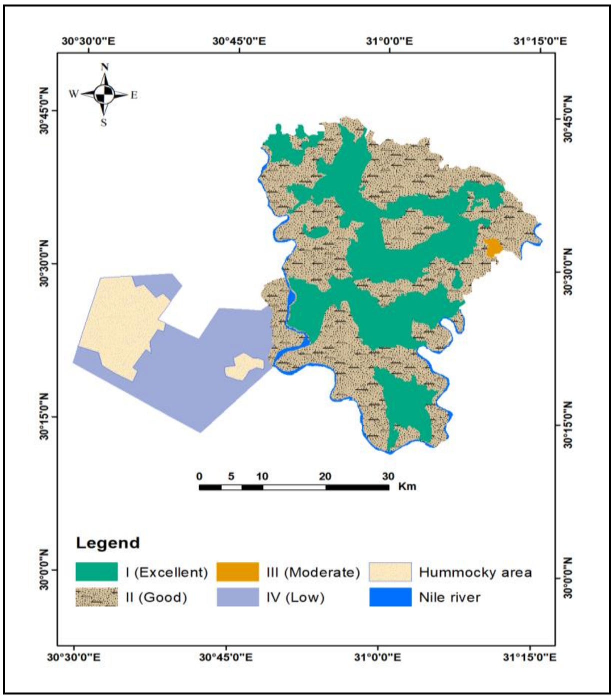

Fig. 10. Map of Sustainable land management index of El-Minufiya Governorate.

CONCLUSION

The main objective of this study is to use GIS to produce a model of Sustainable Land Management Index (SLMI), depending on five factors (productivity, security, protection, economic viability and social acceptability). This study found that more than 72% of El-Minufiya Governorate achieved sustainability, while 25.5% of the area did not. Achieving sustainable land management in the agricultural land of El-Minufiya Governorate is accompanied by many obstacles which could be cited as follows: 1- deterioration of land and water quality; 2- rapid population growth in El-Minufiya and effects on the economy and society aspects; 3- fragmentation of the farm; and 4- use insufficient credits. Therefore, sustainable agriculture in El-Minufiya Governorate requires much more governmental and public efforts through: 1- use of effective management of soil and water; 2- Attention to social and economic factors; 3- Educate farmers to improve agricultural productivity and 4- Using of precision agriculture as a technique maximize agricultural yield.

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استخدام نموذج إدارة التربة المستدامة لتقييم مؤشر الاستدامة فى محافظة المنوفية، مصر.

هبة شوقى عبدالله راشد

قسم الأراضى و المياه- كلية الزراعة- مشتهر- جامعة بنها- مصر.

هذة الدراسة تهدف إلى تقييم تقدير دليل إدارة التربة المستدامةSLMI فى أراضى محافظة المنوفية من خلال خمسة دلائل (دليل الإنتاجية، ودليل الأمان ، ودليل الحماية، ودليل الجدوى الاقتصادية، ودليل القبول الاجتماعى). المنطقة التى تم فحصها تقدر مساحتها بحوالى ٢١٧١٦٠ هكتار، وتقع بين دائرتى عرض ٣٠ °١٠'و ٣١ °٢٥ 'شمالا، وخطى طول ٣٠°١٠ 'و ٣٠ °٤٠ 'شرقا. ويعبر تلك المحافظة فرعى النيل دمياط ورشيد، لذلك فان الاستخدام الأساسى للأراضى فى ريف تلك المحافظة هو الزراعة. منطقة الدراسة بها شكلين أساسيين لسطح الأرض وهما السهل الفيضى والسهل الريحى، أراضى منطقة الدراسة تقع تحت رتبة واحدة وهى رتبة الاراضى الحديثة وصنفت كالتالى Typic Torrifluvents :و Vertic Torrifluvents و .Typic Torripsamments وتم حفر ١٥ قطاع أرضى لتغطية جميع الوحدات الخرائطية بالمنطقة. نموذج SLMI مصمم باستخدام الادوات الطيفية لبرنامج ال Arc GIS عن طريق التكامل بين ثلاثة عوامل وهى البيوفيزيائية و الاقتصادية-الاجتماعية و البيئية. أربعة درجات لإدارة التربة المستدامة بمنطقة الدراسة وهى الدرجة الأولى (Class I) والتى توجد فى الوحدات الخرائطية التالية: الرفوف الفيضية، الأحواض الفيضية والتى تمثل ٢٤,١% من منطقة الدراسة (٥٢٣٣٣ هكتار). والوحدات الخرائطية التالية: الأحواض التجميعية، الشرفات التهرية العالية و المتوسطة و المنخفضة ((Class IIويمثلوا نسبة ٤٨,٣ % من منطقة الدراسة (١٠٤٩٩١ هكتار). والدرجة الثالثة (Class III) وتوجد فى وحدة ظهور السلاحف وتمثل ٠,٣% من منطقة الدراسة (٦٤٢ هكتار). الدرجة الرابعة لدليل الإستدامة (Class IV) وفيها إدارة التربة لا تقابل متطلبات الإستدامة على الاطلاق وتوجد فى وحدة الفرشات الرملية وتمثل ١٦,٧% من منطقة الدراسة (٣٦٢٥٥ هكتار).