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Determination of Soil Productivity Potentials: A Case Study in El-Sharkia Governorate of Egypt

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SOIL productivity evaluation is a major concern in soil science. The current study was conducted to evaluate the productivity of soils in El-Sharkia Governorate of Egypt. The study area covers about 457586 ha. It consists of eight major physiographic units: overflow mantel (OM), overflow basin (OB), decantation basin (DB), river terrace (RT), turtle back (TB), clay flat (CF), alkali flat (AF) and sand remnant (SR). One soil profile was taken from each unit. Land productivity index (LPI) was based on parametric approaches using GIS. The Storie land productivity index (SLPI) and the Requier land productivity index (RLPI) were used taking into account soil and topographic parameters using specific formulas, productivity classification for each mapping unit. Comparisons were made between SLPI and RLPI values obtained for the selected sites. From 38.02 to 61.77 % of the total area consist of excellent and good classes (I and II) in terms of agricultural use. The average class III represents from 10.64 to 23.75% of the total area, whereas 10.97 to 17.67 % of the total area has poor class IV. The remaining of the area (2.41 % to 19.75 %) showed low values of productivity due to management practices which did not meet productivity requirements (class V and VI).

Keywords: El-Sharkia Governorate, Land productivity, Storie index, Riquier index.

Soils cover most lands of the earth, but regarding their service for humans they are a limited and largely a non-renewable resource (Blum, 2006). About 3.2 billion hectares are used as arable land, in the world which is about a quarter of the total land area (Scherr, 1999 and Davis & Masten, 2003). Agriculture is the backbone of the economy in many countries, especially the least developing ones (UNDP, 2007). Agriculture is one of the world’s most important activities supporting human life. From the beginning of civilization man used land resources to satisfy his needs. Land resources regeneration is very slow while the population growth is very fast, leading to an unbalance. Potential land use assessment is likely to be the prediction of land potential for productive land use (Fresco *et al.*, 1994 and Mirlotfi & Sargolzehi, 2013). With a majority of the world population living in rural areas in developing countries, agriculture remains a key activity for providing people the capacity to feed themselves by producing their own food or the source of employment and income to access to food supplies (Costanza *et al.,* 1992; Pearce & Warford, 1993 and Andzo-Bika & Kamitewoko, 2004). Agriculture is an important sector for sustaining growth and reducing poverty in Africa (World Bank, 2007). Only 2.5% of Egypt's land area, the Nile delta and the Nile valley, is suitable for intensive agriculture. The Nile delta is very fertile and is one of the oldest intensely cultivated areas on earth. It is very heavily populated (up to 1600 inhabitants per square kilometer) and the fertile floodplains are surrounded by deserts (Zeydan, 2005). The Nile Delta and the Nile Valley are the main contributor to food production, trading activities and national economy. During the past four decades vast areas at the desert fringes of the Nile Valley and Delta were reclaimed (El-Bagouri, 2008). The Nile Delta comprises about 63% of Egypt's fertile land (Abu Al-Izz, 1971 and Shehata, 2014).

Soil quality is a measure of the ability of soil to carry out particular ecological and plant productive functions. It reflects the combination of chemical, physical, and biological properties. Some of the soil properties are relatively more important than the others and unchangeable. Others can be changed by human activity (Blum, 2003 and Novak *et al.*, 2010). The term "soil quality" has different meanings (Blum, 1998; Wander *et al.* 2002 and Schjonning *et al.* 2004). The term soil quality encompasses both productive and environmental capabilities of the soil (Warkentin 1992; Wander *et al.* 2002 and Bone *et al.*, 2010) as well the capacity to resist and recover from degradation (Blum, 1998). Schjonning *et al.* (2004) state that "soil quality" as a term should be used when related to sustainability such as the soil productivity, impact on the environment, and effect on human health. Land quality refers to the capability of land to maintain ecosystems of high biodiversity and productivity without allowing the soil to be degraded and preventing other ecological and environmental problems (Pierzynski *et al.,* 1994; Acton and Gregorich, 1995; Dumanski and Pieri, 2000; Bouma, 2002 and Dengiz *et al.*, 2010). Soil quality has interconnections with management practices, productivity and other ecosystem aspects, showing an interdependence controlled by feedback mechanisms. It is also connected to human health since soil acts as a source and/or a pathway of disease. Management practices can directly affect productivity, and human health (Haberern, 1992; Doran, 2002 and Zornoza *et al.,* 2015). Land productivity capacity or land quality is a comprehension, and a precise concept in terms of agricultural activities. It is a measure of capability of land to perform specific functions (Devi and Kumar, 2008). Soil/land quality or productivity is the ability of soil/land to perform and to sustain crop production (Wander & Bollero 1999 and Southorn and Cattle, 2000). Agricultural land health assessment as an aggregate that considers the quality and productivity of land its environment (Dengiz & Baskan, 2009; Doran & Zeiss, 2000; Masto *et al.,* 2008 and Shearer *et al.,* 2009).

Agricultural productivity is defined in agricultural geography as well as in economics as "output per unit of input" or "output per unit of land area", and the improvement in agricultural productivity is the results of efficient use of the factors of production (Singh and Dhillion, 2002 and Dharmasiri, 2009). In terms of productivity loss land degradation is a result of mismatch between land use and land quality (Brady & Weil, 1999; Van Lynden & Kuhlman, 2003; Barrow, 2009 and Tekwa *et al.,* 2011). An increase in crop production leads to an increase in food productivity and income. An increase in food production contributes to long run household' food stability. In this context and considering the predicted adverse impacts of climate change threat to food security goal, increasing agricultural productivity is a major challenge for meeting food security (Delgado and Lopez, 1998; Dengiz, 2007; Kokoye *et al.*, 2013 and Mirlotfi & Sargolzehi, 2013). Declining soil fertility is closely linked to productivity is one of the root causes of declining per capita food production (Sanchez and Leakey, 1997). Soil fertility decline is an important cause for low productivity soil (Sanchez, 2002). The human activity is an important driving factor behind soil formation and may have positive or negative effects on soil productivity (John *et al.,* 2006). Each agricultural system entrains its own pattern of social organization (Kirch, 1994). The examination of the effect of land productivity has been based in recent years on an index of suitability of land for agriculture (Ramankutty *et al.*, 2002). To quantify soil productivity, there have been several attempts at devising systems that provide a productivity index, or rating, by means of numerical or parametric methods (Delgado and Lopez, 1998). Based on the existing and traditional methods of assessing overall soil/land productivity, Mueller *et al.* (2010) advocated a straight forward indicator based soil functional evaluation and classification. The productivity index (PI) model is a measure of soil productivity, used as an algorithm based on the assumption that crop yield is a function of root-growth, including rooting depth, which is controlled by the soil environment (Lindstrom et al., 1992). It provides a single scale on which soils may be rated according to their suitability for crop production (Ziblim *et al.,* 2012).

The current study was carried out to (i) determine soil productivity potentials in view of soil physical and chemical characteristics as the well as biodiversity factors; (ii) assess the effects of soil characteristics on soil productivity using remote sensing data; and (iii) produce soil productivity map of EL-Sharkia Governorate.

Materials and Methods

Site description

El Sharkia Governorate is located in the Eastern Nile Delta of Egypt, and is one of the governorates of East Delta. It extends between latitudes 29º 54` and 31º 12` N and longitudes 31º20` and 32º 15` E, Fig. 1. To the north of El Sharkia Governorate situated El-Manzala Lake and El-Dakahlia Governorate, while El-Kalubia is located to the west of El Sharkiaa Governorate, and is 47 miles by rail north-northeast of Cairo Governorate. At the east of El Sharkiaa Governorate located 2 Governorates of the Suez Canal Governorates: Ismailia and Port Said. It is bound by Situated on the Nile Delta in the midst of a fertile district; El-Sharkia is a centre of the cotton and grain trade of Egypt. It covers an area of 457586 ha. topographically, the elevation of the area around 13 m above the mean sea level (a.m.s.l.).

The top soil includes different types of soils. Clay and silty soils dominate the western parts of the governorate near the Nile delta, while sandy soils dominate the desert areas in the south and east. Soil in many parts of the governorate, especially the northern parts, suffers from erosion, which has led to desertification of some agricultural land in the governorate. Dameitta branch of the Nile is the western border of Sharkia Governorate and forms the main source of water. There are main irrigation canals that pass through the governorate such as Manayef Canal in the north, Bahr Moyes and Bahr Faqous in the middle and Ismailia Canal in the south. There are also major agricultural drains that pass through the governorate such as Bahr El Baqar and Mahsama Drains (ESIAF, 2010). The population of the governorate was 6,327,562 capita in 2014, in which urban population was 25% and rural population was 75% (EAD, 2014).

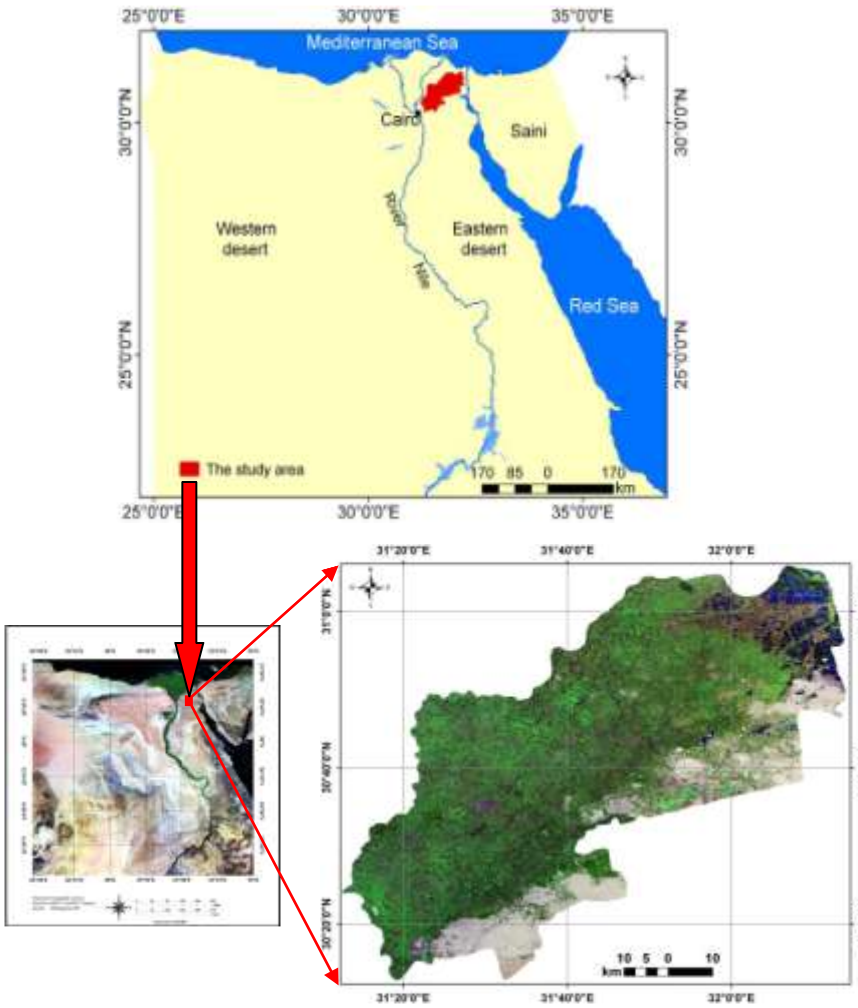
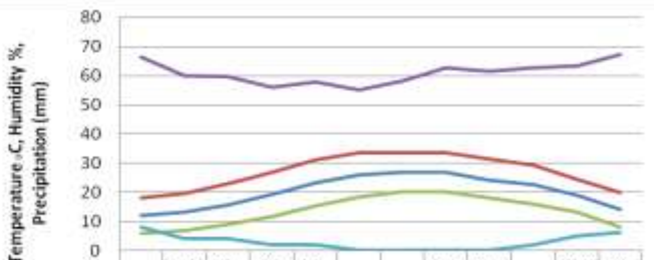


Fig. 1. Location of El-Sharkia Governorate

Climate conditions

The area is characterized by a climate of Mediterranean Sea with hot arid summer and little rain winter, the average temperature range is 13.52 °C to 26.98 °C. The highest monthly average temperature is 33.6 °C in July and August, while the lowest monthly average low temperature is 5.6 °C in January. The driest months are June, July, August, and September. The wettest months are January and February. Average annual relative humidity is 60.87 % and average monthly relative humidity ranges from 55.04 % in June to 67.42 % in December, Fig. 2 shows the climatologically diagram of El-Sharkia.



	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Daily mean Temperature (°C)	11.9	13	15.7	19.2	23.2	26	26.9	26.8	24	22.6	18.8	13.9
Max. Temperature (°C)	17.9	19.4	22.7	26.9	31.2	33.6	33.6	33.5	31.4	29.3	24.5	19.8
Min. Temperature (°C)	5.9	6.8	8.8	11.6	15.2	18.4	20.2	20.1	18	16	13.2	8
Mean humidity (%)	66.4	60.1	59.5	55.8	57.7	55	58.2	62.8	61.4	62.8	63.4	67.4
Mean Precipitation (mm)	8	4	4	2	2	0	0	0	0	2	5	6

Source: Climate-Data.org.(2013).

Fig. 2. Climate graph and climate table of El-Sharkia Governorate

Geology and geomorphology

Land of the Governorate belongs to the late Pleistocene which is represented by the deposits of the Neonile which lowering its course at a rate of 1m/1000 years (Said, 1993). There are three major geomorphic units in east of Nile Delta, namely: young deltaic plain, old deltaic plain, young Aeolian deposits, and Lacustrine plain (EI-Fayoumy, 1968 and Mohamed, 2006). The aquifer south of El-Sharkia Governorate is a part from the main Quaternary aquifer system of the Nile Delta. It consists of thick layers of graded sand and gravel intercalated by clay lenses. The thickness of this aquifer increases towards the north and northwest directions. It directly rests on the Miocene hard limestone. The aquifer is covered by a layer of clay-silt deposits, which acts as a semi-pervious aquitard of thickness ranging from 5m to 9m (Attia, 1985).

Hydrogyology

A cross-sections was constructed to reveal the subsurface Quaternary aquifer system (Fig. 3), where it was classified based on the lithologic faices variation into three zones; the top Holocene clay cap, which is composed of clay, Nile silt and sandy clay. It acts as an aquitard for the aquifer. This Holocene cap layer is underlain by the Late Pleistocene aquifer, which consists of fluviatile and fluviomarine sand with intercalations of clayey sand. This layer overlies the Early Pleistocene aquifer, which consists of coarse quartizitic sands with cherty and flinty pebbles (Elewa *et al.,* 2013).

Satellite data processing

Digital image processing of Landsat 7.0 ETM^+ satellite images dated to year 2014 was executed using ENVI 4.7 software (ITT, 2009). 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).

Soil classification

According to Egyptian Meteorological Authority (1996), and the USDA (2010), the soil temperature regime of the studied area is defined as thermic and soil moisture regime as torric. Soils could be classified under two soil orders, Aridisols and Entisols.

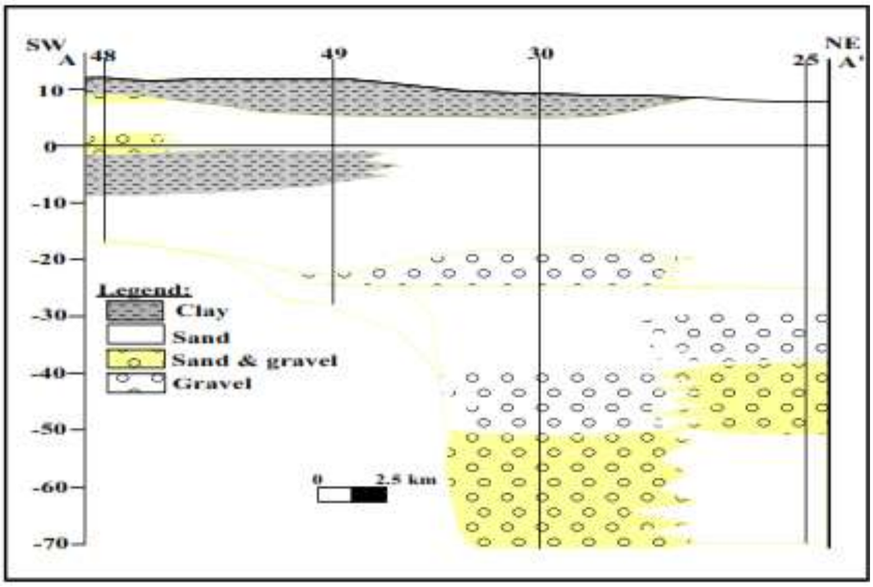


Fig. 3. Geological cross section (after RIGW, 1980)

Soil survey and field work

A semi detailed survey was carried out throughout the investigated area in order to gain an appreciation on soil patterns, land forms and the landscape characteristics. One profile pit was dug at each of the major soil types, since these soils have been identified as benchmark soils. Eight soil profiles were observed and the morphological features were outlined according to the **FAO (2006)**. Soil samples were taken from the pedogenic horizons or layers of the profiles for laboratory analysis.

Soil laboratory analyses

Soil samples were air-dried in the laboratory ground and sieved through a 2 mm sieve.

Physical analyses

Particle size distribution was determined according to USDA (2004).

Chemical analyses

Electric conductivity (EC), soluble cations and anions, organic matter, pH, exchangeable sodium percent, macro nutrients (NPK) and CEC were determined according to Bandyopadhyay (2007).

Soil productivity index

Productivity potential of the representative soil profiles were assessed by applying the mathematical models proposed by Storie (1978) and Riquier *et al.* (1970).

Storie Land Productivity Index (SPI)

The Storie Land Productivity Index (SLPI) was estimated for the different mapping units of the study area using the model produced by Storie (1978) as:

$$SLPI (\%) = (Factor\ A/100) \times (Factor\ B/100) \times (Factor\ C/100) \times (Factor\ X/100) \times 100$$

where SLPI is the Storie Land Productivity Index, A is the soil profile group, B is the surface texture, C is the slope/gradient, and X is the dynamic properties like drainage, soil reaction, fertility level, erosion etc.

Each factor is rated on a scale from 0 to 100, the actual percentages being multiplied by each other. Storie Index ratings were previously a score between the numbers 0 to 100.

Storie Index Rating System (SIRS)

The Storie Index Rating System ranks soil characteristics according to their suitability for agriculture from Grade 1 soils (80 to 100 rating), which have few or no limitations for agricultural production, to Grade 6 soils (less than 10 rating), which are not suitable for agriculture. Under this system, soils deemed less than prime can function as prime soils when limitations such as poor drainage, slopes, or soil nutrient deficiencies are partially or entirely removed. The six grades, ranges in index rating, and definition of the grades, as defined by the NRCS (2007), are provided below in Table1.

TABLE 1. NRCS Storie Productivity Index Rating System

Grade	Index Rating	Definition
I – Excellent	**80 through 100**	Soils are well suited
II – Good	**60 through 79**	Soils are good agricultural soils, although they may not be so desirable as Grade 1 because of moderately coarse, coarse, or gravelly surface soil texture; somewhat less permeable subsoil; lower plant available water holding capacity, fair fertility; less well drained conditions, or slight to moderate flood hazards, all acting separately or in combination.
III – Fair	**40 through 59**	Soils are only fairly well suited to general agricultural use and are limited their use because of moderate slopes; moderate soil depths; less permeable subsoil; fine, moderately fine or gravelly surface soil textures; poor drainage; moderate flood hazards; or fair to poor fertility levels, all acting alone or in combination.
IV – Poor	**20 through 39**	Soils are poorly suited. They are severely limited in their agricultural potential because of shallow soil depths; less permeable subsoil; steeper slope; or more clayey or gravelly surface soil textures than Grade 3 soils, as well as poor drainage; greater flood hazards; hummocky micro-relief; salinity; or fair to poor fertility levels, all acting alone or in combination.
V – Very Poor	**10 through 19**	Soils are very poorly suited for agriculture, are seldom cultivated and are more commonly used for range, pasture, or woodland.
VI – Nonagricultural	**Less than 10**	Soils are not suited for agriculture at all due to very severe to extreme physical limitations, or because of urbanization.

Source: NRCS, 2007.

Riquier Land Productivity Index (RLPI)

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

$$RLPI = (H/100) \times (D/100) \times (P/100) \times (T/100) \times (S/100) \times (O/100) \times (A/100) \times (M/100) \times 100$$

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.

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 2.

TABLE 2. Class and rating limit of actual soil productivity (P) and potential soil productivity (P/) indices

P	P/	Rating	Class
1	I	65-100	Excellent
2	II	35-64	Good
3	III	20-34	Average
4	IV	8-19	Poor
5	V	0-7	Extremely Poor to Nil

Results and Discussion

Geomorphologic features and soils

The geomorphologic units were identified by analyzing the landscape extracted from satellite imagery with the aid of Digital Elevation Model (DEM). The geomorphology map of the investigated area (Figure 4) shows three main landscapes as follows:

1) Flood plain containing overflow mantle (OM), overflow basin (OB) and decantation basin (DB), river terrace (RT) and turtle back (TB). The soils in this landform were classified into Vertic Torrifluvents, Typic Torrifluvents and Typic Torripsamments.
2) Fluvio-lacustrine plain with five landforms; clay flat (CF) and alkali flat (AF). The soils in this landform were classified into Typic Natriargids and Typic Aquisalids.
3) Aeolian (Marine) plain including sandy remnants (SR). The soils in this landform were classified as Typic Torripsamments. The obtained results, as shown in Table 3.

Soil productivity potentials

Accurate estimates of future soil productivity are essential in making agricultural policy decisions. The Storie index and the Riquier index (Gantzer and McCarty, 1987), are the main systems in determining land productivity.

Storie Land Productivity Index (SPI)

The productivity potential of soil was determined by following the revised Storie Index Soil Rating Procedure (Storie, 1978). The Storie Index is a soil rating based on soil properties that govern a soil's potential for cultivated agriculture. The Storie Index assesses the productivity of a soil based on the degree of soil profile development, texture of the surface layer, slope, and manageable features.

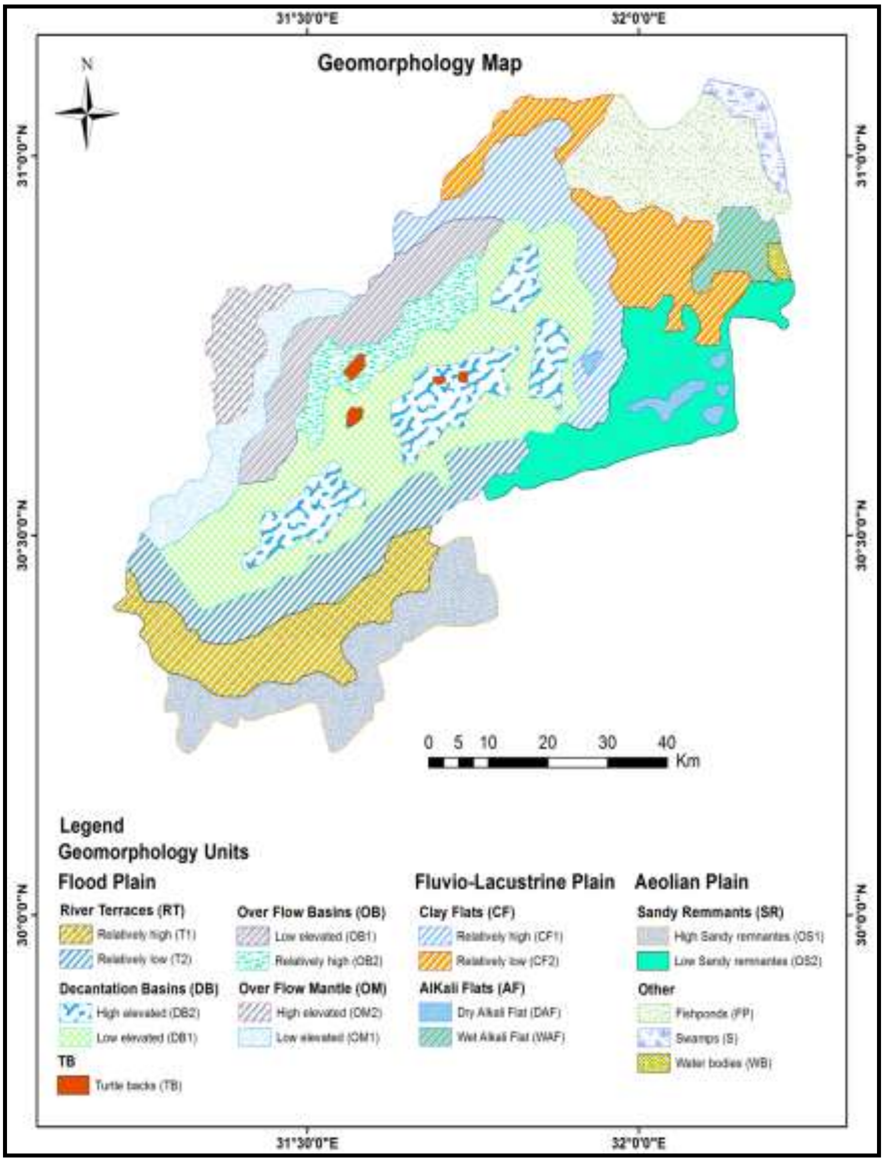


Fig. 4. Geomorphologic map of the study area

TABLE 3. Landforms and soils of the investigated area

Landscape	Relief	Landform	Mapping unit	Profile No.	Soil Classification	Area (ha)	Area %
Flood plain	**Almost flat to gently undulating**	Overflow mantle	**OM**	1	**Vertic Torrifluvents**	34658	7.60
		Overflow basin	**OB**	2	**Vertic Torrifluvents**	50712	11.10
		Decantation basin	**DB**	3	**Typic Torrifluvents**	123191	26.92
		River terrace	**RT**	4	**Vertic Torrifluvents**	73895	16.15
		Turtle back	**TB**	5	**Typic Torripsamments**	1511	0.33
Fluvio-lacustrine plain	**Almost flat to gently undulating**	Clay flats	**CF**	6	**Typic Natriargids**	48681	10.64
		Alkali flats	**AF**	7	**Typic Aquisalids**	10975	2.41
Aeolian plain	**Gently undulating**	Sandy remnants	**SR**	8	**Typic Torripsamments**	79325	17.34

Storie index model

The Storie index, interpretation criteria were modeled based on soil properties traditionally incorporated into the hand-generated Storie Index (1978). The most elements that pertain to the Storie 1978 criteria were used. Storie model uses discrete and fuzzy logic functions to obtain more precise scores for the factors associated with the index. Many of these criteria were incorporated in this model, and other factors were modified to adapt the index to a relational database. A system of interpretation generation using fuzzy logic was included within the database structure. Storie model uses fuzzy rule sets to more accurately score Factors C and X. Discrete numerical scores in combination with fuzzy logic functions were used for factor A and B. The structure organization of the Storie model is summarized in Figure 5.

Determination of Storie Land Productivity index

An area of 173903 ha (38.02% of the total) showed a rising productivity and consists of excellent and good classes (I and II). The soils are of OB and DB mapping units. An area of 108553 ha (23.75% of the total) has a fair class (III). The soils are of OM and RT mapping units. An area of 50192 ha (10.97% of the total) has poor class (IV). The soils are of CF and TB mapping units. The remaining area of 90300 ha (19.75 % of the total area) showed a reduction in productivity and consist of very poor and nonagricultural (V and VI). They are soils of SR and AF mapping units. Land productivity classes of the study area varies from “excellent” to “non-agricultural” due to different limiting factors

(Fig. 5). Some of these limiting factors are not correctable such as; soil depth and soil texture, while salinity and SAR can be corrected. The results of the of the parametric evaluation system for Storie land productivity index are given in Tables 4 to 6, and their map is shown in Figure 6 using GIS.

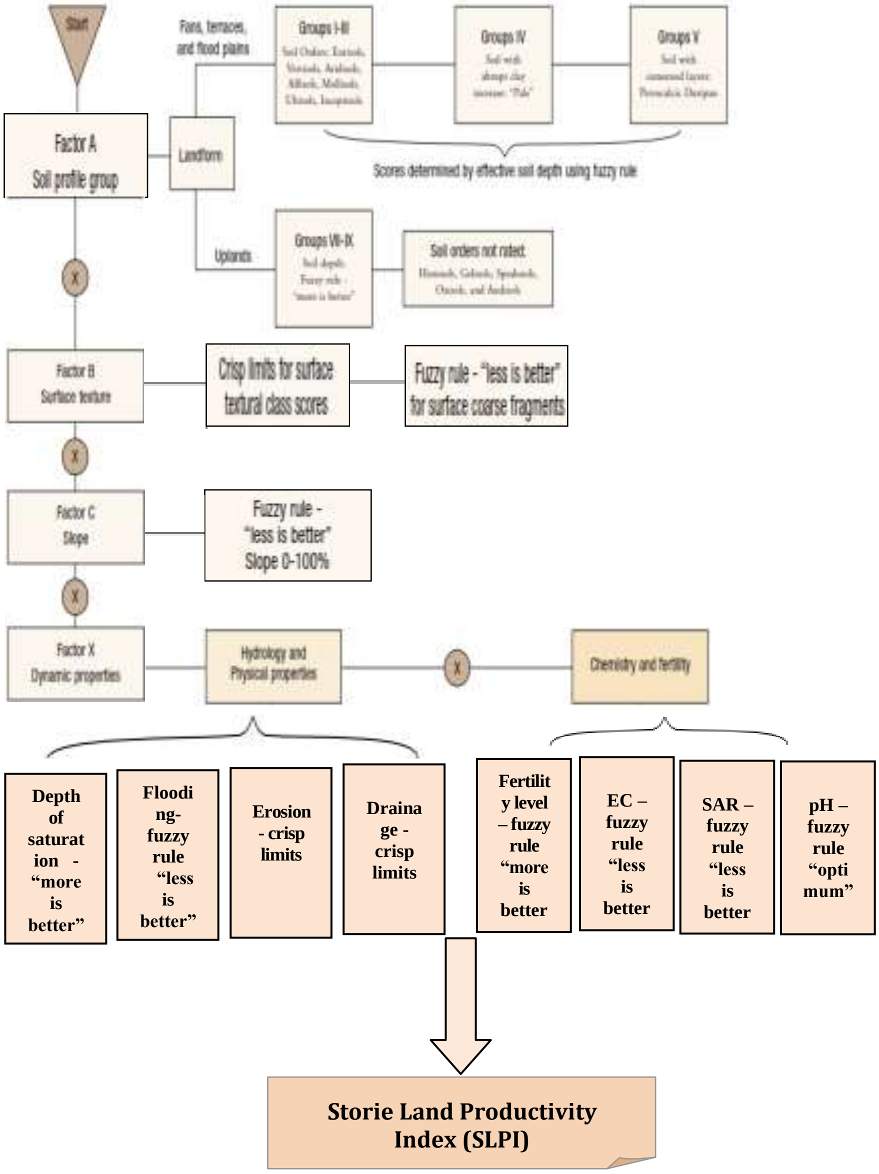


Fig. 5. Outline of the Storie index applied to (USDA NRCS, 2007)

TABLE 4. Values of the factors of Storie land productivity index of the studied soils of the investigated area

Mapping unit	Factor A Soil profile group	Factor B Surface texture	Factor C Slope %	Factor X Dynamic properties							
				Hydrologic and physical conditions				Chemical and fertility limitations			
				Depth to saturation	Drainage	Flooding frequency	Erosion	Fertility level	EC (dS/m)	SAR	pH
OM	Soil profile group A	Clay	Nearly level	120	Fairly well drained	Very rare	None to slight	High	5.73	11.12	7.64
OB	Soil profile group A	Clay loam	Nearly level	150	Well drained	Very rare	None to slight	High	3.86	4.97	7.87
DB	Soil profile group A	Clay	Nearly level	120	Well drained	Very rare	None to slight	High	1.93	7.56	8.03
RT	Soil profile group A	Clay	Nearly level	110	Fairly well drained	Very rare	None to slight	High	3.04	5.53	7.55
TB	Soil profile group A	Sand	Gently undulating	90	Well drained	None	None to slight	Very poor	2.16	8.93	7.23
CF	Soil profile group	Clay	Nearly level	100	Fairly well drained	None	None to slight	High	9.11	21.62	8.38
AF	Soil profile group A	Silty loam	Nearly level	50	Moderately waterlogged	Occasional	None to slight	Fair	33.40	34.20	8.71
SR	Soil profile group A	Sand	Gently undulating	100	Well drained	None	None to slight	Very poor	7.85	13.30	7.48

TABLE 5. Assessment of Storie land productivity index of the investigated area

Mapping unit	Factor A Soil profile group	Factor B Surface texture	Factor C Slope %	Factor X Dynamic properties								Storie Land Productivity Index	Grade
				Hydrologic and physical conditions				Chemical and fertility limitations					
				Depth to saturation	Drainage	Flooding frequency	Erosion	Fertility level	EC (dS/m)	SAR	pH		
OM	90	80	100	100	90	100	100	100	85	80	100	44.06	**III**
OB	95	95	100	100	100	100	100	100	90	100	100	81.23	**I**
DB	90	80	100	100	100	100	100	100	100	100	100	72.00	**II**
RT	85	80	100	100	90	100	100	100	90	100	100	55.10	**III**
TB	75	60	95	90	100	100	100	60	100	100	100	23.11	**IV**
CF	80	80	100	100	90	100	100	100	65	60	100	22.46	**IV**
AF	50	95	100	65	40	85	100	95	10	50	100	0.51	**VI**
SR	80	60	95	100	100	100	100	60	75	70	100	14.36	**V**

TABLE 6. Distribution of Storie Land Productivity Index of the study area

Storie Productivity Index PI (%)	Grade	Class	Mapping unit	Area (ha)	Area %
80 – 100	**I**	Excellent	**OB**	50712	11.10
60 – 79	**II**	Good	**DB**	123191	26.92
40 – 59	**III**	Fair	**OM and RT**	108553	23.75
20 – 39	**IV**	Poor	**CF and TB**	50192	10.97
10 – 19	**V**	Very poor	**SR**	79325	17.34
0-9	**VI**	Nonagricultural	**AF**	10975	2.41

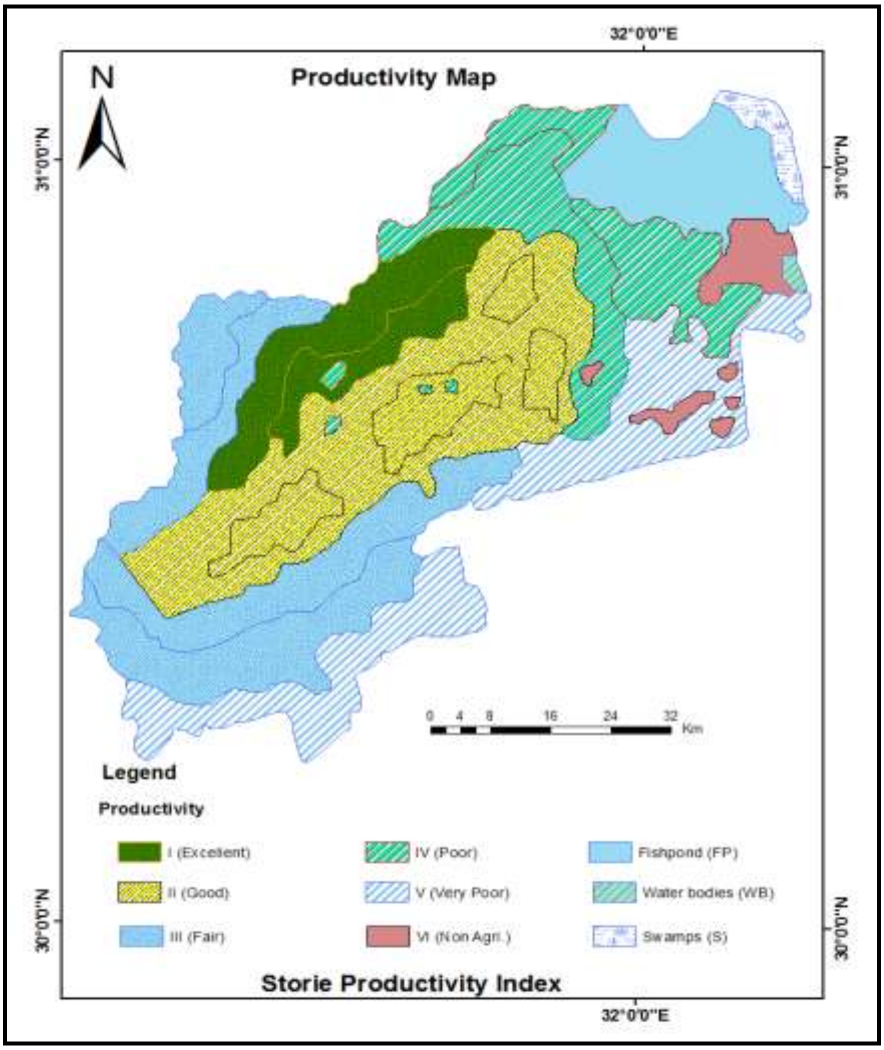


Fig. 6. Storie Productivity Index map

Riquier Land Productivity Index (RLPI)

Soil productivity is the capacity of soil in to produce a specific plant or sequence of plants under specific systems of management inputs. Riquier *et al.* (1970) described soil productivity as the initial soil capacity to produce a certain amount of crop per hectare per annum. Soil potential productivity on the other hand is the productivity of soil when all possible improvements are made. It is thus, the future potentiality of that soil taking into account physical and chemical characteristics which are modified by conservation practices or improvements and also those characteristics which are not modifiable by present day technology (Riquier *et al.,* 1970).

Riquier Index Model

In this model, interpretation criteria are modeled based on soil properties traditionally incorporate (Riquier *et al.*, 1970). The structure organization of the Riquier model is summarized in Figure 7.

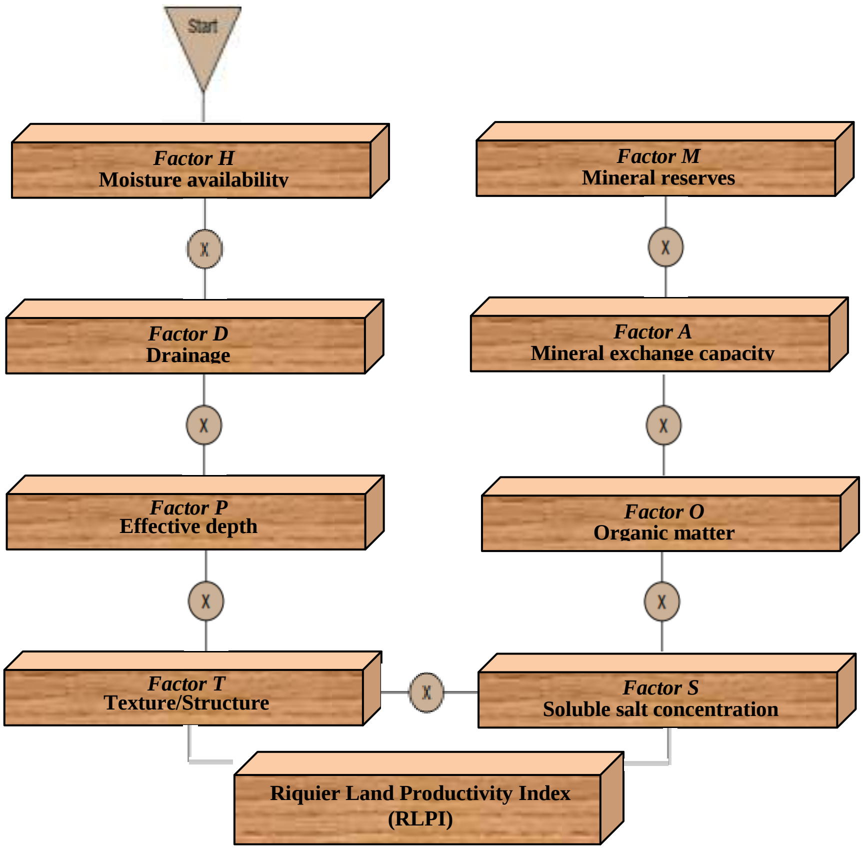


Fig. 7. Model of the Riquier Productivity Index

Determination of Riquier Land Productivity Index

While most of the study area 61.77% (282456 ha) consists of excellent and good classes (I and II) in terms of agricultural use: OB, DB, OM and RT mapping units. A portion of 10.64% (48681 ha) of study area has average (III): CF mapping unit, and 17.67% (80836 ha) has low (IV): TB and SR mapping units. The remaining 2.41% (10975 ha) has extremely low (V): AF mapping unit. This study demonstrates that more than half of El-Sharkia area has productive lands. Table shows values of the factors Requier productivity index. Land capability classes of the area varies from "excellent" to "extremely poor to nil" due to different limiting factors (Figure 7). Some of these limiting factors are not correctable such as; soil depth and soil texture, while salinity and CEC that can be corrected. The parametric evaluation system of Riquier index were given in Tables 7 to 10 , and their map is shown in Figure 8 using GIS.

TABLE 7. Values of the factors of land productivity of the studied soils of the investigated area

Mapping unit	Moisture availability	Drainage	Effective depth (cm)	Texture / structure	Soluble salt concentration (dS/m)	Organic matter content (g/kg)	Cation exchange capacity ($cmol_c/kg$)	Mineral reserve in B horizon
OM	Rooting zone below wilting point for 3 months of the year	Good drained	120	Clay	5.73	13.43	47.33	Minerals derived from basic or calcareous rocks
OB	Rooting zone below wilting point for 3 months of the year	Well drained	150	Clay loam	3.86	18.65	43.39	Sands, sandy materials or ironstone
DB	Rooting zone below wilting point for 3 months of the year	Well drained	120	Clay	1.93	24.84	55.21	Minerals derived from basic or calcareous rocks
RT	Rooting zone below wilting point for 3 months of the year	Good drained	110	Clay	3.04	16.93	53.78	Minerals derived from basic or calcareous rocks
TB	Rooting zone below wilting point for 9 months of the year	Well drained	90	Sand	2.16	3.56	6.45	Minerals derived from sands, sandy material or ironstone
CF	Rooting zone above wilting point and below field capacity for most of the year	Moderate drained	100	Clay	9.11	12.54	34.82	Basic or calcareous rocks
AF	Rooting zone below wilting point for 3 months of the year	Soil flood for 2 to 4 months of year	50	Silty loam	33.40	29.23	50.76	Sands, sandy materials or ironstone
SR	Rooting zone below wilting point for 7 months of the year	Well drained	100	Sand	7.85	4.02	5.06	Minerals derived from sands, sandy material or ironstone

TABLE 8. Soil characteristics of the investigated area

Mapping unit	Moisture availability (H)	Drainage (D)	Effective depth (P)	Texture / structure (T)	Soluble salt concentration (S)	Organic matter content (O)	Cation exchange capacity (A)	Mineral reserve in B horizon (M)
OM	H4c	D3a	P5	T5b	S2	O2	A3	M3c
OB	H4c	D4	P6	T6b	S2	O2	A3	M3a
DB	H4c	D4	P5	T5b	S1	O3	A3	M2c
RT	H4c	D3a	P5	T5b	S1	O2	A3	M2c
TB	H2c	D4	P5	T4b	S1	O1	A1	M2a
CF	H5	D2a	P5	T5b	S3	O2	A2	M3c
AF	H4c	D1b	P3	T7	S6	O3	A3	M3a
SR	H3b	D4	P5	T4b	S3	O1	A1	M2a

TABLE 9. Assessment of Requier Land Productivity Index of the study area

Mapping unit	Moisture availability (H)	Drainage (D)	Effective depth (P)	Texture / structure (T)	Soluble salt concentration (S)	Organic matter content (O)	Cation exchange capacity (A)	Mineral reserve in B horizon (M)	Riquire Productivity Index (RPI)	Grade
OM	100	80	100	80	90	90	100	100	51.84	**II**
OB	100	100	100	90	90	100	100	95	76.95	**I**
DB	100	100	100	80	100	100	100	100	80.00	**I**
RT	100	80	100	80	100	90	100	100	57.60	**II**
TB	40	100	100	50	100	85	95	85	13.73	**IV**
CF	100	40	100	80	80	90	100	100	23.04	**III**
AF	100	10	50	100	15	100	100	95	0.71	**V**
SR	60	100	100	50	50	85	90	85	9.75	**IV**

TABLE 10 . Distribution of Requier Land Productivity Index of the study area

Riquier Land Productivity Index RLPI (%)	Grade	Class	Mapping unit	Area (ha)	Area %
65 – 100	**I**	Excellent	**OB and DB**	173903	38.02
35 – 64	**II**	Good	**OM and** RT	108553	23.75
20 – 34	**III**	Average	**CF**	48681	10.64
8 – 19	**IV**	Low	**TB and SR**	80836	17.67
0 – 7	**V**	Extremely low	**AF**	10975	2.41

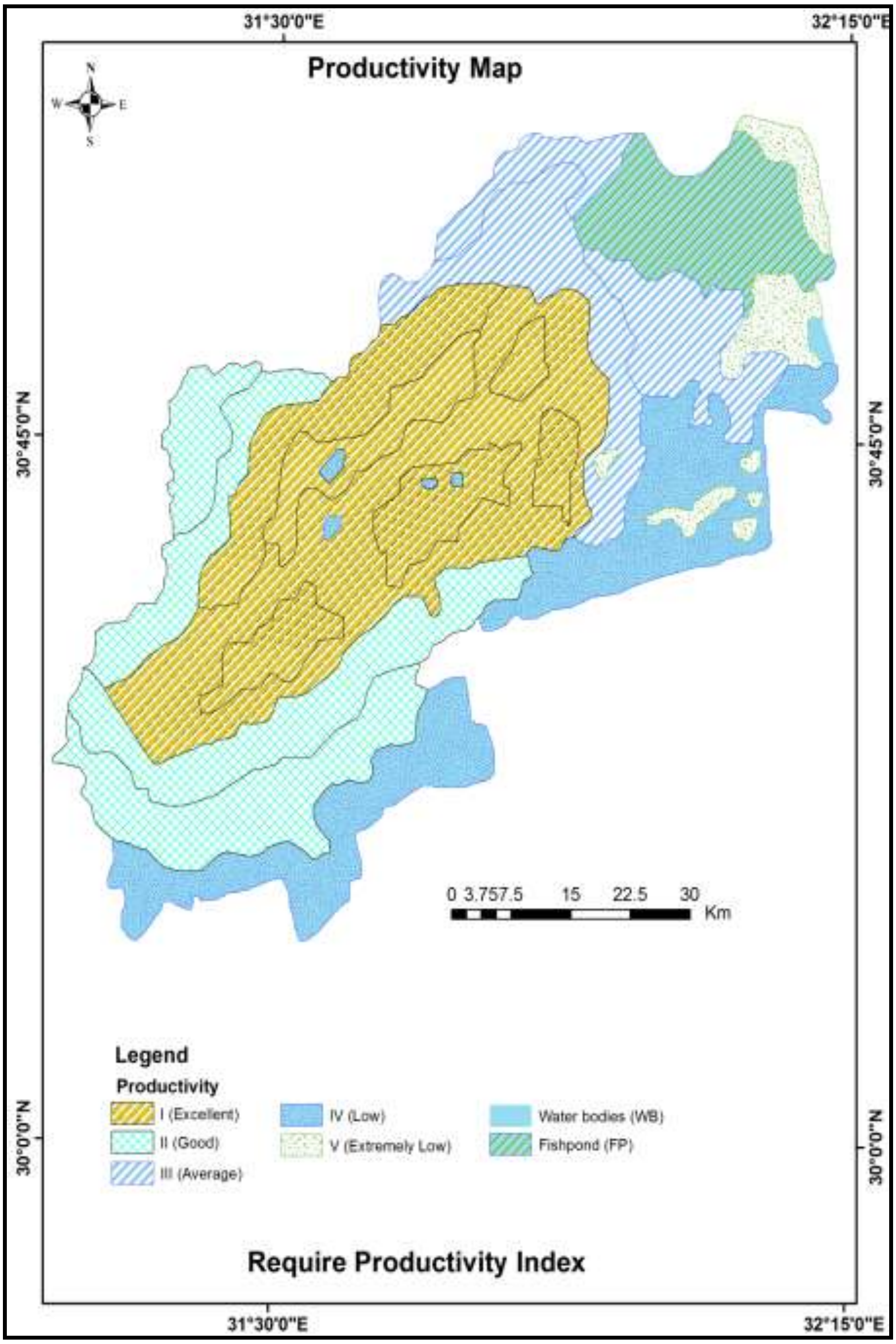


Fig. 8. Riquier Productivity Index map

Comparison between Storie and Riquier index

The changes in values of soil productivity index between Stoire (1978) and Riquire *et al.* (1970) in the different mapping units are illustrated in Table 11 and Fig. 9. The landforms of the flood plain were represented by soil profiles of 1 to 5. Soil Land Productivity Index LPI for the OM mapping unit was changed from class II to class III in Riquier and Storie Index respectively. The main factors reduced the productivity index in the OM unit are soluble salts, alkalinity and the effective soil depth. For the OB mapping unit the grade of soil productivity still class I in Storie and Riquier Index. Soils of the DB mapping unit were enhanced as the LPI value increased from 72.00 (II) in Storie Index to 80.00 (I) in Riquier Index. The enhancements of soil productivity in overflow and decantation basins indicate that the drainage network is efficient in these mapping units. The productivity index in the RT unit increased from 55.10 (III) in Storie Index to 57.60 (II) in Riquier Index. For the TB mapping unit, the grade of soil productivity is IV in Storie and as well as Riquier Index. Data in Table 3 indicate that soils as well as of the fluvio-lacustrine plain landform were represented by profiles 6 and 7. The LPI of the clay flats (CF) and alkali flats (AF) are naturally degraded as they are located near to Lake El Manzala. In the CF unit the productivity index was low in both Storie and Reqier Index (22.44 and 23.04 respectively). For the AF mapping unit the grade of soil productivity changed from class V in Requier Index to class VI in Storie Index, despite the decreased LPI from 0.71 to 0.51. The changes of soil productivity in these mapping units of (CF and AF) are mainly related to the decreased effective depth and the increment of soluble salts. Aeolian deposits of the SR mapping unit were represented by profiles 8, the productivity indexes of these profile were poor (IV) and very poor (V) in Riquier and Storie Indexes respectively; due to the low quality of the soil properties (e.g. soil texture / structure, OM, CEC). Results indicate that the LPI of the study area is mainly affected by soil salinity, alkalinity and water-logging.

TABLE 11. Change in the value of land productivity index between Storie and Riquier Index in the study area

Mapping unit	Storie Productivity Index (SPI)	Riquier Productivity Index (RPI)	Changes
OM	44.06	51.84*	±7.78
OB	81.23*	76.95	±4.28
DB	72.00	80.00*	±8.00
RT	55.10	57.60*	±2.50
TB	23.11*	13.73	±9.38
CF	22.46	23.04*	±0.58
AF	0.51	0.71*	±0.20
SR	14.36*	9.75	±4.61

*refers to the highest value

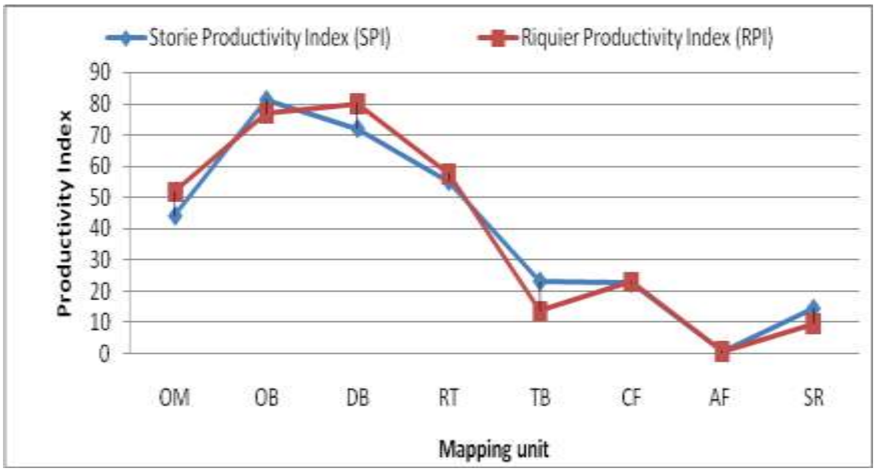


Fig. 9. Change between Storie and Riquier index in the study area

Conclusion

The agricultural productivity is influenced by a number of physico-socio-economic, institutional and organization factors among them drought and climatic conditions play vital role. The variation in productivity is well marked within the various regions and also from one region to another depending upon water availability and irrigation facility, characteristics of relief, slope, and transportation facilities, utilization of fertilizers and pesticides and soil fertility. The present crop yield levels can be increased and sustained by measurers including more efficient plant protection and proper irrigation practices. As yields increase, external inputs will be essential to maintain soil productivity. Although continued cultivation without additional external inputs leads to yield reduction, excessive use of chemicals and water could be detrimental to soil productivity.

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تحديد قدرات الأرض الأنتاجية: حالة الدراسة فى محافظة الشرقية - مصر

هبة شوقى عبدالله راشد
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تقييم إنتاجية التربة يعد الإهتمام الأعظم لعلم التربة. والدراسة الحالية تم إجرائها لتقييم إنتاجية التربة فى محافظة الشرقية – مصر. منطقة الدراسة تغطى مساحة تقدر بحوالى 457586 هكتار. وتتضمن المنطقة ثمانية وحدات فيزيوجرافية: كتف النهر الفيضى (OM) – أحواض فيضية (OB) – أحواض تجميعية (DB) – شرفات نهرية (RT) – ظهور السلاحف (TB) – السهل الطينى (CF) – السهل القلوى "السبخة" (AF) – البقايا الرملية (SR). تم أخذ قطاع أرضى من كل وحدة فيزيوجرافية. دليل إنتاجية التربة (LPI) يكون محسوب على أساس مقترحات حدودية بأستخدام نظم المعلومات الجغرافية. Storie Land Productivity Index (SLPI) وRiquier Land Productivity Index (RLPI) تم أستخدامهم فى رصد مؤشرات التربة وطبوغرافيتها بأستخدام صيغ خاصة وعمل تصنيف لإنتاجية التربة لكل وحدة خرائطية. تمت مقارنة بين قيم SLPI و RLPI المتحصل عليها للمواقع المختارة لمنطقة الدراسة. من38.02% الى 61.77% من المساحة الكلية يتبع الأقسام (I-II) الممتاز والجيد وتكون صالحة تماما للأستخدام الزراعى. والقسم الثالث المتوسط (III) يمثل 10.64% الى 23.75% من المساحة الكلية ، بينما 10.97% الى 17.67% من المساحة الكلية تتبع القسم الرابع الفقير الإنتاجية (IV). وباقى المساحة (2.41% الى 19.75%) يظهر قيم منخفضة للإنتاجية وهذا ناشئ عن ممارسات إدارة التربة التى لا تواجة متتطلبات الإنتاجية (القسم الخامس V والسادسVI).