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# GIS Modeling Incorporated with Python Programming Language to Determinate Land Productivity Index

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## ABSTRACT

In order to assess the soil productivity in the Northern section of Sohag Governorate, Egypt, a thorough soil survey conducted. For this, Thirty-four profiles, including old-cultivated, new-cultivated, and barren soils, represented three different agricultural land uses. The profiles selected, and samples taken from each horizon and examined for their physical and chemical characteristics. The Land Productivity Index (LPI) utilized to assess soil productivity. The index individually calculated by each of the earlier studies. However, this procedure takes a long time and is challenging, especially when there are many soil samples. After that, using a weighted overlay tool, create a final map of the productivity index overlay. In order to automate soil productivity, a Python program developed and used in conjunction with the Designed Land Productivity Spatial Model (DLPSM). Such a programme could managed, improved, and transferred by many users and authorities in the current Era of distinctive advancement in information technology.

***Keywords:*** Land Productivity Index (LPI), python program, Designed Land productivity spatial model (DLPSM).

## INTRODUCTION

Soil is the most valuable natural resource for any nation and the awareness about soil resource properties is a precondition for sustainable agriculture. Over 75% of the Earth's land area is already degraded, and over 90% could become degraded by 2050 (Charlet *et al*., 2018). While human demands on land are unbounded, the resource's constraints are finite. Declining agricultural yield, deterioration of the quality and quantity of the land, and competition for available land are signs of increased demand for or pressure on the land resource. While agriculture continues to release significant amounts of greenhouse gases, the effects of climate change on yields and rural livelihoods are growing (FAO, 2018). The majority of Egypt's population lives inside the banks of the Nile River, in an area of only 4% of the country's total size, where the majority of the country's fertile lands are located (CAPMAS, 2009). Egypt is a populous nation with a total area of roughly 1 million km2. Additionally, irrigated fields account for almost 95% of its agricultural output. With the Delta making up 63% of Egypt's fertile area, the Nile Delta and Nile Valley are the primary contributors to food production, trade, and the national economy (Shehata, 2014). In terms of agricultural operations, understanding and precision are two phrases that refer to the capacity of the land for productivity or the quality of the land. It could be characterized as a gauge of a land's capacity to carry out particular tasks (Devi and Kumar, 2008). Another definition given by Dengiz *et al*. (2009) is "the condition and capacity of land, including its soil, climate, topography, and biological properties, for purpose of production, conservation, and environmental management". Either a direct or in direct approach can be used to assess the land's productive capability. Direct evaluation can done through some studies in the field, greenhouse, or laboratory under specific climatic and regulated settings. Indirect evaluations involve creating and using several models of variable complexity in an effort to estimate land productivity (Dengiz, 2007). The main objective of this study is to show case a new Python program that automates soil productivity based on the methodology introduced by Riquier *et al.* (1970). The program, developed by Mustafa *et al*., is readily available on the website (http://soilhealth .pythonany where.com). Furthermore, the study employs GIS spatial analyst techniques to apply the Designed Land Productivity Spatial Model (DLPSM) in assessing the factors influencing land productivity.

## MATERIALS AND METHODS

### Site Description and Location

Sohag is one of the Governorates of Upper Egypt and bounded the northern edge of Qena Governorate and the southern edge of Assiut Governorate. It is located between latitudes 26°07′ N and 26°57′ N and longitudes 31°20′ E to 32°14′ E. The study area (Figure 1) is located at the Northen part of Sohag Governorate. The area covers a total area of approximately 715.15 km$^2$ and is generally characterized by hot summer and mild winter with low rainfall and high evaporation. There were three land uses in the area under study viz. old cultivated soils, new reclaimed soils and barren soils.

### Soil Sampling and laboratory analysis

To obtain more precise knowledge of the soil patterns and landscape characteristics, ground truth studies were carried out. Important characteristics were examined during a field survey using the FAO (2006) approach. At typical areas, soil profiles were examined and ground truth observation sites were located using a global positioning

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system (Fig. 2). The chosen locations exhibit a variety of soil types, including newly reclaimed soils, old, farmed soils, and desert terrain. Horizontally oriented soil samples were gathered, air-dried, crushed, sieved, and stored for use in analyzing the physical and chemical characteristics of the soil using the certified analytical techniques described by the USDA (2004). The analyzed parameters are clay (%), sand (%), silt (%), exchangeable sodium percentage (ESP %), organic carbon (OC %), electrical conductivity (EC dS/m), soil reaction (pH), cation exchange capacity (CEC cmol(p+)/kg) and calcium carbonate total content (%).

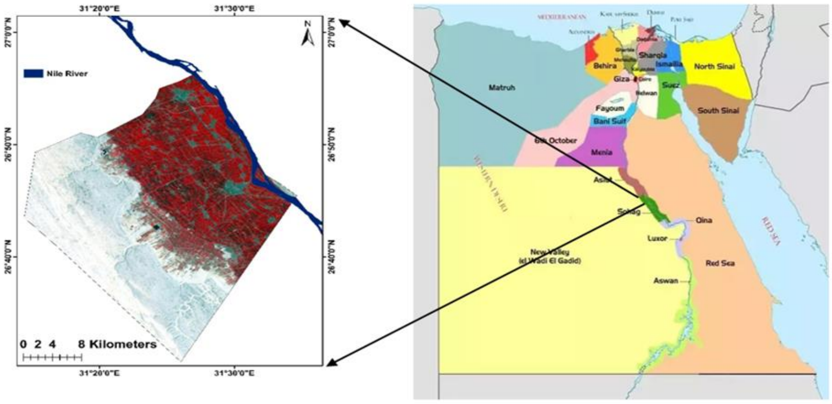


**Figure 1. Location of the study area.**

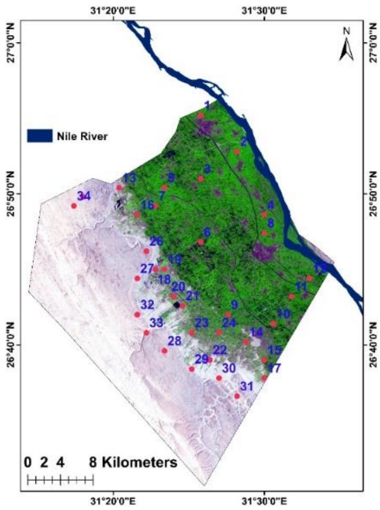


**Fig. 2. Location of the selected soil profiles**

**Productivity classification approach:**

Applying the mathematical model developed by Riquier *et al.* (1970), the productivity potential of the soil profiles was evaluated. The system suggested nine elements into account for calculation the productivity index. These elements are the following: soluble salts (S), soluble organic matter (O), CEC (A), drainage (D), effective depth (P), texture/structure (T), texture/structure (T), and mineral reserves (M). Each element is given a score between 0 and 100, and the resulting productivity index is then compared to a scale that assigns the soil to one of five productivity classes (Table 1).

**Table 1. Land productivity classes**

| Land productivity index | Definition | Symbol |
|---|---|---|
| 65-100 | Excellent | I |
| 35-64 | Good | II |
| 20-34 | Average | III |
| 8-19 | Poor | IV |
| 0-7 | Extremely poor or nill | V |

The diagnostic factors of each thematic layer were assigned values of factor rating identified in Tables 2 - 6.

**Table 2. Definition of soil moisture and organic matter**

| Soil Moisture Content (H) | | Organic matter in A1 horizon (O) | |
|---|---|---|---|
| H1 | Rooting zone below wilting point all the year round | O1 | Very little organic matter , less than 1% |
| H2 | Rooting zone below wilting point for 9 to 11 months of the year H2a:11, H2b:10, H2c:9 months. | O2 | Little organic matter, 1-2% |
| H3 | Rooting zone below wilting point for 6 to 8 months of the year H3a:8, H3b:7, H3c:6 months. | O3 | Average organic matter content,2-5% |
| H4 | Rooting zone below wilting point for 3 to 5 months of the year H4a:5, H4b:4, H4c:3 months. | O4 | High organic matter content, over 5% |
| H5 | Rooting zone above wilting point and below field capacity for most of the year | O5 | Very high content but C/N over 25 |

**Table 3. Definition of soil depth**

| Soil Depth (P) | |
|---|---|
| P1 | Rock outcrops with no soil cover or very shallow cover |
| P2 | Very shallow soil, < 30 cm |
| P3 | Shallow soil, 30- 60 cm |
| P4 | Fairly deep soil, 60-90 cm |
| P5 | Deep soil 90-120 cm |
| P6 | Very deep soil >120 cm |

**Table 4. Definition of soil drainage and reserves Weatherable mineral**

| | Drainage (D) | | Reserves of Weatherable mineral in B horizon (M) |
|---|---|---|---|
| D1a | Marked waterlogging, water table almost reaches the surface all year round | M1 | Reserves very low to nil |
| D1b | Soil flooded for 2 to 4 months of year | M2 | Reserve fair |
| D2a | Moderate waterlogging, water table being sufficiently close to the surface to harm deep rooting plants | M2a | Minerals derives from sands, sandy material or ironstone |
| D2b | Total waterlogging of profile for 8 days to 2 months | M2b | Minerals derives from acid rock |
| D3a | Good drainage, water table sufficiently low not to impede crop growing | M2c | Minerals derives from basic or calcareous rocks |
| D3b | Waterlogging for brief period (flooding), less than 8 days each time | M3 | Reserve large |
| | | M3a | Sands, sandy material or ironstone |
| D4 | Well drained soil, deep water table; no waterlogging of soil profile | M3b | Acid rock |
| | | M3c | Basic or calcareous rocks |

**Table 5. Definition of soil texture and structure of root zone and base saturation and pH**

| | Texture and structure of root Zone (T) | | Base saturation and pH (1:1) of A Horizon (N) |
|---|---|---|---|
| T1 | Pebbly, stony or gravelly soil | N1 | BS:<15% pH:3.5-4.5 |
| T1a | Pebbly, stony or gravelly >60% by weight | N2 | BS:15 - 35% pH:4.5-5.0 |
| T1b | Pebbly, stony or gravelly from 40-60% | N3 | BS:35 - 50% pH:5.0-6.0 |
| T1c | Pebbly, stony or gravelly from 20-40% | N4 | BS: 50 - 75% pH: 6.0- 7.0 |
| T2 | Extremely coarse textured soil | N5 | BS:>75% pH:7.0 – 8.5 |
| T2a | Pure sand of particle structure | N6 | Soil excessive calcareous >30% |
| T2b | Extremely coarse textured soil (>45% coarse sand) | | Soluble Salt content (S) |
| T2c | Soil with non - decomposed raw humus (>30% organic matter) and fibrous structure | S1 | < 0.2% |
| T3 | Dispersed clay of unstable structure (ESP>15%) | S2 | 0.2 – 0.4% |
| T4 | Light textured soil, FS, LS,SL,CS and Si | S3 | 0.4 -0.6% |
| T4a | Unstable structure | S4 | 0.6 – 0.8% |
| T4b | Stable structure | S5 | 0.8 – 1.0% |
| T5 | Heavy – textured soil: C or SiC | S6 | >1.0% |
| T5a | Massive to large prismatic structure | S7 | Total soluble salt (including $Na_2CO_3$) 0.1 – 0.3% |
| T5b | Angular to crumb structure or massive but highly porous | S8 | 0.3 – 0.6% |
| T6 | Medium – heavy soil: heavy SL,SC,CL,SiCL,Si | S9 | >0.6% |
| T6a | Massive to large prismatic structure | | Mineral Exchange Capacity (A) |
| T6b | Angular to crumb structure (massive but porous) | A0 | Exchangeable capacity of clay <5 cmol+ $kg^{-1}$ |
| T7 | Soil of average, balanced texture: L,SiL and SCL | A1 | Exchangeable capacity of clay <20 cmol+ $kg^{-1}$ |
| | | A2 | Exchangeable capacity of clay 20 - 40 cmol+ $kg^{-1}$ |
| | | A3 | Exchangeable capacity of clay > 40 cmol+ $kg^{-1}$ |

**FS:fine sand, LS:loamy sand, SL: Sandy loam, S:Sand, C:Clay, Si: Silty, SiC: Silty clay, CS: Coarse sand**

**Table 6. Rating of different soil and land characteristics**

| Factors | Crop Growing | Pasture | Tree crop | Factors | Crop Growing | | | Pasture | Tree crop |
|---|---|---|---|---|---|---|---|---|---|
| | H | | | D | H4,H5 | H2,H3 | | | |
| H1 | 5 | 5 | 5 | D1 | 10 | 40 | | 60 | 5 |
| H2a* | 10 | 20 | 10 | D2 | 40 | 80 | | 100 | 10 |
| H2b | 20 | 20 | 10 | D3 | 80 | 90 | | 90 | 40 |
| H2c | 40 | 30 | 10 | D4 | 100 | 100 | | 80 | 100 |
| H3a | 50 | 30 | 10 | P | | | | | |
| H3b | 60 | 40 | 20 | P1 | | 5 | | 20 | 5 |
| H3c | 70 | 60 | 40 | P2 | | 20 | | 60 | 5 |
| H4a | 80 | 70 | 70 | P3 | | 50 | | 80 | 20 |
| H4b | 90 | 80 | 90 | P4 | | 80 | | 90 | 60 |
| H4c | 100 | 90 | 100 | P5 | | 100 | | 100 | 80 |
| H5 | 100 | 100 | 100 | P6 | | 100 | | 100 | 100 |
| | N | | | T | | | | | |
| N1 | 40 | 60 | 80 | T1a | | 10 | | 30 | 50 |
| N2 | 50 | 70 | 80 | T1b | | 30 | | 50 | 80 |
| N3 | 60 | 80 | 90 | T1c | | 60 | | 90 | 100 |
| N4 | 80 | 90 | 100 | | H3,H4,H5 | H3 | H1,H2 | | |
| N5 | 100 | 100 | 100 | T2a | 10 | 10 | 10 | | |
| N6 | 80 | 90 | 100 | T2b | 30 | 20 | 10 | | |
| O | H1,H2,H3 D3,D4 | H4,H5 D1,D2 | | T2c | 30 | 30 | 30 | | |
| N1 | 85 | 70 | | T3 | 30 | 20 | 10 | The same rating as for pasture | The same rating as for crops |
| N2 | 90 | 80 | | T4a | 40 | 30 | 30 | | |
| N3 | 100 | 90 | | T4b | 50 | 50 | 60 | | |
| N4 | 100 | 100 | | T5a | 50 | 60 | 20 | | |
| N5 | 70 | 70 | | T5b | 80 | 80 | 60 | | |
| | A | | | T6a | 80 | 80 | 60 | | |
| A0 | | 85 | | T6b | 90 | 90 | 90 | | |
| A1 | | 90 | | T7 | 100 | 100 | 100 | | |
| A2 | | 95 | | S | T1,T2,T4 | T5,T6,T7 | | | |
| A3 | | 100 | | S1 | 100 | 100 | | | |
| M | H1,H2,H3 | H4,H5 | | S2 | 70 | 90 | | | |
| M1 | 85 | 85 | | S3 | 50 | 80 | | | |
| M2a | 85 | 90 | | S4 | 25 | 40 | | | |
| M2b | 90 | 95 | | S5 | 15 | 25 | | | |
| M2c | 95 | 100 | | S6 | 5 | 15 | | | |
| M3a | 90 | 95 | | S7 | 60 | 90 | | | |
| M3b | 95 | 100 | | S8 | 15 | 60 | | | |
| M3c | 100 | 100 | | S9 | 5 | 15 | | | |

***Rating for H2a is 10; when the soil is irrigated, the rating becomes 100**

In general, the LPI model calculation involves three main steps. The stages that follow (figure 3) describe how the model works.

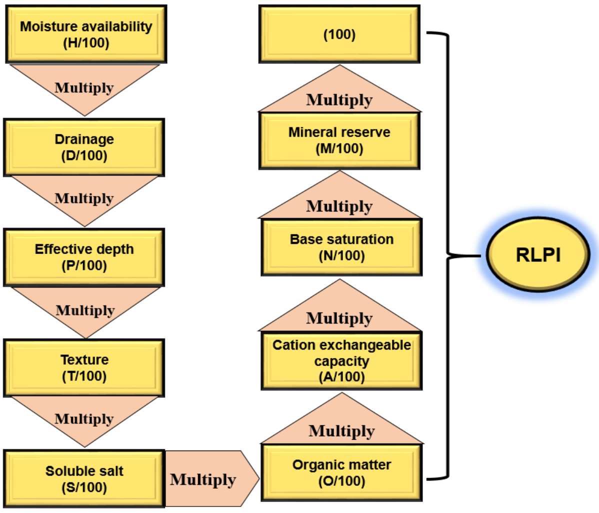


**Fig. 3. Steps for calculating RLPI model.**

1-The soil parameters, which are all employed as diagnostic criteria, include effective moisture availability (H), drainage (D), effective depth (P), texture/structure (T), soluble salt (S), organic matter (O), cation exchange capacity (A), base saturation (N), and mineral reserve in B horizon (M).

2-The soil is assessed using a calculated mean weighted mean value for each identified soil attribute, which is calculated by multiplying each horizon's parameter value by its thickness, then dividing that result by the profile depth as a whole.

3- The RLPI was calculated according to the following equation:

$$RLPI = \frac{H}{100} \times \frac{D}{100} \times \frac{P}{100} \times \frac{T}{100} \times \frac{S}{100} \times \frac{O}{100} \times \frac{A}{100} \times \frac{N}{100} \times \frac{M}{100} \times 100$$

**Automation of RLPI model:**

The Python software used in this research can save, retrieve, display, manage, and analyse various types of data. The python programme was used to code the soil factors, which included effective moisture availability (H), drainage (D), effective depth (P), texture/structure (T), soluble salt (S), organic matter (O), cation exchange capacity (A), base saturation (N), and mineral reserve in B horizon (M). Then, using the software created by Mustafa *et al.* (2022), Riquier *et al.*'s (1970) mathematical models were applied to all of these elements in order to generate the RLPI.

**Designed Land Productivity spatial model (DLPSM):**

Utilising the inverse distance weighted technique (IDW) and the productivity factors database, the designed land productivity spatial model (DLPSM) was created using ArcGIS software 10.4 and included all of the useful soil factors (discussed above). After that, using a weighted overlay tool, create a final map of the productivity index overlay. Figure 4 depicts the flowchart of the land productivity based on DLPSM.

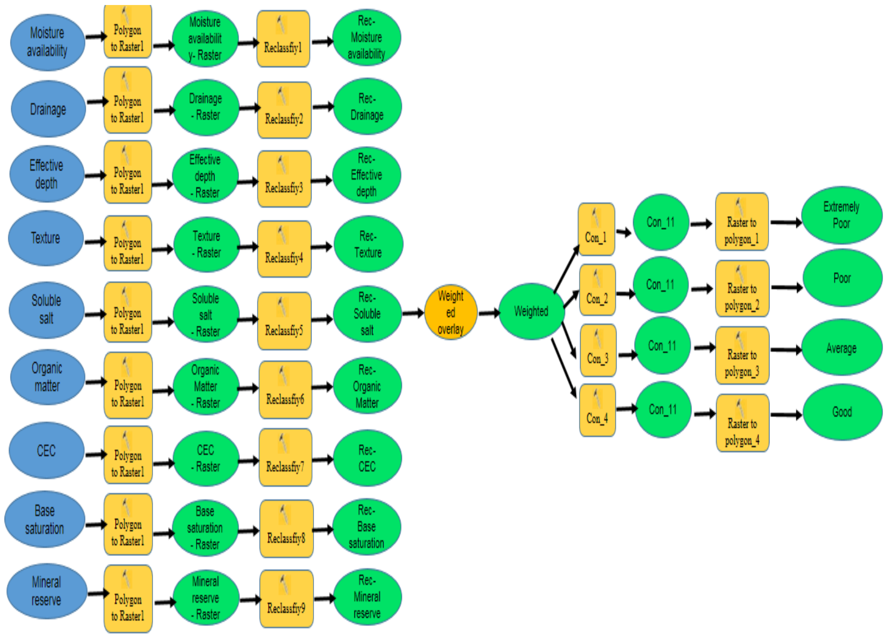


**Fig. 4. Flowchart of the land productivity based on DLPSM**

## RESULTS AND DISCUSSION

**Soil characterization**

The descriptive statistics values for the examined soil parameters are given in Table 7. In addition, the major soil characteristics of the studied area are tabulated in Table 8. The studied area could be grouped into three categories as following:

**Old cultivated soil:**

The pH values of the old cultivated soils ranged from 7.44 to 8.21, indicating that these soils fall into the slightly and moderately alkaline categories. Furthermore, all values indicate that these soils are non-saline, as they are below 4 dS $m^{-1}$. The dominant texture classes in these soils were sandy loam and sandy clay loam, with clay textured soils occurring in only a few soil profiles. The cation exchange capacity of these soils ranged from 4.03 cmol+/kg to 17.43 cmol+ $kg^{-1}$, indicating a low to moderate capacity.

The ESP values are low for these soils (below 15%) and ranged from 1.13 to 14.73 %. Soil organic matter was low to moderate. Calcium carbonate content was low and ranged from 5.3% to 49.6 mg $kg^{-1}$.

**Table 7. Descriptive statistics values for the examined soil parameters**

| Land use | property | Mean | Minimum | Maximum | Standard Deviation | Standard Error |
|---|---|---|---|---|---|---|
| Old cultivated lands | Soil Depth (cm) | 110.0 | 70.0 | 150.0 | 18.2 | 5.3 |
| | CEC (Cmol+ $kg^{-1}$) | 8.19 | 4.03 | 17.43 | 3.40 | 0.98 |
| | ESP | 6.70 | 1.13 | 14.73 | 4.64 | 1.34 |
| | OM (mg $kg^{-1}$) | 9.31 | 5.00 | 25.17 | 5.37 | 1.55 |
| | ECe ($dSm^{-1}$) | 0.68 | 0.26 | 1.98 | 0.48 | 0.14 |
| | pHe | 7.82 | 7.44 | 8.21 | 0.23 | 0.07 |
| | CaCO3 (mg $kg^{-1}$) | 24.90 | 5.30 | 49.60 | 16.99 | 4.91 |
| | Base saturation (%) | 96.02 | 83.40 | 99.00 | 4.96 | 1.43 |
| | Soil texture | | | SL,L,SC,C | | |
| | Drainage | | | GD | | |
| New reclaimed soils | Soil Depth (cm) | 110.0 | 100.0 | 120.0 | 7.1 | 2.0 |
| | CEC (Cmol+ $kg^{-1}$) | 6.44 | 1.73 | 18.05 | 4.92 | 1.42 |
| | ESP | 9.04 | 3.39 | 17.13 | 3.91 | 1.13 |
| | OM (mg $kg^{-1}$) | 5.32 | 0.52 | 13.62 | 4.41 | 1.27 |
| | ECe ($dSm^{-1}$) | 0.96 | 0.31 | 3.65 | 0.94 | 0.27 |
| | pHe | 7.98 | 7.66 | 8.72 | 0.33 | 0.10 |
| | CaCO3 (mg $kg^{-1}$) | 142.84 | 22.10 | 313.50 | 107.45 | 31.02 |
| | Base saturation (%) | 97.47 | 92.80 | 99.00 | 1.98 | 0.57 |
| | Soil texture | | | SC, SL, SCL, CL, S, C | | |
| | Drainage | | | GD, WD | | |
| Barren soils | Soil Depth (cm) | 122.0 | 110.0 | 150.0 | 16.0 | 7.2 |
| | CEC (Cmol+ $kg^{-1}$) | 3.09 | 2.21 | 3.70 | 0.62 | 0.20 |
| | ESP | 8.77 | 5.36 | 15.33 | 2.66 | 0.84 |
| | OM (mg $kg^{-1}$) | 1.83 | 0.17 | 7.76 | 2.97 | 0.94 |
| | ECe ($dSm^{-1}$) | 13.19 | 7.65 | 24.15 | 6.47 | 2.04 |
| | pHe | 7.99 | 7.65 | 8.32 | 0.25 | 0.08 |
| | CaCO3 (mg $kg^{-1}$) | 279.43 | 176.70 | 381.20 | 83.19 | 26.31 |
| | Base saturation (%) | 97.51 | 90.40 | 99.60 | 2.86 | 0.91 |
| | Soil texture | | | S, SL | | |
| | Drainage | | | GD, WD | | |

**SL: sandy loam, L: loam, SCL: sandy clay loam, C: clay, SC: sandy clay, CL: clay loam, S: sandy, GD: Good drained, WD: Well drained.**

**Table 8. The major soil characteristics of the studied area:**

| Land use | Profile No. | Drainage | Effective depth (cm) | Texture class | CEC (Cmol+ kg-1) | BS % | OM (mg kg-1) | ECe (dS m-1) | pHe | CaCO3 (mg kg-1) |
|---|---|---|---|---|---|---|---|---|---|---|
| Old cultivated soils | 1 | GD | 120 | SL | 7.43 | 97.5 | 7.41 | 0.26 | 7.65 | 5.3 |
| | 2 | GD | 100 | SCL | 8.01 | 98.4 | 5.34 | 0.96 | 7.61 | 10.7 |
| | 3 | GD | 110 | SCL | 8.93 | 98.5 | 8.45 | 0.61 | 8.21 | 42.5 |
| | 4 | GD | 100 | SCL | 7.88 | 98.0 | 10.52 | 0.55 | 8.14 | 38.4 |
| | 5 | GD | 112 | C | 18.05 | 97.3 | 13.62 | 0.51 | 7.77 | 30 |
| | 6 | GD | 115 | C | 10.98 | 98.9 | 9.48 | 0.89 | 7.88 | 44 |
| | 7 | GD | 110 | SCL | 6.54 | 99.0 | 7.93 | 0.68 | 7.64 | 37.4 |
| | 8 | GD | 110 | L | 8.20 | 98.6 | 10.34 | 0.30 | 7.88 | 9.1 |
| | 9 | GD | 110 | SL | 7.10 | 91.6 | 6.55 | 0.28 | 8.01 | 6.2 |
| | 10 | GD | 100 | SL | 5.24 | 99.0 | 25.17 | 0.46 | 7.44 | 30 |
| | 11 | GD | 70 | C | 17.43 | 99.0 | 10.00 | 0.89 | 7.62 | 49.6 |
| | 12 | GD | 115 | SL | 6.55 | 90.3 | 5.52 | 0.32 | 7.96 | 7.8 |
| New reclaimed soils | 13 | GD | 115 | SC | 8.44 | 98.7 | 6.03 | 0.47 | 7.81 | 47.7 |
| | 14 | GD | 110 | SL | 3.60 | 98.1 | 0.52 | 1.29 | 7.88 | 196.5 |
| | 15 | GD | 100 | SCL | 8.42 | 95.0 | 9.14 | 0.38 | 7.66 | 22.1 |
| | 16 | GD | 110 | SCL | 9.16 | 98.2 | 4.48 | 0.40 | 7.68 | 37.2 |
| | 17 | GD | 120 | CL | 11.72 | 98.8 | 10.00 | 3.65 | 8.54 | 49.1 |
| | 18 | WD | 100 | S | 5.19 | 98.1 | 2.41 | 0.31 | 7.90 | 105.9 |
| | 19 | WD | 110 | S | 1.73 | 92.8 | 0.69 | 0.99 | 8.72 | 313.5 |
| | 20 | GD | 110 | SL | 2.89 | 99.0 | 8.62 | 0.47 | 8.07 | 206.6 |
| | 21 | WD | 115 | S | 1.94 | 95.6 | 1.03 | 1.07 | 8.02 | 305.5 |
| | 22 | GD | 120 | S | 2.52 | 99.0 | 6.72 | 0.45 | 8.00 | 211.3 |
| | 23 | GD | 150 | SL | 4.03 | 83.4 | 5.00 | 1.98 | 7.82 | 17.8 |
| | 24 | GD | 100 | SL | 3.63 | 99.0 | 0.52 | 1.47 | 7.76 | 188.7 |
| Barren soils | 25 | WD | 150 | S | 3.12 | 99.0 | 7.07 | 7.70 | 7.70 | 191.6 |
| | 26 | WD | 110 | S | 2.25 | 97.2 | 1.38 | 8.05 | 8.05 | 339.4 |
| | 27 | WD | 120 | S | 3.27 | 94.8 | 7.76 | 7.65 | 7.65 | 188.9 |
| | 28 | GD | 115 | SL | 3.70 | 90.4 | 0.52 | 7.65 | 7.65 | 202.2 |
| | 29 | GD | 115 | SL | 3.60 | 98.1 | 0.52 | 7.88 | 7.88 | 176.7 |
| | 30 | WD | 150 | S | 3.69 | 99.6 | 0.17 | 19.23 | 8.21 | 292.5 |
| | 31 | WD | 150 | S | 3.60 | 99.0 | 0.34 | 11.64 | 8.11 | 378.7 |
| | 32 | WD | 150 | S | 2.25 | 99.0 | 0.17 | 20.41 | 8.32 | 287.4 |
| | 33 | WD | 150 | S | 3.21 | 99.0 | 0.17 | 24.15 | 8.14 | 355.7 |
| | 34 | WD | 150 | S | 2.21 | 99.0 | 0.17 | 17.55 | 8.17 | 381.2 |

**SL: sandy loam, L: loam, SCL: sandy clay loam, C: clay, SC: sandy clay, CL: clay loam, S: sandy, GD: Good drained, WD: Well drained.**

New cultivated soils were alkaline and having pH values ranged from 7.66 to 8.72. These soils were characterized as slightly to moderately alkaline. These soils are categorized under sandy loam, loam and sandy texture classes. Cation exchange capacity of these soils is low. The ESP values varied from low to high and ranged between

3.39 to 17.13%. Organic matter content of these soils ranges between low to moderate. These soils are calcic soils and calcium carbonate content ranges from low to extremely high which ranges from 22.1 to 313.5 mg $kg^{-1}$. Barren soils these soils are uncultivated yet but may be a prospective area for agricultural activities. These soils having the coarsest fractions (sandy texture class is dominant) as compared to the previous discussed soils. These soils are very high saline and ranged from 7.65 to 24.15 dS $m^{-1}$. In addition, the organic carbon content is very low. These soils are calcic which calcium carbonate content range from 176.7 to 381.2 mg $kg^{-1}$. Cation exchange capacity and exchangeable sodium percentage are low.

**Productivity index assessment**

The productivity potential of the soil profiles assessed using the mathematical model developed by Riquier *et al.* (1970). Previous studies individually calculated the productivity index. However, manual processing is time-consuming and challenging, especially when dealing with numerous soil samples. Therefore, an attempt made to automate soil productivity using the Python programming language. The developed program can accessed on the website (https://soilhealth .pythonany where.com). The system recommends calculating a productivity index based on eight parameters that determine land production. These parameters include soluble salts (S), soluble organic matter (O), cation exchange capacity (A), drainage (D), effective depth (P), texture/structure (T), texture/structure (T), and mineral reserves (M). Each of these elements coded in Python to automate the calculation of the productivity index. Due to certain preexisting limitations, the real production classes of soils were categorized as good, moderate, low, and severely poor (Table 9).

**Table 9. Productivity assessment of the studied soils**

| Land use | Profile No. | Moisture H | Drainage D | Depth P | Texture T | Reserves of weatherable mineral in B horizon M | OM O | Salinity S | CEC A | BS/ pHe N | LPI % | Definition / symbol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Old cultivated soils | 1 | H4c | D3a | P5 | T6b | M3c | O1 | S1 | A1 | N5 | 51.03 | Good II |
| | 2 | H3a | D3a | P5 | T7 | M3c | O1 | S1 | A1 | N5 | 34.42 | Good II |
| | 3 | H4b | D3a | P5 | T7 | M3c | O1 | S1 | A1 | N5 | 51.03 | Good II |
| | 4 | H4c | D3a | P5 | T7 | M3c | O1 | S1 | A1 | N5 | 56.7 | Good II |
| | 5 | H5 | D3a | P5 | T5b | M2c | O1 | S1 | A1 | N5 | 45.36 | Good II |
| | 6 | H5 | D3a | P5 | T5b | M3c | O1 | S1 | A1 | N5 | 45.36 | Good II |
| | 7 | H4a | D3a | P5 | T7 | M3c | O1 | S1 | A1 | N5 | 45.36 | Good II |
| | 8 | H3a | D3a | P5 | T7 | M3c | O1 | S1 | A1 | N5 | 34.42 | Good II |
| | 9 | H4c | D3a | P5 | T6b | M3c | O1 | S1 | A1 | N5 | 51.03 | Good II |
| | 10 | H3a | D3a | P5 | T6b | M3c | O1 | S1 | A1 | N5 | 30.98 | Average III |
| | 11 | H5 | D3a | P4 | T5b | M3c | O1 | S1 | A1 | N5 | 36.29 | Good II |
| | 12 | H4c | D3a | P5 | T6b | M3c | O1 | S1 | A1 | N5 | 51.03 | Good II |
| New reclaimed soils | 13 | H5 | D3a | P5 | T6a | M2c | O1 | S1 | A1 | N5 | 45.36 | Good II |
| | 14 | H4c | D3a | P5 | T6a | M2c | O1 | S1 | A0 | N5 | 42.84 | Good II |
| | 15 | H4a | D3a | P5 | T7 | M2c | O1 | S1 | A1 | N5 | 38.56 | Good II |
| | 16 | H4a | D3a | P5 | T7 | M2c | O1 | S1 | A1 | N5 | 42.84 | Good II |
| | 17 | H5 | D3a | P5 | T6a | M2c | O1 | S2 | A1 | N5 | 45.36 | Good II |
| | 18 | H2c | D4 | P5 | T2b | M2a | O1 | S1 | A1 | N5 | 2.46 | Ex. Poor V |
| | 19 | H2c | D4 | P5 | T2b | M2a | O1 | S1 | A0 | N5 | 2.46 | Ex. Poor V |
| | 20 | H3a | D3a | P5 | T4a | M2c | O1 | S1 | A0 | N5 | 9.27 | Poor IV |
| | 21 | H2c | D4 | P5 | T2b | M2a | O1 | S1 | A0 | N5 | 2.46 | Ex. Poor V |
| | 22 | H3b | D3a | P5 | T4a | M2a | O1 | S1 | A0 | N5 | 9.95 | Poor IV |
| | 23 | H3a | D3a | P6 | T6a | M3c | O1 | S1 | A0 | N5 | 26.01 | Average III |
| | 24 | H3a | D3a | P5 | T6a | M2c | O1 | S1 | A0 | N5 | 24.71 | Average III |
| Barren soils | 25 | H2c | D4 | P6 | T2b | M2a | O1 | S1 | A0 | N5 | 2.46 | Ex. Poor V |
| | 26 | H2c | D4 | P5 | T2b | M2a | O1 | S1 | A0 | N5 | 2.46 | Ex. Poor V |
| | 27 | H2c | D4 | P5 | T2b | M2a | O1 | S2 | A0 | N5 | 2.46 | Ex. Poor V |
| | 28 | H3a | D3a | P5 | T6b | M2c | O1 | S1 | A0 | N5 | 27.80 | Average III |
| | 29 | H3a | D3a | P5 | T6b | M2c | O1 | S1 | A0 | N5 | 27.80 | Average III |
| | 30 | H2c | D4 | P6 | T2b | M1 | O1 | S6 | A0 | N5 | 0.12 | Ex. Poor V |
| | 31 | H2c | D4 | P6 | T2b | M1 | O1 | S4 | A0 | N5 | 0.61 | Ex. Poor V |
| | 32 | H2c | D4 | P6 | T2b | M1 | O1 | S6 | A0 | N5 | 0.12 | Ex. Poor V |
| | 33 | H2c | D4 | P6 | T2b | M1 | O1 | S6 | A0 | N5 | 0.12 | Ex. Poor V |
| | 34 | H2c | D4 | P6 | T2b | M1 | O1 | S6 | A0 | N5 | 0.12 | Ex. Poor V |

**Ex= Extremely**

**Designed Land Productivity Spatial Model (DLPSM)**

The study area's productivity was categorized and assessed using nine thematic factors: effective moisture availability (H), drainage (D), effective depth (P), texture/structure (T), soluble salt (S), organic matter (O), cation exchange capacity (A), base saturation (N), and mineral reserve in B horizon (M). This model was created using ArcGIS software 10.4.1. This was accomplished by creating databases for all previously specified factors (H, D, P, T, S, O, A, N, and M) and using the factors equation. In order to calculate productivity index and create a final productivity classes map, weighted overlay tool is applied. Figure 4 displays a flowchart for the DLPSM.

Based on the adopted method, the LPI and its ranking under land use types in the study area were calculated (Table 9).The LPI ranged from 30.98 to 51.03 % and from 2.46 to 45.36 % and from 0.12 to 27.80 % for old cultivated, new cultivated and barren soils, respectively. The LPI is classified into four zones. The first zone is characterized by a good index that represents about 45.58% (325.96 km2) of the total geographical area (TGA). The soils of this zone are located mainly in old cultivated soils. The second zone characterized by average index and covers about 15.77% of TGA (112.78 km2). This class observed in some old, new reclaimed soils and barren soils.

This may be due to the addition of alluvium soils at different amounts on the surface of new reclaimed soils to enhance their characters. As these soils have low values of favorable studied indicators lead to negative effects on the LPI. The third zone is poor and covers about 20.46% (146.32 $km^2$) of TGA and located mainly in some new reclaimed soils as well as desert soils that have low content of favorable and high content of unfavorable conditions for plant growth. The last zone characterized by extremely poor class and located in barren soils and covers an area of about 18.19 % (130.08 $km^2$). The major limitations of these soils are coarse texture, low organic matter content and low CEC. Regarding to Barren soils, the major limitations that mentioned above as well as high salinity conditions hinder the productivity of these soils. Thus, the LPI of these soils may be enhanced through the applications of some management plan. This plan must take into consideration the application of organic manure, green manuring, mulching, and crop rotation. The high salinity soils can be removed by applying leaching and supplying the affected area with efficient drainage system in case of good quality water. The spatial variability of LPI based on DLPSM is shown in figure 5.

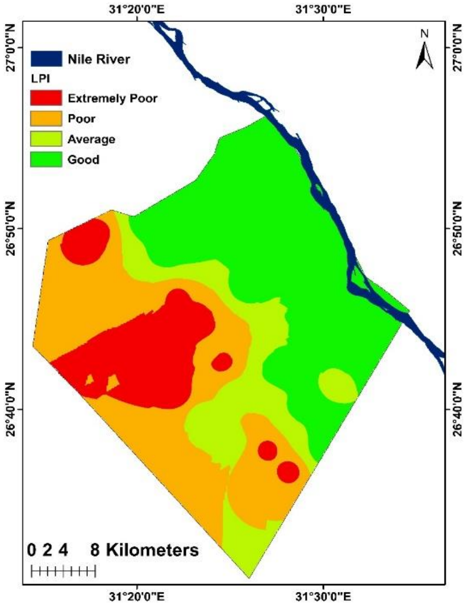


**Fig. 5. The spatial variability of LPI based on DLPSM**

## CONCLUSION

The LPI ranged from 30.98 to 51.03 % and from 2.46 to 45.36 % and from 0.12 to 27.80 % for old cultivated, new cultivated and barren soils, respectively. The LPI is classified into four zones. The first zone is characterized by a good index that represents about 45.58% (325.96 $km^2$) of TGA. The second zone characterized by average index and covers about 15.77% of TGA (112.78 $km^2$). The third zone is poor and covers about 20.46% (146.32 km2) of TGA. Finally, the fourth zone characterized by extremely poor class and cover an area of about 18.19 % (130.08 $km^2$).The developed programe was demonstrated in this study to automate the procedure of land productivity index. Unlike the conventional approach, the results obtained by this approach are reproducible and computation time is low. This may paved the way for automating other indices such as land capability, irrigation water quality index (IWQI) and others. In addition, based on available soil data, the fertilizer recommendations and irrigation water requirements can calculated automatically with high precision.

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# دمج نمذجة نظم المعلومات الجغرافية مع لغة برمجة بايثون لتحديد مؤشر إنتاجية الأرض

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## الملخص

تم اجراء فحص تفصيلي لتقييم انتاجية التربة في الجزء الشمالي من محافظة سوهاج ، مصر. تم تحديد عدد ٣٤ قطاع تربة ممثل لاستخدامات التربة الزراعة وهي الاراضي القديمة المنزرعة ، الاراضي حديثة الزراعة والاراضي الغير منزرعة. أخذت عينات من كل افق من افاق التربة ومن ثم تم اجراء التحليلات الطبيعية والكيميائية. وبناء علي ذلك تم حساب مؤشر انتاجية التربة. والطريقة المتبعة عادة في الحساب هي طريقة يدوية تقليدية تستهلك كثيرا من الوقت والجهد خاصة مع وجود عدد كبير من العينات. لذلك تم استخدام لغة البرمجة البايثون لحساب مؤشر انتاجية التربة مع دمج النتائج المتحصل عليها بالنمذجة باستخدام نظم المعلومات الجغرافية. حيث تم استخدام النموذج المكاني لإنتاجية الاراضي لانتاج خرائط لمؤشر انتاجية التربة. ويعتبر استخدام لغات البرمجة في حساب مؤشر انتاجية التربة من الامور المطلوبة خاصة في عصر تكنولوجيا المعلومات.