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**Actual and Potential Land Productivity of Certain Soils in Egypt's Eastern Desert along the
Sohag-Red Sea Road**

Lariysa¹, Hirumi Kiaytara².

São Paulo State University, Postgraduate Course in Agronomy, Brazil.

Research Article

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ABSTRACT

In order to boost tourist and agricultural operations, the Egyptian government concentrates on development initiatives, particularly in new areas like the Sohag-Red Sea route. The purpose of this research is to evaluate the potential and current productivity of land. Based on the six mapping units of the research region, seventeen soil profiles were selected. Soil samples were taken from each horizon and soil profiles were drilled. Soil moisture content (H), drainage (D), depth (P), texture (T), soluble salt content (S), average nutrient content (N), organic matter content (O), cationic exchange capacity (A), and stocks of weatherable minerals (M) were the nine land parameters that were measured or calculated. Using normal soil analysis techniques, soil samples were examined for the aforementioned characteristics. Thus, for every soil profile under study, the land productivity (PI) and potentiality ($P \square I$) indices were computed. The findings showed that the researched area's real land productivity is very low and may be increased 17 times by enhancing the soil's moisture level, texture, and organic matter content, which are the main governing elements. Arc GIS 10.1 was used to create maps of actual and projected land production. Decision-makers may find these findings useful for planning the reclamation of new lands and improving agricultural output.

Keywords: Sohag-Red Sea Road, soil mapping, and land productivity

INTRODUCTION

The Nile River valley and delta's soils begin to lose their fertility and productivity due to urban development and fast population increase (Mustafa and Negim 2016). In order to increase agricultural output and lessen the strain on the country's current agricultural land, the Egyptian government concentrated on horizontal expansion (FAO 2006). Furthermore, one of the most significant reclamation initiatives is the Golden Triangle Project, which spans a sizable portion of the Eastern Desert (NGage 2016). According to Denton et al. (2017), the function of soil researchers seems to be to provide the knowledge and data required to start the reclamation of such areas as well as to create appropriate soil management techniques and land-use planning. The majority of Egypt is made up of low-fertility desert regions that are dispersed across the east and west Nile Valley. The Eastern desert's calcareous, coarse-textured, neutral to alkaline soils range from non-salty to very saline. There is little organic carbon (Ibrahim and Ali 2009). For improved land resource management and increased land productivity, GIS's capability for evaluating land productivity is crucial (Ibrahim et al., 2017). In addition to estimating the prospective land productivity after the enhancement of land productivity characteristics, this research attempts to assess the actual land productivity state of various Sohag-Red Sea roadside soils.

MATERIALS AND METHODS

Site description

The research location is located in the Eastern Desert near Wadi Qena on the Sohag-Red Sea route. This region, which spans ≈ 204 km², is located between latitudes 26o.65 and 26o.75 (N) and longitudes 32o.7 and 32o.9 (E). The region being studied is situated between the Red Sea highlands in the east and the Nile Valley in the west. Figure (1) displays the geographic map of the region under study as well as the locations of the soil profiles. The Quaternary sediments that cover Wadi Qena are made up of sand, gravel, and fine clay elements that are bonded together (El-Shamy 1988). A typical desert basin with an exceptionally dry environment is the Wadi Qena watershed. Figure (2) displays the geological map. The yearly rainfall varies from 2.75 to 50 mm, and flash floods are often caused by heavy rains in the winter. The temperature ranges from 5 to 14 degrees Celsius at the low and

from 28 to 42 degrees Celsius at the highest. The range of the relative humidity (RH) is 30% to 56%. June has the highest monthly evapotranspiration of 23.5 mm, while December has the lowest value of 3.1 mm (Awad 2008). An vegetation is limited and dispersed haphazardly over the region, and the predominant winds are mostly from the northwest to the southeast. The typical native plants in the region include *Salvadoroprisca*, Wild Caper, and *Moringa*. Additionally, there are relatively little agricultural operations in the region (El-Zawahry et al. 2004). Six mapping units—Wadi-Floor (WF), Low-elevated Sand Sheet (LSS), High-elevated Sand Sheet (HSS), Bajada (B), Piedmont (P), and Table Land (TL)—represent the region being studied.

Field-work

In accordance with the grid method, seventeen soil profiles were chosen for sampling and mapping the region under study. GPS "Garmin-eTrix" utilizing the WGS84 coordinate system was used to determine the latitudes and longitudes of each soil profile. Based on FAO (2006), a thorough morphological description of every soil profile was recorded.

Soil analysis

The in situ descriptions of soil profiles were used to estimate soil moisture content, drainage, and soil depth. Samples of soil were powdered, air-dried, and sieved through a 2 mm screen. The international pipette technique was used to determine the particle size distribution (Jackson 1969). Using an EC-meter, the electrical conductivity (EC) of a 1:1 soil-water extract was measured (Jackson 1973). The wet-oxidation technique was used to calculate the organic matter contents (Walkley and Black, 1934). Ammonium acetate (pH 7.0) and sodium acetate (pH 8.5) were used to measure exchangeable cations and Cation Exchange Capacity (CEC) (Black 1982). The EDTA titration technique was used to determine exchangeable Ca^{+2} and Mg^{+2} , while a flame photometer was used to measure Na^{+1} and K^{+1} .

The ratio of the observed basic exchangeable cations to CEC was used to determine the base saturation percentage.

Estimation of actual and potential land productivity

The process of (Riquier et al., 1970) was used to calculate the actual and prospective productivity indices. Soil productivity, soil moisture content (H), drainage (D), depth (P), texture (T), soluble salt content (S), average nutrient content (N), organic matter content (O), soil cationic exchange capacity (A), and reserves of weatherable minerals (M) were all determined using this method. The productivity index (PI), as shown in (Equation.1), was determined by multiplying the actual percentages by each element, which was graded on a scale from 0 to 100. $H \times D \times P \times T \times S \times A \times N \times M \times O = \text{PI}$ (1) The resulting productivity index, which also ranged from 0 to 100, was compared to a scale that categorized the soil into five production classes: excellent, good, medium, poor, and severely bad. After enhancing characterizations that were thought to be productivity limits, the potentiality index ($P \square I$) was computed as indicated by (Equation.2). Equation 3 was then used to obtain the coefficient of improvement of land productivity ($P \square I / \text{PI}$). $P \square I = H \times D \times P \times T \times S \times A \times N \times M \times O + 10\%$. (2) $I / \text{PI} = \text{Productivity Index} / \text{Potentiality Index}$. (3) Land productivity mapping The IDW-interpolation function in Arc GIS10.1 software was used to create maps of actual and projected land production (ESRI, 2012).

RESULTS AND DISCUSSION

Soil profiles' characterization

GPS was used to gather the geo-coordinates of the sites of soil profiles and elevation data, which were then recorded in decimal degree format. These values were utilized to map each soil profile's related soil attribute data. In situ descriptions and estimates were made of soil morphological characteristics, including soil moisture content, soil drainage, and the depth of the soil profile. The soil profile characterisation for each land productivity metric is shown in Table (1). All mapping units and their corresponding soil profiles had a soil moisture content in the rooting zone below the wilting threshold around nine months of the year, according to the data collected. These soils are deep (greater than 120 cm) and have good drainage. The investigated area's soils have a high sand concentration and a coarse texture. While the sand texture predominates in other mapping units, the soil texture of WF and B units is sandy loam. While the soil organic matter content was low and varied from 0.14% to 0.40% with an average of 0.24%, the total soluble salts in these soils ranged from low to moderate (0.36% to 0.56%) with an average of 0.49%. These soils have cationic exchange capacities ranging from 1.92 to 6.10 cmole (p+).kg-1, averaging 3.50 cmole(p+).kg-1. Base saturation had a mean of 86.77%, with minimum and maximum values of 79.60% and 95.80%, respectively.

Actual land productivity evaluation

A soil moisture content of 40, which is below the wilting limit for around nine months of the year, may be classified as H2c. After classifying soil depth, soil drainage, and average nutrient content as P6, D4, and N5, respectively, each was assigned a value of 100. While coarse-textured soil (more than 45 percent sand) is present, soil texture has a T2b class and a rating of 10. With the exception of one profile in the HSS unit and another in the TL unit, all soil profiles fall inside the S3 category (50) for soil soluble salts (70). These soils have a low (O1) organic matter concentration, with less than 1% and an 85 rating. All soil profiles in the examined region have a cationic exchange capacity of less than 5 meq/100g soil (A0), with the exception of profiles 1, 3, 10, and 13, which have a CEC of more than 5 and less than 20 meq/100g soil (A1). The ratings for the A0 and A1 classes were 85 and 90, respectively.

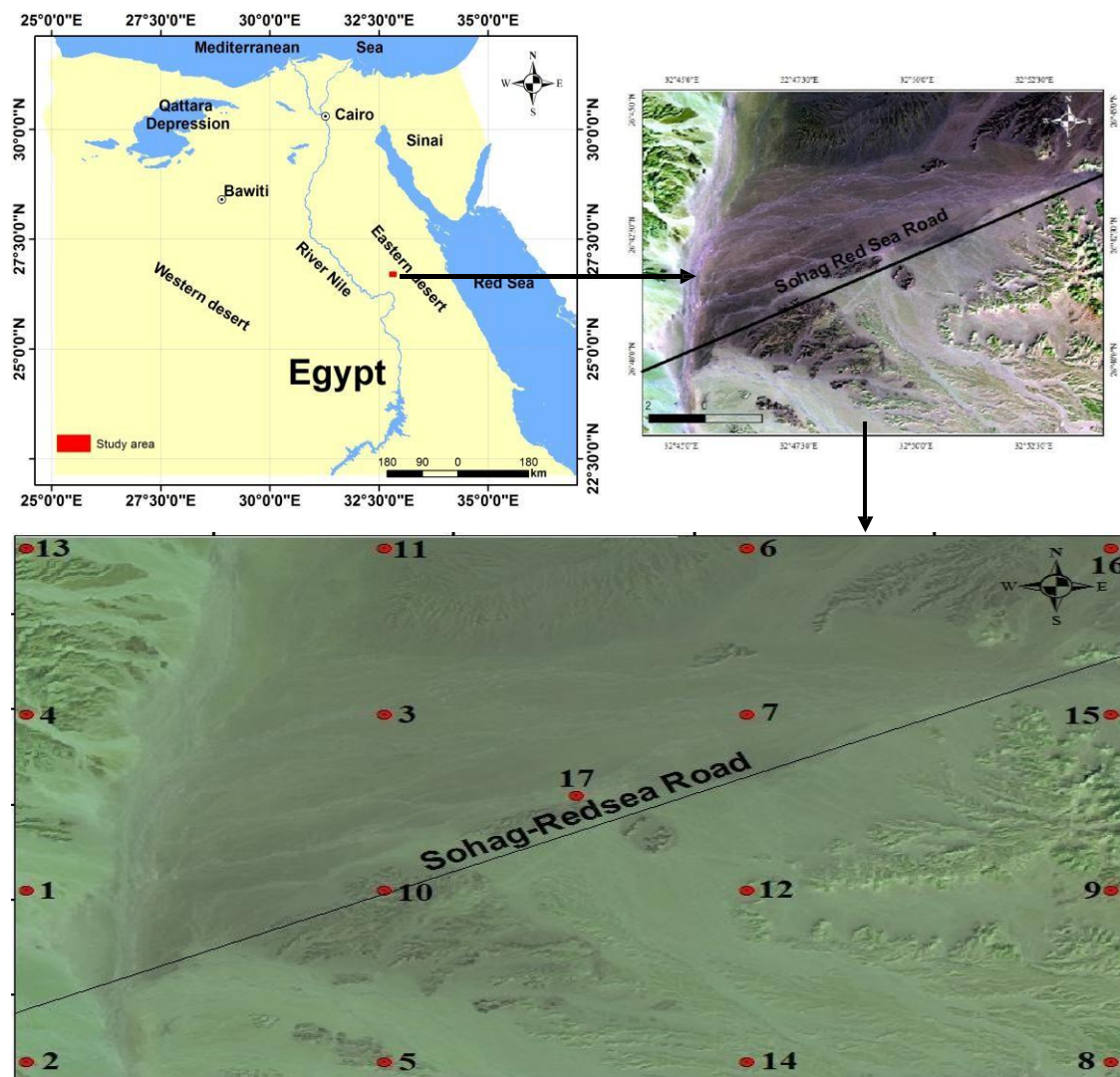


Fig.1: Location map of the studied area and soil profiles' locations.

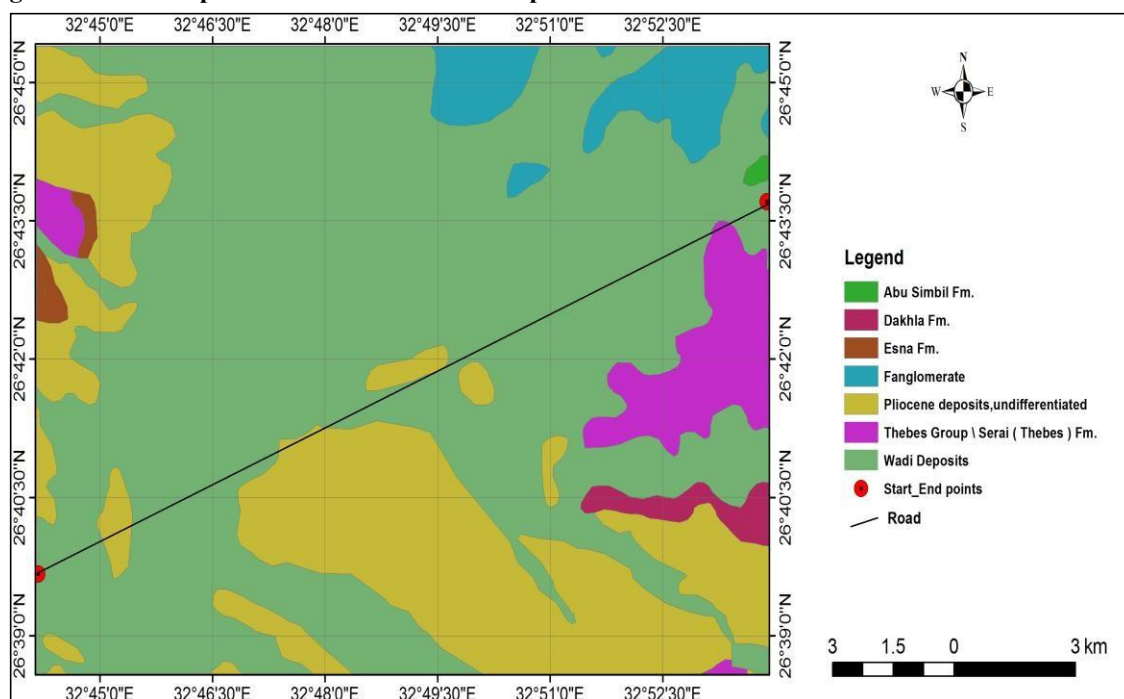


Fig.2: Geological map of the study area.

Table 1: Characterization of soil profiles of the studied area.

Profile No.	Mapping unit	Longitude	Latitude	H	D	P	T	S	O	M	A	N
1	Wadi Floor (WF)	32.738	26.682	<5	Well	130+	LS	0.44	0.34	Very Low	6.10	84.80
2		32.738	26.646	<5	Well	120+	S	0.56	0.29	Very Low	4.30	92.90
3		32.790	26.719	<5	Well	120+	LS	0.46	0.31	Very Low	5.29	85.42
4	Low-elevated Sand Sheet (LSS)	32.738	26.719	<5	Well	130+	S	0.55	0.20	Very Low	2.88	80.66
5		32.790	26.646	<5	Well	130+	S	0.45	0.30	Very Low	2.13	87.53
6		32.843	26.754	<5	Well	125+	LS	0.48	0.27	Very Low	2.44	82.54
7		32.843	26.719	<5	Well	120+	S	0.52	0.33	Very Low	2.51	84.36
8	High-elevated sand Sheet (HSS)	32.896	26.646	<5	Well	120+	S	0.52	0.14	Very Low	2.30	91.33
9		32.896	26.682	<5	Well	120+	S	0.39	0.18	Very Low	1.92	89.80
10	Bajada (B)	32.790	26.682	<5	Well	110+	LS	0.53	0.29	Very Low	5.48	95.80
11		32.790	26.754	<5	Well	120+	LS	0.57	0.19	Very Low	3.23	88.95
12		32.843	26.682	<5	Well	125+	LS	0.53	0.22	Very Low	4.24	86.91
13	Piedmont (P)	32.738	26.754	<5	Well	130+	LS	0.51	0.40	Very Low	5.38	79.60
14		32.843	26.646	<5	Well	130+	S	0.49	0.14	Very Low	2.88	88.23
15		32.896	26.719	<5	Well	120+	LS	0.49	0.20	Very Low	3.28	87.87
16	Table Land (TL)	32.896	26.754	<5	Well	130+	S	0.52	0.16	Very Low	2.58	87.50
17		32.818	26.702	<5	Well	130+	S	0.36	0.16	Very Low	2.48	80.90

H: Moisture Content (%), D: Soil Drainage, P: Soil Depth (cm), T: Soil Texture Grade, S: Total soluble salts (%), O: Soil organic matter (%), M: Reserves of weatherable minerals, A: Cationic exchange capacity, and N: Average nutrient content/Base saturation.

Fig.3: Actual and potential land productivity maps of the studied area.

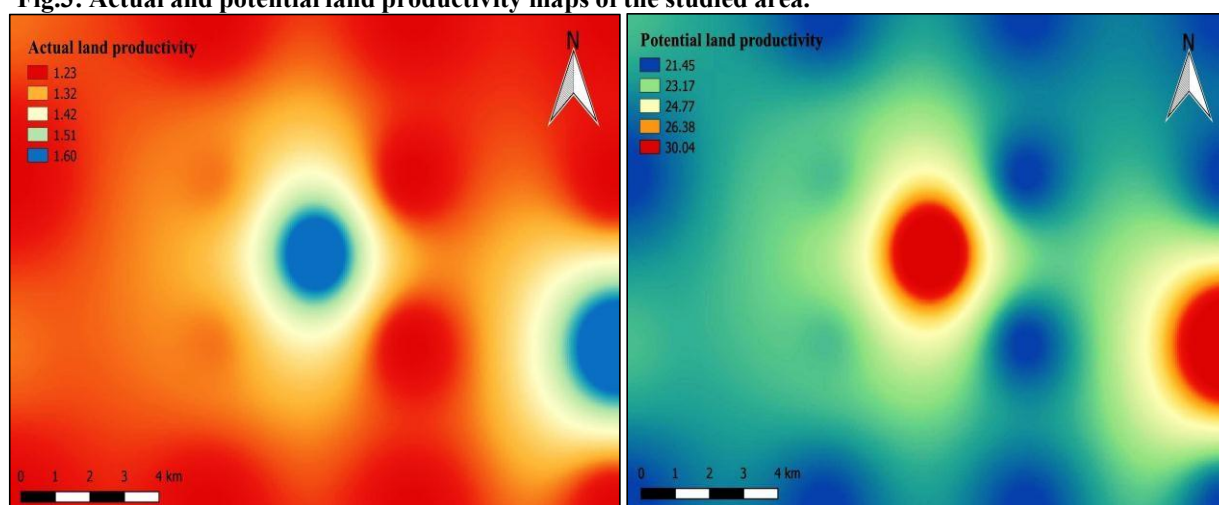


Table 2: Actual land productivity parameters.

Profile No.	Mapping unit	H	D	P	T	S	O	M	A		PI
1	Wadi Floor (WF)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A1 (90)		PI5 (1.30)
2		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)		P5 (1.23)
3		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A1 (90)		PI5 (1.30)
4	Low-elevated Sand Sheet (LSS)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
5		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)		PI5 (1.23)
6		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
7		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
8	High-elevated sand Sheet (HSS)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
9		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S2 (70)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.72)
10	Bajada (B)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A1 (90)	N5 (100)	PI5 (1.30)
11		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
12		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
13	Piedmont (P)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A1 (90)		PI5 (1.30)
14		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)		PI5 (1.23)
15		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)	N5 (100)	PI5 (1.23)
16	Table Land (TL)	H2c (40)	D4 (100)	P6 (100)	T2b (10)	S3 (50)	O1 (85)	M1 (85)	A0 (85)		PI5 (1.23)
17		H2c (40)	D4 (100)	P6 (100)	T2b (10)	S2 (70)	O1 (85)	M1 (85)	A0 (85)		PI5 (1.72)

H2c: Soil moisture (H) in rooting zone below wilting point around 9 months of the year, D4: Well-drained soil with a deep water table (hydromorphic horizon at over 120 cm depth) and no water-logging of the soil profile, P6: Very deep soil with over 120 cm depth, T2b: Soil texture and structure of root zone which extremely coarse-textured soil (more than 45 percent sand), S2: Total soluble salts between 0.2 to 0.4 percent, S3: Total soluble salts between 0.4 to 0.6 percent, O1: Soil organic matter in A1 horizon which less than one percent, M1: Reserves of weatherable minerals in B horizon very low to Nil, A0: Cationic exchange capacity in B horizon less than 5 meq/100g, A1: Cationic exchange capacity in B horizon less than 20 meq/100g, N5: Average nutrient content in A horizon whereas base saturation over 75 percent, and PI5: Land productivity is extremely poor to Nil.

Table 3: Potential land productivity parameters after improvement.

Profile No.	Mapping unit	H	D	P	T	S	O	M	A	N	P [□] I
1	Wadi Floor (WF)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P [□] I3 (22.72)
2		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
3		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P [□] I3 (22.72)
4	Low-	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
5		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (22.72)

	elevated	(90)	(100)	(100)	(60)	(50)	(100)	(85)	(85)	(100)	(21.46)
6	Sand Sheet (LSS)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
7		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
8	High-elevated	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
9	sand Sheet (HSS)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S2 (70)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (30.04)
10		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P [□] I3 (22.72)
11	Bajada (B)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
12		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
13		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A1 (90)	N5 (100)	P [□] I3 (22.72)
14	Piedmont (P)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
15		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
16	Table Land (TL)	H4c (90)	D4 (100)	P6 (100)	T6a (60)	S3 (50)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (21.46)
17		H4c (90)	D4 (100)	P6 (100)	T6a (60)	S2 (70)	O3 (100)	M1 (85)	A0 (85)	N5 (100)	P [□] I3 (30.04)

H4c: Soil moisture content (H) when rooting zone below wilting point for 3 months and wet below field capacity for over 6 months of the year, T6a: texture and structure of root zone when dominant texture grades are heavy sandy loam, sandy clay, clay loam, silty clay loam, or silt, O3: Soil organic matter in A1 horizon is averaged from 2 to 5 percent, and P[□]I3: Land potential productivity after improvement which under average productivity class.

Each soil profile's productivity index was determined, and it is clear that all soil profiles have very low to nonexistent land productivity (PI between 0 and 7). Table (2) displays the relevant facts.

Improvement of land productivity parameters

According to earlier findings, soil moisture content (H), soil texture (T), and soil organic matter (O) are these soils' constraints for land production. To boost land production, several criteria may be improved. As a result, supplemental irrigation techniques like spray irrigation will be used to water these soils. This procedure will raise the rate of the soil moisture parameter from H2c to H4c, which has a rating of 90. Heavy-textured soil that has been transferred from other agricultural fields may be blended with the top layer (0–25 cm) of these soils. Soil texture may be improved by adding organic materials and nutrients, applying manure, rotating crops, and improving humic conditions. Texture from T2b to T6a (from 10 to 60) may be improved by these techniques. It may be raised from O1 to O3 (85 to 100) after organic matter has improved. The final index will increase by 10% due to improvements in organic matter. Table (3) displays the land productivity metrics data after improvement.

Potential land productivity evaluation

Land potential productivity (P[□]I), which varied from 21.46 to 30.04, was determined using the data of land productivity characteristics after improvement. The potential productivity of these soils was determined to be average. The computed coefficient of improvement (P[□]I/PI) for the region under study was 17.48. It implies that if all appropriate management strategies are used, productivity may be increased by more than 17 times.

Land productivity mapping, both current and prospective As shown in figure (3), present and projected land productivity maps were created using the IDW-Interpolation tool in Arc GIS 10.1 software. These maps demonstrate that, in comparison to the rest of the investigated area, the Central and Eastern regions are more productive. Following the development of land productivity metrics, land productivity rose. The region under study has low moisture content in its soils. These soils have a gritty texture, are deep, and have good drainage. Total soluble salts vary from low to moderate, and the amount of organic matter in the soil is low. Additionally, BS exceeds 75% and CEC is minimal. These soils have very low production, according to the real land productivity index. To increase land production, certain procedures and methods of land management should be adhered to. Soil organic matter, soil texture, and soil moisture content are the soils' constraints. After improvement, there is a 17-fold increase in potential land production. An efficient method for generating both geographical and land productivity data is the combination of soil surveys, sampling, laboratory analysis, and GIS techniques. These information may be used to improve agricultural output, plan for the reclamation of new land, and manage land usage more effectively.

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