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Egypt. J. Soil. Sci. Vol. **61**, No. 3, pp. 311-321 (2021)

Egyptian Journal of Soil Science
http://ejss.journals.ekb.eg/

Monitoring Land Degradation and Soil Productivity in Bilqas District, Dakahlia Governorate, Egypt

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SOIL DEGRADATION is one of the most serious obstacles to agricultural development. This study aimed at assessing soil degradation, soil productivity, and the correlation coefficient between them in Bilqas District,Dakahlia Governorate. Soil data of the study area were acquired from a previous study (2010) and compared with soil data collected from the current study. Sixteen soil profiles representing the main landforms dominating the study area were dug. Soil samples were collected and analyzed for determining physicochemical properties. The results indicate that the most active soil degradation processes are salinity, waterlogging, and alkalinity. The land degradation rate was low in all soil profiles except occasional profiles were moderate. The degree of degradation due to the water table was high in all profiles, and due to salinity and alkalinity degree degradation was low to moderate except profiles 9, 10, 11, and 5 (high to very high), while due to soil compaction degree degradation was low except profiles 5, 7, 8 and 12 (moderate and high), while profile 6 was very high. After evaluating the soil productivity, it was found that its productivity indexes were decreased in most soil profiles, while it was stable in some profiles and increased in few profiles where the limiting factors of productivity were texture and structure of root zone, soluble salt content, and effective depth. There was a positive correlation between soil productivity and groundwater level, while there was a negative correlation between productivity and both salinity and alkalinity. Accordingly, it was necessary to take the necessary precautions to prevent the degradation of those properties by improving soil management, whether by adding leaching requirements and/or increasing the efficiency of drainage networks, thus obtaining the highest productivity and ensuring sustainable use of the soil.

Keywords: Chemical and Physical degradation, soil management, Dakahlia governorate, Egyptian lands.

Introduction

Land degradation is defined as the process that reduces the current capability and/or potential capability of soils to produce goods or services, such as crop production (Nenova and Behrend, 2016). Land degradation is also defined as a reduction in soil quality, due to direct or indirect man-made, processes expressed as a long-term reduction or complete loss of at least one of the following: biological productivity, environmental integrity, or value to humans (Olsson et al., 2019). The main causes of soil degradation fall under Physical, chemical, or biological degradation. Physical degradation processes include, erosion (by water, wind, or tillage), compaction, reduced water storage capacity and, soil sealing, while chemical degradation processes include, acidification, salinization, nutrient depletion, contamination.Finally, biological degradation processes include soil organic matter depletion, and Loss of biological diversity (Lal et al. 2019). According to FAO (2015) statistics, about 33% of the world's land is moderate to severely degrade

[*]Corresponding author email: Dr.MohamedSaeed84@gmail.com
DOI: 10.21608/ejss.2021.82334.1456
Received : 24/6/2021 ; Accepted: 26/8/2021

due to various forms of degradation. Therefore, using a scale by which to identify and assess the degree of land degradation and then develop a strategy to increase soil productivity and combat soil degradation (Hassan et al. 2017).

In arid and semi-arid conditions, the most active land degradation processes are salinization and alkalization, as the mainland degradation processes in irrigated lands are post-water logging (Dwivedi et al., 1999,Abuzaid, 2018and Abdel Kawy& Darwish, 2019). Although farmers and the Egyptian government have made great efforts in the past few decades to resist soil degradation, soil degradation is still considered the main obstacle to the development of the agricultural sector, as a result of the link between soil productivity and soil degradation (AbdelKawy and Ali, 2012). According to several studies, the main types of land degradation in Egypt, especially in the areas of in Nile Valley and Delta, are salinization, waterlogging, alkalization, and compaction. This is due to mistakes of human activity and unconscious management of the land such as excessive irrigation, improper use of machinery, and shortage of soil conservation processes (Mohamed et al., 2019).

Land degradation leads to a significant reduction in crop production and, consequently, farmers' net returns from crops, affecting the well-being of the rural population (Datta and de Jong 2002). According to the Soil Science Society of America (SSSA) (2008), soil productivity is defined as the capacity of a soil to produce a certain yield of crops or other plants with a specified system of management. However, the total land productivity is related to several factors including climate, parent material, and topography, as well as soil physical and chemical properties.By assessing the productivity of the land, agricultural practices can be improved and thus preserve the ability of the soil to produce various commodities (Field, 2017). Land productivity assessment is usually performed directly by field experiments to measure crop yield, or indirectly by the development and application of mathematical models for estimating the productivity index based on an integrated assessment of evaluation factors (Dengiz&Sa□lam, 2012 and Baskan et al., 2017).

Soil degradation leads to a negative impact on soil quality, thus reducing its productivity and grain yield, which ultimately adversely affects the environment. Therefore, it is important to carefully assess and predict the impact of land degradation on soil productivity (Gu et al., 2018).A good understanding of soil productivity and its association with land degradation can help decision-makers and farmers to use more appropriate agricultural management to increase productivity and maximize land use(Zhang et al., 2004).Agricultural lands are undergoing rapid changes as a result of natural and artificial factors. Monitoring these changes is essential to be able to update geospatial information systems to deal with these changes inappropriate ways and ensure the sustainable use of land resources (Lynden&Mantel, 2001 and Fadl& Sayed, 2020).

Few studies indicated the impact of soil degradation on productivity, especially in the Egyptian lands, so it was important to conduct the current study, which mainly aims to assess and monitor land degradation and soil productivity and the correlation coefficient between them during the past nine years in the Bilqas district as part of the Dakahlia Governorate.

Materials and methods

The current study was completed through several steps and stages, including**:**

Study area descriptions

This study was carried out at Bilqas District, Dakahlia Governorate, Egypt. The studied area covers about 683 km^2 and is located between the coordinates of 31°10' 36 '' and 31° 30' 42"N & 31° 14' 49" and 31° 33' 50" E (Figure 1). Elevations varies between 0.1 and 5 m above the mean sea level (a.m.s.l.). Also, the area is almost flat with a slope varying from 0 to 2%. Serag El-Din (1989) reported that Bilqas formation consists mainly of fine detritus materials ranging between the two classical end members; clay and silt including some sand tracks, particularly in the east and north-central parts of the prevent delta and sand dunes in the northern coastal area. The lithofacies of Bilqas formation shows distinct lateral variation from sand facies or silt, south of the Delta and extending to the east and west borders. The sediments of the Nile Delta had been deposited by the floodwaters of the Nile River in the recent geological period Land of Bilqas District belongs to the late Pleistocene era. The northern part of the study area is covered with marine deposits while the southern part is covered with alluvial deposits (Hagag, 1994 and Said, 1993). According to the keys to soil taxonomy, the soil temperature regime of the studied area is Thermic, and the soil moisture regime is Torric(Soil Survey Staff, 2014).

Fieldwork and laboratory analyses

Based on a previous study conducted by Abdel Kawy and Ali (2012) sixteen soil profiles were remapping and chosen to represent the landforms of the investigated area, as shown in Figure 2. The location of these profiles is the same location of the previous study detailed by Omar (2010). The morphological description of profiles was carried out according to the soil survey manual (USDA, 2012).

The soil samples were collected during 2018 and then air-dried, crushed to pass through a 2mm sieve, sieved, and stored to determine some soil physical and chemical properties. The analyses of soil include Soil pH (1:2 soil: water suspension), Exchangeable cations (1M ammonium acetate), Organic matter (Walkley and Blackmethod), Electrical conductivity (saturated soil paste extraction), Exchangeable sodium percentage (1M ammonium acetate), Bulk density (core method), Total calcium carbonate (Collin's calcimeter), and Particle size distribution (pipette method).

All laboratory analysis was carried out according to the method mentioned in Estefan et al. (2013) and Ryan et al. (1996).

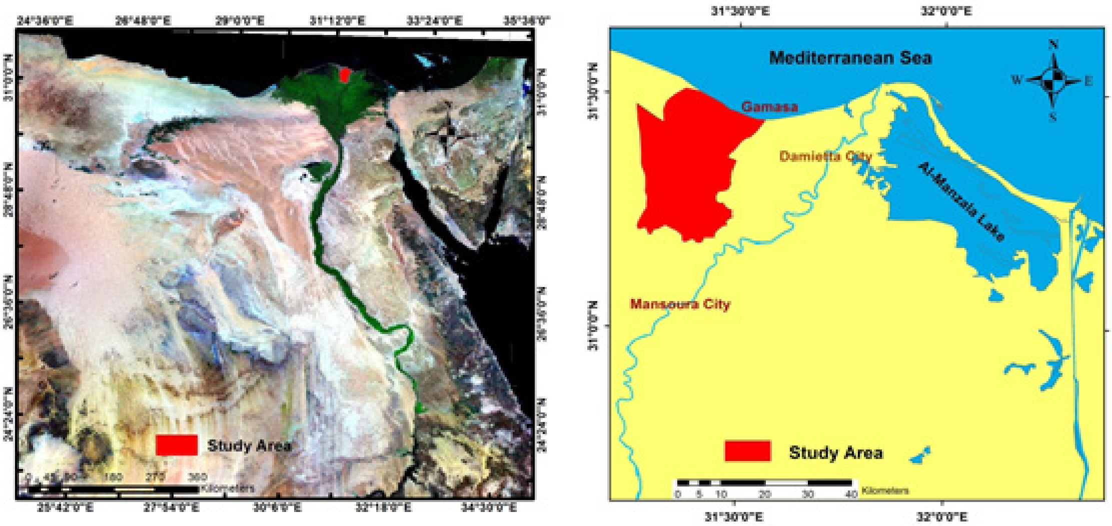

Fig. 1. location of the study area

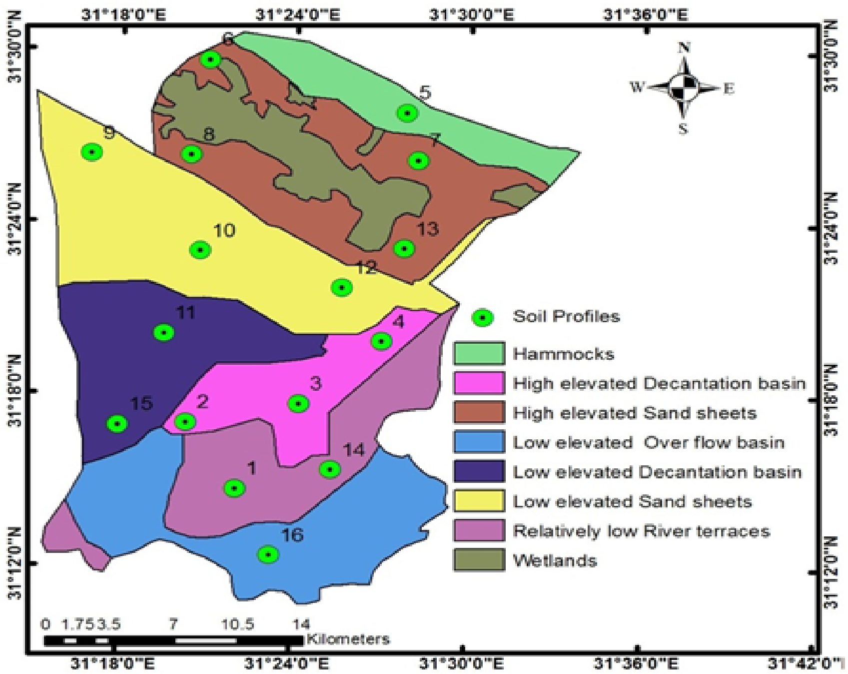

Fig. 2. Geomorphic map of the study area and location of soil profiles

Land degradation assessment

Land degradation status (hazards types and classes) in the studied area was evaluated according to the FAO/UNEP (1979) methodology as presented in Tables 1 and 2. The rate of land degradation was assessed by comparing the results of the current study with those reported by Omar (2010).

Soil productivity index

The soil productivity index (PI) was estimated for the years 2010 and 2018 using the model developed by Riquier et al.(1970) as follows:

PI =(H/100* D/100 * P/100 * T/100 *S/100 * O/100* A/100 *M/100) * 100

Where

PI:Productivity indexH:Moisture availability

D:DrainageP:Effective depth

T:Texture/structureS: Soluble salt concentration

O: Organic matter content

A:Mineral exchange capacity/nature of clay

M: Mineral reserve in B horizon.

Values of the land productivity index(LPI) and the corresponding productivity classes are shown in Table 3.

Statistical analysis

A statistical analysis of soil properties was carried out using SPSS 20 program to determine the correlation coefficient between the different degradation processes and soil productivity.

TABLE 1. Criteria used to determine the degree of the different degradation types

Critical/Hazard type	Indicator	Unit	Hazard class			
			Low	Moderate	High	Very high
Salinization	EC	dS/m	4	4-8	8-16	>16
Alkalinization	ESP	%	10	10-15	15-30	>30
Compaction	Bulk density	g/Cm^3	1.2	1.2-1.4	1.4-1.6	>1.6
Water Logging	Water Table level	Cm	150	150-100	100-50	<50

TABLE 2. Soil degradation classes and rates

Chemical degradation	Salinization (Cs) increase in (EC) per $dSm^{-1}year^{-1}$	Alkalinization (Ca) increase in $ESPYear^{-1}$
Non to slight	<0.5	<0.5
Moderate	0.5-3	0.5-3
High	3-5	3-7
Very high	>5	>7
Physical degradation	**Compaction/increase in bulk density per Mg $m^{-3}year^{-1}$**	**Water logging/increase in water table in $cmyear^{-1}$**
Non to slight	<0.1	<1
Moderate	0.1-0.2	1-3
High	0.2-0.3	3-5
Very high	>0.3	>5

Adapted FAO (1979).

TABLE 3. Classes of productivity (P) and potentiality (P*)

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

Results and Discussion

Physiography and Landforms

The main physiographic units in the study area were identified as shown in Table 4 and Figure 3; to include the following:

1- Aeolian plain: In general, it is dominated by sand sheets (mass accumulations of sand) as a result of wind activity as a soil-forming factor and is characterized by a gently undulating, and representing 51.5% of the studied area (352.6 km2). The largest in the area is the low elevated sand sheets (21.1%) and the smallest is the hammocks (6.6%).

2- Flood Plain: This landscape is generally characterized by an almost flat to gently undulating relief. It includes a group of Landforms, which were exposed to river sediments, but in varying amounts, representing 48.5% of the study area (330.6 km^2). The largest in the area is the low elevated overflow basin (15.0%) and the smallest is the high elevated decantation basin (8.4%).

Physiography and soils

Aeolian plain

Coarse texture (Sandy) predominates in this landscape. The depth of the soil profiles ranged from 55 to 90 cm (Moderately deep), while the electrical conductivity ranged between 1.5 to 39.5 dS m-1. with an average of 10.1 dS m-1. The exchangeable sodium percentage ranged between 2.41 to 26.8 with an average of 10.9. The average bulk density 1.32 Mg m-3.

Flood plain

The predominant texture in this landscape was clay to sandy clay loam texture (Moderately fine to fine texture), while the depth of the soil profiles ranged from 65 to 110 cm (Moderately deep to deep), while the electrical conductivity ranged between 1.0 to 16.0 dS m-1 with an average of 4.63 dS m-1. The exchangeable sodium percentage ranged between 2.2 to 19.3 with an average of 7.6. The average bulk density 1.06 Mg m-3.

Soil degradation

The soil degradation parameters were investigated for the different soils to assess the waterlogging, compaction, salinization, and alkalinization process in the studied areas. The rate of land degradation was estimated by comparing the main soil characteristics studied in 2010 and 2018 (Tables 5,6,7 and 8).The data for the profiles indicate that the degradation in it was as follows:

The rate of degradation was low in all soil profiles except for profiles 5, 9, 10, 12, 3, and 11 had a moderate rate of degradation, while the degree of degradation affected by the water table was high in all profiles, and the value of the degree of degradation was high in profiles 9 and 10 affected by salinity and alkalinity, and in the same context, the value of the degree of degradation was high in profiles 5 and 11 affected by salinity.

As for bulk density rate (compaction): This characteristic has improved significantly, as the density values decreased in all profiles with an average of 0.3 Mg m^{-3}, and this indicates the interest of farmers in the processes of adding organic fertilizers and phosphate mineral fertilizers. However, the degree of degradation resulted from soil compaction was very high in profile 6 while was high in profiles 5 and 7 and then decreased in profiles 8 and 12 and reached the lowest value in average in profiles 9, 10 and 13 (Non to slight).

Based on this information, an increase in the water table in the study area due to over-irrigation, poor drainage, and the damage of subsurface drainage networks plays an effective role in determining the depth of the soil profile and electrical conductivity values in the study area.

It is suggested that farmers take into account the interest in adding leaching requirements to remove excess salts in the soil profiles, and the competent authorities should pay attention to increasing the efficiency of drainage so that it is not a renewable source of soil degradation.

TABLE 4. Physiography, relief and landforms of the study area

Physiography	Relief	Landform	Profiles No.	Area %	Area km^2
Aeolian plain	Gently undulating	Hammocks	5	6.6	45.3
		High elevated Sand sheets	6,7,8,13	15.4	105.2
		Low elevated Sand sheets	9,10,12	21.1	144.4
		Wetlands	-----	8.4	57.7
Flood plain	Almost flat to gently undulating	Low elevated Over flow basin	16	15.0	102.6
		Low elevated Decantation basin	11,15	12.8	87.4
		High elevated Decantation basin	2,3,4	8.4	57.1
		Relatively low River terraces	1,14	12.2	83.5

TABLE 5. Monitoring of the mainland characteristics in the Aeolian plain landscape of the study area

Profile No.	Water table level (cm)		Bulk density Mg m^{-3}		EC dsm^{-1}		ESP		Texture	Drainage
	2010	2018	2010	2018	2010	2018	2010	2018		
5	65	55	1.73	1.42	3.24	39.5	0.86	3.06	S	W
6	82	80	1.77	1.67	1.82	5.7	0.74	3.63	S	M
7	82	90	1.77	1.53	1.23	3.2	0.92	4.54	S	M
8	82	80	1.69	1.39	0.3	1.5	1.19	2.41	S	M
9	65	65	1.3	1.05	5.84	13.6	10.48	26.2	SC	P
10	100	75	1.29	0.99	0.81	8.3	11.66	26.8	C	P
12	63	55	1.72	1.27	0.53	5.4	1.33	13.2	S	M
13	100	80	1.49	1.22	0.52	3.6	4.67	7.57	SL	M
average	79.88	72.5	1.6	1.32	1.79	10.1	3.981	10.9		
max	100	90	1.77	1.67	5.84	39.5	11.66	26.8		
Min	63	55	1.29	0.99	0.3	1.5	0.74	2.41		

EC, electrical conductivity; ESP, exchangeable sodium percentage; S, sand; SC,Sandy clay;C, Clay;SL, Sandy loam; W=Well Drained; M, Moderately Well Drained; P, Poorly Drained.

TABLE 6. Monitoring of the mainland characteristics in the Flood plain landscape of the study area

Profile No.	Water table level (cm)		Bulk density Mg m^{-3}		EC ds m^{-1}		ESP		Texture	Drainage
	2010	2018	2010	2018	2010	2018	2010	2018		
1	100	100	1.42	1.09	0.34	1.3	3.84	2.19	L	W
2	100	100	1.25	1.09	0.33	1	9.75	2.46	C	W
3	100	85	1.22	1.07	0.68	5.8	7.03	14.38	C	W
4	100	110	1.26	1.03	0.57	1.5	5.06	2.37	C	W
11	100	65	1.45	1.04	0.62	16.7	3.88	19.28	SCL	P
14	90	80	1.33	1.09	0.63	1.9	5.08	3.06	CL	W
15	65	70	1.42	1.07	0.92	5.8	7.33	13.25	SCL	M
16	90	80	1.36	1.01	0.39	3	4.79	4	CL	W
average	93.1	86.3	1.34	1.06	0.56	4.63	5.85	7.624		
max	100	110	1.45	1.09	0.92	16.7	9.75	19.28		
Min	65	65	1.22	1.01	0.33	1	3.84	2.19		

EC, electrical conductivity; ESP, exchangeable sodium percentage; L, loam, clay, SCL, Sandy clay loam;C L, clay loam;and C, Clay; M, Moderately Well Drained;W, Well Drained; P, Poorly Drained.

TABLE 7. Land degradation ratesin the different soil profiles of the studied area

	Profile No.	W	C	S	A		Profile No.	W	C	S	A
Aeolian plain landscape	5	2	1	3	1	Flood plain landscape	1	1	1	1	1
	6	1	1	1	1		2	1	1	1	1
	7	1	1	1	1		3	2	1	2	2
	8	1	1	1	1		4	1	1	1	1
	9	1	1	2	2		11	3	1	2	2
	10	2	1	2	2		14	1	1	1	1
	12	1	1	2	2		15	1	1	2	1
	13	2	1	1	1		16	1	1	1	1

W, water logging; C, compaction; S, salinity; A, alkalinity; 1,Non to slight; 2, Moderate; 3, High.

TABLE 8. Land degradation degrees in the different soil profiles of the studied area

	Profile No.	W	C	S	A		Profile No.	W	C	S	A
Aeolian plain landscape	5	3	3	4	1	Flood plain landscape	1	3	1	1	1
	6	3	4	2	1		2	3	1	1	1
	7	3	3	1	1		3	3	1	2	2
	8	3	2	1	1		4	2	1	1	1
	9	3	1	3	3		11	3	1	4	3
	10	3	1	3	3		14	3	1	1	1
	12	3	2	2	2		15	3	1	2	2
	13	3	1	1	1		16	3	1	1	1

W, water logging; C, compaction; S, salinity; A, alkalinity ; 1, Non to slight; 2, Moderate; 3, High; 4, Very High.

Land productivity

The data in Table 9 and Figures 3 and 4 indicate that the land productivity index (LPI) decreased in the study area in general as follows: In the Aeolian plain unit was Most of the soil consists of class IV and V in terms of agricultural use, the average value of the LPI in the previous study was 13.9, compared to 8.25 in the current study. Also, the highest value of the LPI in the previous study decreased from 19.4 (Moderate) to 13.8 (Poor) in the current study. In contrast, the lowest value of the LPI in the current study was 0,5 (Extremely Poor), compared to 9.9 (Poor) in the previous study.In general, the LPI decreased in all profiles except for profiles 7 and 8. The productivity index for them was stable.

In the soils of the Aeolian plain, the limiting factors that affected the productivity index values were texture and structure of root zone (T), Soluble salt content (S), and Effective depth (P).The Flood Plain Unit: Most of the soil in this unit consists of class II, the value of the LPI in it ranged between 42 (the current study) and 47 (the previous study). The highest value of the LPI was 68 (excellent) in the current study was 62 (good) in the previous study. In the same context, the lowest value of the LPI in the current study was 8.7 (poor), while the lowest value in the previous study was 34.9 (good).In general, the value of the LPI recorded a decrease in profiles 3, 11, 15, and 16, while that value increased in profiles 1 and 2 and did not change in profiles 4 and 14.In flood plain soils, the limiting factors that affect the LPI values were the soluble salt content (S) and effective depth (P).In general, the results indicate that nearly half of the area of Bilqas District is productive land

Soil degradation correlates with productivity

Descriptive statistical analyses were performed in the SPSS software package, to find out the degree of correlation of each of the degradation factors separately on soil productivity between 2010 and 2018.Through the results obtained (Table 10), the following was found,

soil degradation factors are obvious in the study area, salinity, alkalinity, and waterlogging; Usually, salinity and alkalinity result from excessive irrigation due to the use of traditional flood irrigation, the lack of leaching requirements, and damage of irrigation network in addition to the dry climate (high evapotranspiration rate). All these factors often lead to the accumulation of salt in the root zone of the plant. Salinity has negative effects on crops in different and direct ways, whether it is reduced water availability due to osmotic effects, specific ion toxicity, and/ or disturbances in the nutrient relationship. On the other hand, alkalinity affects the plant but indirectly, as it negatively affects the physical properties of the soil, which leads to reduced oxygen diffusion and an increase in soil strength. While waterlogging due to insufficient drainage causes changes in the soil environment such as decreased O_2 and increased levels of CO_2, NH_4, and C_2H_4. These changes adversely affect root respiration and nutrient uptake, thus reducing crop yield potential (Rashed2015,Minhas et al.2020, Zein et al.2020and Dhaouadi et al.2021).

Concerning the soils of the Aeolian plain, it was noticed that the productivity was affected by the Water table level and salinity in general. The highest correlation coefficient (0.897) and highly significant (p <0.01) was found for the productivity with a water table (2018), It was also observed that significant correlations (p <0.05) was found for the productivity with a water table (2010) in addition to salinity (2018).In the same context, there was no clear correlation coefficient between the productivity of floodplain soil and any of the degradation indicators in 2010, while there was a correlation coefficient between productivity and all degradation indicators in 2018 except for the bulk density. Where the highest correlation coefficient (although it is negative) and high significance ($p < 0.01$) for productivity with salinity and alkalinity (2018), and significant correlations ($p < 0.05$) for productivity with groundwater level (2010).

TABLE 9. Changes in soil productivity index and classes between 2009 and 2018

	Profile No.	Rating		Classes		Difference	Change
		2010	2018	2010	2018		
Aeolian plain landscape	5	15.6	0.5	IV	V	15.1	-
	6	13.8	7.7	IV	IV	6.1	-
	7	13.8	13.8	IV	IV	0	0
	8	11	11	IV	IV	0	0
	9	10.4	3.9	IV	V	6.5	-
	10	17.4	10.9	IV	IV	6.6	-
	12	9.9	4.6	IV	V	5.3	-
	13	19.4	13.6	III	IV	5.8	-
Flood plain landscape	1	61.8	68.6	II	I	6.9	+
	2	46.7	54.9	II	II	8.2	+
	3	46.7	30.7	II	III	15.9	-
	4	49.4	49.4	II	II	0	0
	11	34.9	8.7	II	IV	26.2	-
	14	44.5	44.5	II	II	0	0
	15	46.7	38.4	II	II	8.2	-
	16	49.4	44.5	II	II	4.9	-

-: decreased, 0: no change, +: increased.

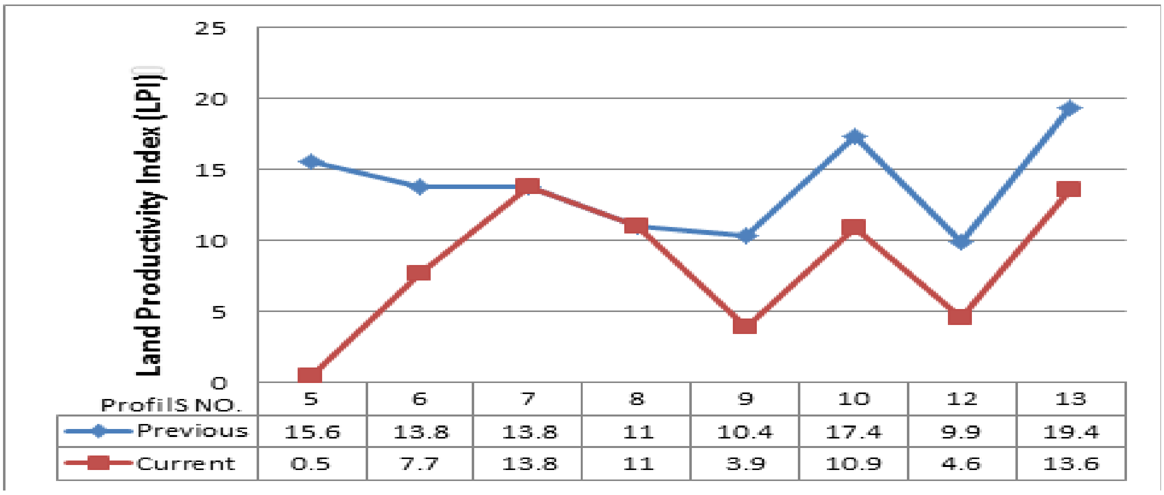

Fig. 3. Changes in the LPI in the different Soil Profiles in the Aeolian plain units

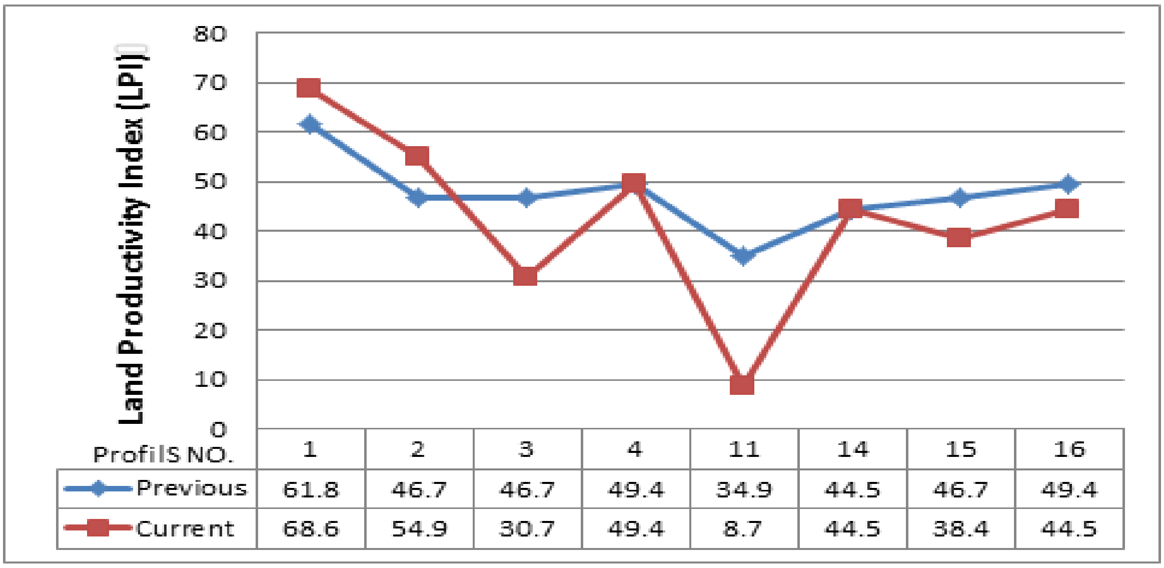

Fig. 4. Changes in the LPI in the different Soil Profiles in the flood plain units

TABLE 10. Parameter of soil degradation and its correlation with the rate of soil productivity

Aeolian plain		**Water table**	**Bulk density**	**EC ds/m**	**ESP**
Rating 2010	Pearson Correlation	.753*	-.242	-.279	.200
	Sig. (2-tailed)	.031	.563	.503	.634
	N	8	8	8	8
Rating 2018	Pearson Correlation	.897**	.043	-.764-*	-.128
	Sig. (2-tailed)	.003	.920	.027	.763
	N	8	8	8	8
Flood plain		**Water table**	**Bulk density**	**EC ds/m**	**ESP**
Rating 2010	Pearson Correlation	.063	-.049	-.444	-.099
	Sig. (2-tailed)	.883	.909	.270	.816
	N	8	8	8	8
Rating 2018	Pearson Correlation	.753*	.373	-.907-**	-.887-**
	Sig. (2-tailed)	.031	.363	.002	.003
	N	8	8	8	8

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Conclusion

The present study aims to assess soil degradation and productivity and the relationship between them. This was accomplished by comparing the soil properties of the study area in two time periods, 2010 and 2018. According to the methodology used in this research, the obtained results indicated that the main types of human-induced land degradation in the investigated areas are salinization, alkalinization, and water-logging. Most of the soil profiles were examined under high physical degradation and low chemical degradation . In general, the LPI decreased in all profiles except for profiles 4,7,8 ,and 14.The productivity index for them was stable to a high degree, while that value increased in profiles 1 and 2 . There was also a clear correlation coefficient between soil productivity and water table level (positive), and salinity and alkalinity (negative), so it is recommended to pay attention to the application of leaching requirements and to increase drainage efficiency, and therefore the necessity of scheduling irrigation in the study area appropriately and firmly to reduce degradation and thus increase soil productivity and crop yield.This study focused on the need to use more specific approaches to the relationship between soil degradation factors and productivity and which of these factors is most influential. Thus, the results obtained will serve as a scientific basis to ensure the sustainable management of these lands of the study area and the Egyptian lands in general now or in the future and to prevent further degradation of soil resources.

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