J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol. 15 (11):313 - 319, 2024

Journal of Soil Sciences and Agricultural Engineering

Journal homepage & Available online at: www.jssae.journals.ekb.eg

Assessment of Land Degradation Risk in Kafr El-Sheikh Governorate Using Remote Sensing and GIS Techniques

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ABSTRACT

The selected area, located in Kafr El-Sheikh Governorate and covering an area of 371280 ha, had 24 soil profiles described. The geomorphologic features in the study comprised three forms: Flood plain, Aeolian deposits, and and Lacustrine deposits. The main landforms are: overflow basins (OB), decantation basins (DB), high river terraces (RT1), moderate river terraces (RT2), low river terraces (RT3), levees (L), sand sheet (SS), hammocky areas (HA), wet sabkha (WS), and dray sabkha (DS). The most important problems of deterioration in the study area sodicity, water logging, salinity, and sompaction. The area affected by salinity, compaction, Alkalinization, and water logging problems, which covered 14.78, 10.60, 14.78 and 45.39% of the total area, respectively. The WS and DS mapping units were characterized by severe chemical degradation. Additionally, there was a physical degradation risk affecting 14.78% of the study area, The RT1 mapping unit exhibits very high levels of chemical degradation, while physical degradation remains low, accounting for 5.47% of the study area, In the OB mapping unit, chemical degradation is also high, with physical degradation remaining low, representing approximately 14.01% of the total area. There is a moderate risk of physical degradation and a low risk of chemical degradation, representing 8.08% of the total study area, in the SS mapping unit. Additionally, the DB, RT2, and RT3 mapping units show low risks of both chemical and physical degradation, accounting for 39.14% of the study area.

Keywords: Land degradation, Kafr El-Sheikh Governorate, Remote sensing, and Geographic Information Systems (GIS)

INTRODUCTION

Soil is the basic supply of human nutritional needs and is considered a limited, non-renewable natural resource, (Aksoy et al., 2009 and Shokr et al., 2021). Sustainability is maintaining land and water resources, from deterioration (Ceotto, 2008 and Hillel, 2009). The area of land exposed to some risks of drought and degradation by water logging, salinization, and sodification on a global scale is about 43 million hectares about 30% (Rozanov, 1994). Land degradation has increased in the current century due to agricultural intensification, production pressure, urban sprawl, deforestation, climate change such as drought, and coastal erosion due to salinity (Delang 2018; Janečková et al. 2023).L and degradation is due to several reasons, including climate change, especially drought, as well as human activities (AbdelRahman et al. 2022). In a large number of countries, the area of land affected by degradation was about 33%, the population density also reached about 2.6 billion populations (Adams and Eswaran, 2000). The most serious global problem on a global level is land degradation.Every year, about 6 million hectares are lost and become unproductive due to degradation processes (Asio et al., 2009). The most important risks of soil degradation in Egypt are water logging, compaction, sodicity and salinity (El Baroudy, 2005 and 2010). Land degradation in Egypt occurs on 34.4% of the middle Nile Delta, due to salinity and sodicity (Shalaby, 2013). The risks of soil degradation are facing Problems threatening food security in the last period (Afifi and El Semary 2018; Han, et al. 2019; and Wubie and Assen 2020). Land degradation decrees soil capacity to produce crops (El Baroudy, 2011), one of the most obvious challenges at the high level Soil sodicity, biological, physical and salinization degradation (Liberti et al., 2009). Field monitoring can be implemented and land degradation problems can be identified using remote sensing (RS) and GIS techniques, (Gao and Liu, 2008). Geographic Information Systems and remote sensing can be recognition desertification and soil degradation problems. (Pinzon and Tucker, 2014).

Research objectives: (1) Making a geomorphological map of Kafr El-Sheikh Governorate, (2) To identify the geomorphological units and (3) producing maps of land degradation risks based on GIS and remote sensing techniques.

MATERIALS AND METHODS

Description of the study area

The studied area in Kafr El-Sheikh governorate is represented by an area of 371280 ha. The study area is located in the Nile delta, Egypt. It is bordered to the north by the Mediterranean Sea, to the south direction Gharbia Governorate, to the east by Dakahlia Governorate, and to the west by Elbehira Governorate. The coordinates of the study area are 30° 20′ E and 31° 20′ E, and latitudes 31° 00′ N and 31° 40′ N. (Fig. 1). This area is classified as Pleistocene, specifically the deposits associated with the Neonile (Said 1993). According to the USDA (2010), the thermal and humidity regime of the study area is classified as Torric.

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DOI: 10.21608/jssae.2024.322160.1254

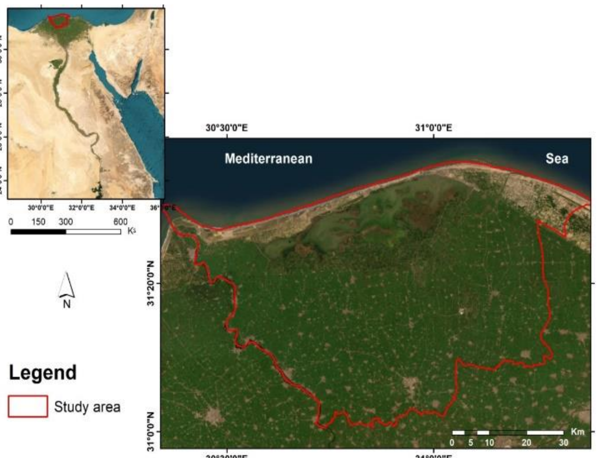

Fig. 1 Location of the study area

Digital Image Processing and Software Used

The Landsat ETM+ image was enhanced using ENVI 5.3 software to improve image quality (Lillesand and Kiefer, 2007). The image quality is improved by applying image enhancement algorithms to the sensor data. The enhanced image is generally easier to interpret than the original one. A digital elevation model (DEM) was extracted through the visual interpretation of satellite images, topographic and field work survey using Arc Scan to obtain a three-dimensional natural terrain. The Landsat ETM+ image can be combined with a digital elevation model to obtain a clearer view of the landscape. Landform units were used as basic geo-relief descriptors in soil and vegetation mapping, and establish the soil database (Čurlík and Šubrina, 1998).

Field Studies and Laboratory Analyses

Soil survey was conducted to identify the landscape characteristics and interpret satellite images. The soil mapping units are covered by 24 soil profiles (72 soil samples). The soil laboratory manual was manual followed was that of the USDA (2004) to conduct laboratory analyses. In the saturated soil solution extract, Electrical conductivity (EC) was estimated, and the exchangeable sodium percentage (ESP) was determined using ammonium acetate (NH_4OAC). Soil bulk density was determined using the calcimeter, and total calcium carbonate was estimated. Particle size distribution was determined using the international pipette method.

Method of Land Evaluation

The degree of soil degradation rate was determined according to FAO/UNEP (1978) using some physical and chemical properties, as shown in Table 1

Table 1. Criteria of Soil Degradation Risk

Degradation Hazard Type	Indicator	Degree	Degradation Hazard Class			
			Low(1)	Moderate(2)	High(3)	Very High(4)
Sodicity	ESP	%	Less than 10	10 to 15	15 to 30	More than 30
Salinization	EC	dS m^{-1}	Less than 4	4 to 8	8 to 16	More than 16
Water Logging	Soil Depth	cm	More than 150	100 to 150	100 to 50	More than 50
Compaction	Bulk Density	Mgm^{-3}	More than 1.6	1.4 to 1.6	1.2 to 1.4	Less than 1.2

Land Degradation Risk Assessment

According to FAO/UNEP (1978, 1979), the Land degradation risk (LDR) has been determined based on climatic factors and soil topography, as expressed in the following equation:

Land Degradation Risk (LDR) = CR×SR×TR

Where **SR: soil rating; TR: topographic rating; CR: climatic rating**

RESULTS AND DISCUSSION

Physiographic Features and Soil Classification of the Study Area

The geomorphologic features (Figure 2) comprised, Flood plain, Aeolian deposits and Lacustrine deposits. The Flood plains include1- Decantation basins(DB): 52017 ha, 14.01% from the investigated area, 2- Overflow basins (OB): 52041 ha 14.01%, 3-High River terraces (RT1): 20299 ha 5.47%, 4-Moderate River terraces (RT2): 76283 ha 20.54%, 5- Low River terraces (RT3)17075 ha 4.59%, 6- Levees (L) 2866 ha 0.79%. The Aeolian deposits include: 1- Sand Sheet: 30024 ha 8.08% from the investigated area, 2- Hammocks areas: 802 ha 0.22% The Lacustrine deposits include: 1- Wet sabkha (WS) 47457 ha 12.78% from the investigated area 2- Dry Sabkha (DS) 7426 ha 2.00%. Other features include: Water bodies (WB) 52368 ha 14.11% and Fish Ponds (FP) 12622 ha 3.39%.

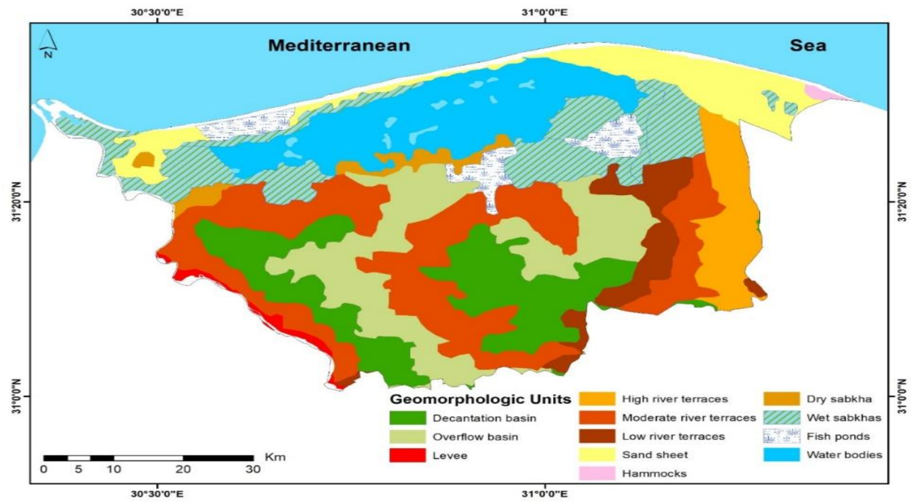

Fig. 2. Geomorphologic Map of Soil Profiles in the Study Area.

Soil classification was according to USDA (2014) to describe the soil profile in the study area. The classification was done according to the sub great group, and to family level. Soils in the study area are Entisols (Table 2). The soil map was reduced to scale of 1: 100,000. There are 4 taxonomic units: *Typic Torrifluvents*, *Vertic Torrifluvents*, *Typic Haplosalids* and *Typic Torripsamments* which occupy 48.56%, 10.06%, 14.78%, and 8.08%, respectively, of the studied area.

Table 2. Geomorphic Units and Landforms of the Study Area

	Geomorphic Unit	Landform	Mapping Unit	Area (km^2)	Area (ha)	of Total Area (%)	Soil Taxonomy
Flood Plain	Decantation Basin (DB)	Decantation Basin	DB	520.17	52017	14.01	*TypicTorrifluvents*
	Overflow Basin (OB)	Overflow Basin	OB	520.41	52041	14.01	*TypicTorrifluvents*
	River Terrace (RT)	High River Terrace	RT1	202.99	20299	5.47	*VerticTorrifluvents*
		Moderate River Terraces	RT2	762.83	76283	20.54	*TypicTorrifluvents*
		Low River Terrace	RT3	170.75	17075	4.59	*VerticTorrifluvents*
	Levee (L)	Levees	L	28.66	2866	0.79	--------
Aeolian Deposit	Sand Sheet (SS)	Sand Sheet	SS	300.24	30024	8.08	*Typic Torripsamments*
	Hammock Area (H)	Hammocks Area	H	8.02	802	0.22	---------
Lacustrine deposit	Wet Sabkha (WS)	Wet Sabkha	WS	474.57	47457	12.78	*Typic Haplosalids*
	Dray Sabkha (DS)	Dray Sabkha	DS	74.26	7426	2.00	*Typic Haplosalids*
Others	Water Bodies (WB)	Water Bodies	WB	523.68	52368	14.11	------------
	Fish Ponds (FP)	Fish Ponds	FP	126.22	12622	3.39	------------------
Total area				3712.80	371280	100	

Land Use/Cover in the Study Area

Land use/cover classification is a basic step for understanding the environmental parameters and their relationships with development. classification was performed on landsat 8 imagery in the study area. This type of classification depends on the strength of the reflected rays within certain spectral ranges, and the user determines the number of categories that have been classified (Rashed, 2010). Supervised is a process which identifies pixels of unknown identity. The study area was divided into 4 classes: Agriculture, Bare lands, Urban and Water bodies.

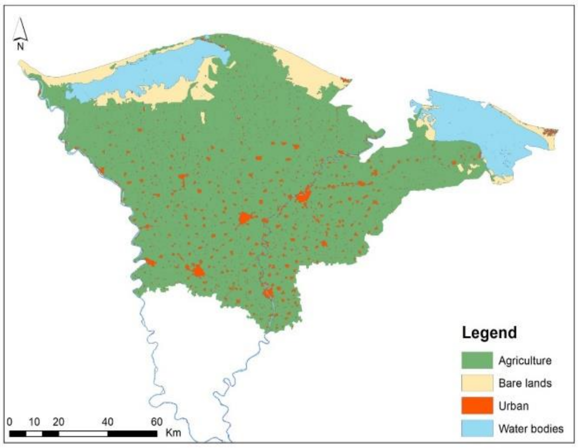

Figure 3. Land Use/Land Cover Features.

Soil Properties and Evidence of Deterioration

Table 3 shows the soil characteristics and physiographic units in the study area. The ranges of sodicity, soil depth, slope, drainage condition, bulk density and soil texture are as follows: 70 to 150 cm, 1.1 to 2.2%, 0.90 to 44.67 dSm^{-1}, 2.37 to 21.30%,1.17 to 1.75g/cm3, poor to well, and sand to clay, respectively. Alkalization, salinization, compaction and water logging, are rated from low to very high. Soils in the RT1, OB, RT3 and RT2 mapping units had EC values < 4 dSm^{-1} (non-saline), while values of 4 to 8 dSm^{-1} were found in DB units and > 8 dSm^{-1} was found in sandy SS, WS and DS units. Soil ESP ranged between 2.37and 21.30. Soils of RT3, RT1, OB, RT2 and DB units had ESP values less than 10 (low), while values in the range of 10 to 15(moderate) values less than 10 (low), while values in the range of SS unit. Soil depth ranged from 70 to 150 cm. The soils in the DB, RT3, RT2, DS, RT1 and SS units had depths of 100 to 150 cm, while the soils in the WS and OB units had depths of 50 to 100 cm. Soil bulk density ranged between 1.17 and 1.75 Mg/m3. Soils in the RT1and RT3 units had values < 1.2 Mg/m3, while soils in the OB and DS unit had values between 1.4 – 1.6 Mg/m^3 Soils in the DB and RT2 mapping units had soil compaction values of 1.2 to 1.4 Mg/m^3, and soils in the WS and SS units had values greater than 1.6 Mg/m^3.

Table 3. Soil Physical and Chemical Properties of the Mapping Units.

Mapping Unit	Soil Depth (cm)	Slope (%)	EC (dS/m)	ESP	Bulk Density (Mg/m^3)	Drainage	Texture Class
DB	100	1.4	4.29	8.07	1.24	Well	Clay
OB	90	1.8	1.22	4.93	1.45	Poor	Clay
RT1	120	1.3	0.90	2.71	1.17	Well	Clay loam
RT2	105	1.4	2.48	6.28	1.32	Well	Clay loam
RT3	100	1.1	1.54	2.37	1.17	Good	Clay
SS	150	2.2	12.25	11.93	1.75	Well	Sand
WS	70	1.7	36.63	16.95	1.62	Poor	Loamy Sand
DS	110	2.1	44.67	21.30	1.60	Good	Loamy Sand

Assessment of Land Degradation Hazards

According to Table 4, the risks of soil degradation are explained, with the most significant problems in the study area being sodicity, salinity, compaction and water logging. Soils that suffer from very high salinity problems represent 14.78% of the investigated. The risk of compaction was very high was in 10.60% from the investegated area. The risk of alkalinization was high represented 14.78% from the investegated area. Where the risk water logging of was very high with percentage was 45.39%, of the investigated shown in Figure 4, 5, 6 and 7.

Table 4. Land degradation paramerters and rates.

Mapping Unit	Salinity (S)	Alkalinization (A)	Compaction (C)	Water Logging (W)
DB	Moderate	Low	High	High
OB	Low	Low	Moderate	High
RT1	Low	Low	Very High	Moderate
RT2	Low	Low	High	Moderate
RT3	Low	Low	Very High	High
SS	High	Moderate	Low	Low
WS	Very high	High	Low	High
DS	Very high	High	Moderate	Moderate

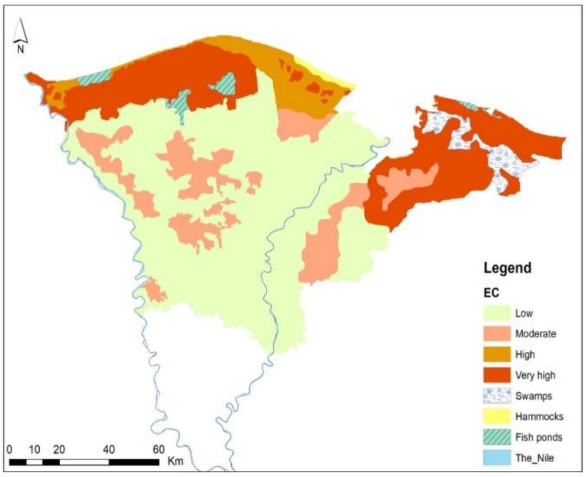

Figure 4. Soil Salinity Map

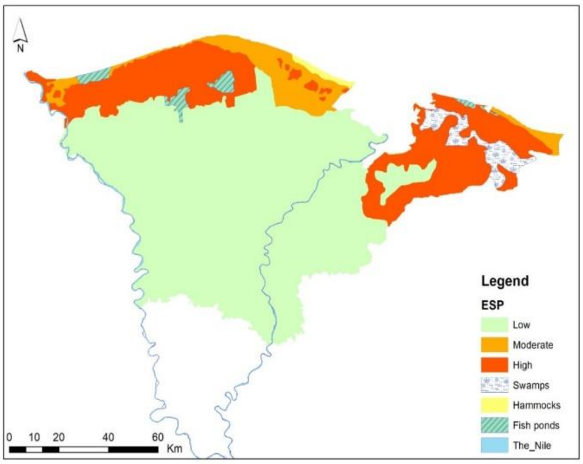

Figure 5. Soil Alkalization Map

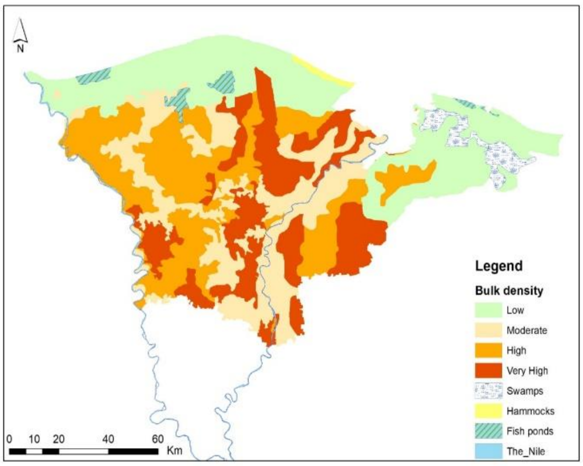

Figure 6. Soil Bulk Density Map

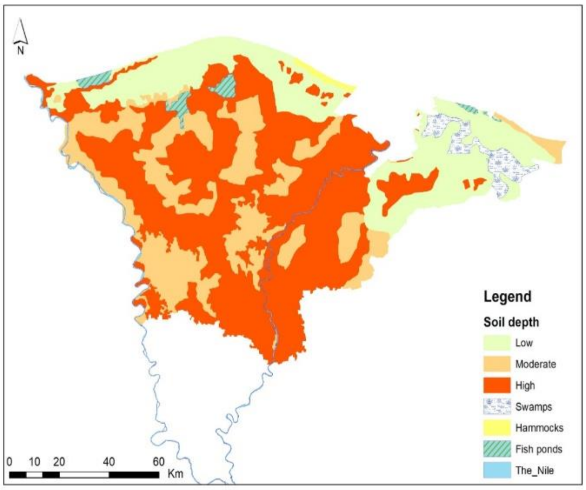

Figure 7. Soil Depth Map

Land Degradation Risk

According to FAO/UNEP (1978, 1979), a specific model was adopted to assess the risks of soil degradation using some equations. The deterioration risk is assessed according to several factors: exchangeable sodium percentage, salinity, groundwater salinity, soil salinity, soil texture, soil depth, surface slope, irrigation water quantity, monthly and annual Precipitation and potential Evapotranspiration, the impact of these factors can be identified through the interpretation of chemical and physical properties, as shown in Figure 8. Land degradation risk classes and ratings shown in the Table 5.

Climatic characteristics related to chemical degradation are calculated as follows:

$$CRc = PET/(Pa + Q)\ 10 \qquad \text{eq. (1)}$$

Where, CRc is the climatic rating of chemical degradation risk, PET is the potential evapotranspiration, Pa is the annual precipitation and Q is the amount of irrigation water used (in mm).

The risk of chemical degradation was calculated based on the climate rating as follows:

$$CRc = (PET/1000)*EC_{gw} \qquad \text{eq. (2)}$$

Where, EC_{gw} = the groundwater salinity.

The risk of physical degradation was calculated based on the climate rating using the following equation:

$$CRp = \Sigma P^2 M/Pa \qquad \text{eq. (3)}$$

Where, CRp is the climatic rating of physical degradation risk, PM is the monthly precipitation (in mm) and Pa is the annual precipitation (in mm).

The risk of physical degradation was calculated based on the soil texture rating according to the following equation:

$$SRp = Si/C \qquad \text{eq. (4)}$$

Where, SRp: soil texture according tophysical degradation problems, Si: is the soil content of silt, and C: is the soil content of clay

The soil degradation problems in the study area were estimated using the following equation:

$$\text{Land Degradation Risk (LDR)} = CR \times SR \times TR \qquad \text{eq. (5)}$$

Where, SR: is the soil rating; TR: is the topographic rating; CR: is the climatic rating

Table 5. Classes and Ranges for Land Degradation Risk.

Land Degradation Risk Class	Range	Class
I	less than 2	Low
II	2 to 4	Moderate
III	4 to 6	High
IV	More than 6	Very High

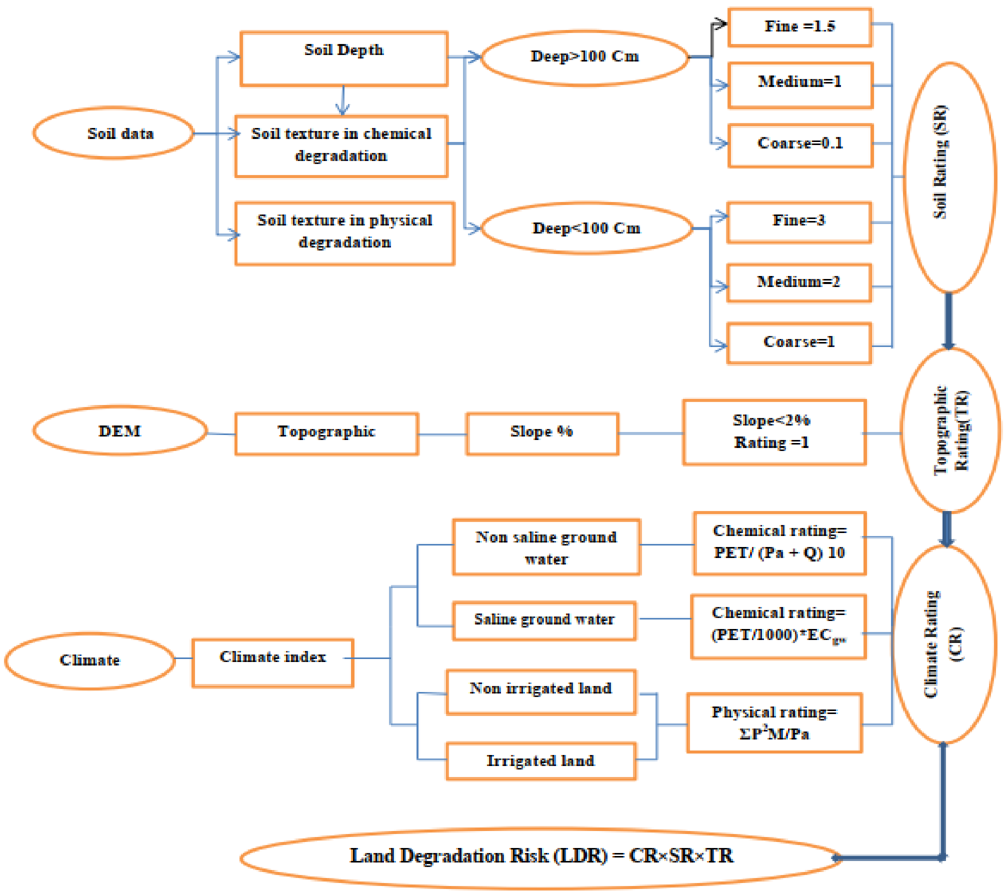

Figure 8. Flowchart of land degradation risk model.

Classification and Determination of Soil Degradation Risks in the Study Area

Tables 6 and 7 explain the chemical degradation was low in the DB, RT2, RT3, and SS units. The area of these soils was 175,399 ha, which is about 47.22% of the investigated area. An area of 52041 ha, representing 14.01% of the total area, was at relatively high risk of deterioration, in the soils of the OB mapping unit. An area of 75,182 ha, representing 20.25% of the total area, was at very high risk of deterioration in the soils of the RT1, WS, and DS mapping units. Figures 9 and 10, along with Table 8, show the physical degradation risk in the study area. The risk of physical degradation ranged from low to moderate and high. The areas with low degradation problems are found in the DB, OB, RT1, RT2, and RT3 mapping units, covering an area of 217,715 ha (58.62% of the total area). The areas at moderate risk were located in the soils of the SS mapping unit, covering 30024 ha (8.08% of the total area). The areas with high degradation problems are found in the WS and DS mapping units, covering 54,883 ha (14.78% of the total area).

Table 6. Calculation of Chemical and Physical Degradation Problems in the Studied Area.

Mapping Unit	Chemical Degradation Risk = SR×TR×CR						Physical Degradation = SR×TR×CR					
	SR	TR	CR	Risk	Class		SR	TR	CR	Risk	Class	
DB	3.0	1	0.02	0.06	I	Low	0.66	1	1.50	0.99	I	Low
OB	3.0	1	1.76	5.28	III	High	0.87	1	1.50	1.30	I	Low
RT1	1.5	1	4.25	6.37	IV	Very High	0.79	1	1.50	1.18	I	Low
RT2	1.5	1	0.02	0.03	I	Low	0.76	1	1.50	1.14	I	Low
RT3	3.0	1	0.02	0.06	I	Low	0.74	1	1.50	1.11	I	Low
SS	0.1	1	3.65	0.36	I	Low	1.46	1	1.50	2.19	II	Moderate
WS	2.0	1	7.25	14.5	IV	Very High	3.34	1	1.50	5.01	III	High
DS	1.0	1	9.60	9.60	IV	Very High	3.39	1	1.50	5.08	III	High

SR, soil rating; TR, topographic rating; CR, climatic rating

Table 7. Distribution and Classification of Chemical Degradation Risk.

Chemical degradation risk rating	Grade	Class	Mapping unit	Area (ha)	Area %
<2	1	Low	DB, RT2, RT3 and SS	175,399	47.22
2-4	2	Moderate	N/A	N/A	N/A
4-6	3	High	OB	52,041	14.01
>6	4	Very High	RT1, WS and DS	75,182	20.25

N/A: Not Applicable

Table 8. Distribution and Classification of Physical Degradation Risk.

physical Degradation Risk Rating	Grade	Class	Mapping Unit	Area (ha)	Area %
<2	1	Low	DB, OB, RT1, RT2 and RT3	217,715	58.62
2-4	2	Moderate	SS	30,024	8.08
4-6	3	High	WS and DS	54,883	14.78
>6	4	Very high	N/A	N/A	N/A

N/A: Not Applicable

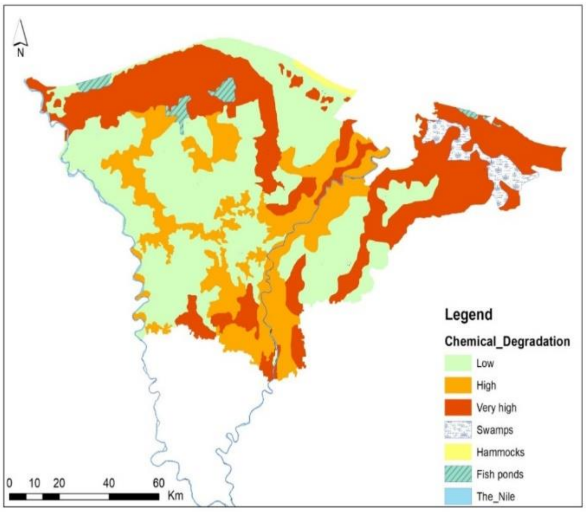

Figure 9. Chemical Degradation Risk in the Study Area

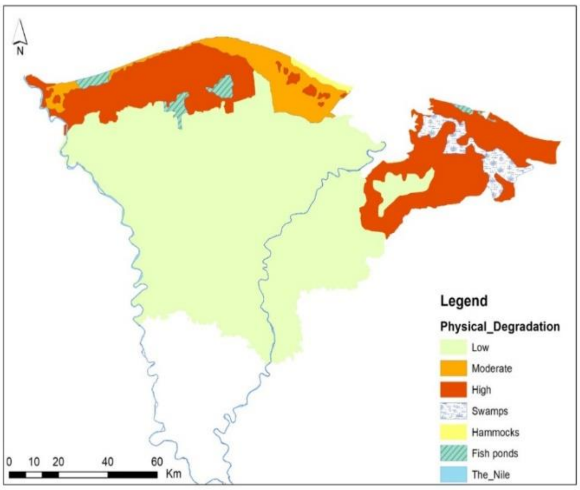

Figure 10. Physical Degradation Risk in the Study Area

CONCLUSION

The soils in Kafr El-Sheikh Governorate showed a low risk of chemical degradation in the DB, RT2, RT3, and SS mapping units. There is a high risk of chemical degradation in soil of OB mapping unit, while a very high risk occurred in the soils of the RT1, WS, and DS mapping units. The risk of physical degradation was low in mapping units of DB, OB, RT1, RT2, and RT3. Moderate physical risk was observed in the soils of The SS mapping unit. High physical risk was observed in the soils of the WS and DS mapping units. Land use/cover classification in the study area was divided into four classes: Agriculture, Bare lands, Urban and Water Bodies, based on an unsupervised classification performed on Landsat-8 imagery.

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تقييم مخاطر تدهور التربة في محافظة كفر الشيخ باستخدام تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية

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الملخص

تمثل منطقة الدراسة في محافظة كفر الشيخ مساحة قدرها حوالى 3712.8 كم2. تتألف الوحدات الجيومورفولوجية في منطقة الدراسة من السهول الفيضية والرواسب الريحية والرواسب البحيرية. تمثل التربة المتأثرة بخطر الملوحة المرتفع جدًا حوالى 14.78٪ من المساحة الإجمالية لمنطقة الدراسة. كان خطر تضاغط التربة المرتفع جدًا موجودًا فى حوالى 10.60٪ من المساحة الإجمالية لمنطقة الدراسة. التربة المتأثرة بخطر القلوية المرتفع جدًا تمثل حوالى 14.78٪ من المساحة الإجمالية لمنطقة الدراسة. التربة المتأثرة بخطر التشبع بالمياه المرتفع جدًا تمثل حوالى 45.39٪ من المساحة الإجمالية لمنطقة الدراسة. تم حساب خطر تدهور التربة فكان خطر التدهور الكيميائي منخفض في الوحدات DB و RT2 و RT3 و SS تمثل مساحة قدرها175399 هكتارًا تمثل 47.22٪ من مساحة منطقة الدراسة. كانت مساحة 52041 هكتارًا تمثل 14.01٪ من مساحة منطقة الدراسة معرضة لخطر تدهور مرتفع نسبيًا في تربة وحدة رسم الخرائط OB. كانت المنطقة التي تبلغ مساحتها 75182 هكتارًا والتي تمثل 20.25٪ من مساحة منطقة الدراسة معرضة لخطر التدهور بدرجة عالية جدًا في تربة وحدات رسم الخرائط RT1 وWS وDS. تراوحت مخاطر التدهور المادي في منطقة الدراسة بين منخفضة ومتوسطة وعالية. تقع المناطق المهددة بقيم المخاطر المنخفضة في تربة وحدات رسم الخرائط DB وOB وRT1 وRT2 وRT3 التي تغطي مساحة 217715 هكتارًا (58.62٪ من المساحة الإجمالية). تقع المناطق المهددة بقيم المخاطر المتوسطة في تربة وحدة رسم الخرائط SS التي تغطي مساحة 30024 هكتارًا (8.08٪ من المساحة الإجمالية). تقع المناطق المهددة بقيم المخاطر العالية في تربة وحدات رسم الخرائط WS وDS التي تغطي مساحة 54883 هكتارًا (14.78٪ من المساحة الإجمالية).