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Assessment of land degradation using the soil quality guide in some arid and semi-arid areas

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Abstract
This study was conducted to assess the state of soil degradation and desertification using the MEDALUS model and the Soil Quality Guide in the semi-arid region located between longitudes 43°54'25" E and 44°03'27" E east, and latitudes 34°05'58" N and 36°04'31" N north, which includes parts of the Kirkuk and Erbil plains within Kirkuk and Erbil governorates, covering a total area of approximately 460,000 hectares. Five pedons were excavated and morphologically described according to Schoeneberger *et al.* (2012), and samples were taken from representative horizons of each pedon. In addition, thirty-six surface soil samples were collected from areas surrounding each pedon, placed in nylon bags, labeled, and transported to the laboratory for physical and chemical analyses, resulting in a total of sixty samples. Satellite imagery from the American Landsat 7 and Landsat 8 satellites at multiple dates (11/6/2000 and 18/6/2020) was used, and spatial distribution maps were prepared using ArcGIS 10.4.1. The study revealed the following:
A- Assessment of Desertification Using the MEDALUS Model:
Soil Quality Index (SQI):
1- The soil texture index ranged from Class 1 (Good), occurring in some parts of the Daqouq area and small parts of Al-Tun Kubri and Qushtapa, to Class 2 (Moderate), found in major parts of Daqouq, Shuwan, Al-Tun Kubri, Shirawa, and Qushtapa, and Class 3 (Poor), occurring in small parts of Daqouq, Al-Tun Kubri, Qushtapa, and Shirawa. These classes covered areas of 731.54, 455,868.21, and 3,400.25 hectares, representing 0.2%, 99.1%, and 0.7% of the total area, respectively.
As for the indices of parent material, rock fragments, slope, soil depth, and soil drainage, they were classified as Class 2 (Moderate), Class 3 (Bare to Slightly Rocky), Class 1 (Very Level), Class 1 (Deep), and Class 1 (Good), respectively.
The organic matter content index fell within Class 2 (Good) in the Shuwan area and parts of Al-Tun Kubri, and Class 3 (Moderate) in Daqouq, Shirawa, and Qushtapa. The area of Class 2 (Good) was 172,897.40 hectares, representing 37.59%, while Class 3 (Moderate) covered 287,102.6 hectares, or 62.41% of the study area.
The calcium carbonate content index was classified as Class 3 (Poor). The pH index of the study area soils fell within Class 3 (Moderate) in Daqouq and Class 4 (High) in Qushtapa, Shirawa, Al-Tun Kubri, Shuwan, and parts of Daqouq, covering areas of 121,782.76 and 338,217.24 hectares, representing 26.47% and 73.53%, respectively.
Meanwhile, the electrical conductivity (EC) index for the soils of the study area was classified as Class 1 (Low).
2- The Soil Quality Index (SQI) for the study area fell within Class 2 (Moderate Quality).
B- Assessment of Desertification and Degradation Using Remote Sensing Techniques:
1- The imagery resulting from the supervised classification for the period between 2000 and 2020 indicated a change in land cover features, with a clear transformation of large areas of agricultural or arable lands into urban or non-agricultural lands.

Keywords: Soil degradation, desertification, MEDALUS model, remote sensing, soil quality index

Introduction

Soil is one of the most important renewable natural resources and is not a static mass as many believe. It forms through the interacting effects of climate and living organisms on parent material under the influence of topography over a period of time. This indicates that soil formation in arid and semi-arid regions differs significantly from soils formed in humid regions. Due to the mismanagement of lands by their owners, the rate of land degradation and desertification has accelerated because of increasing pressures on agricultural production and the unscientific exploitation of land resources. This results in the removal of vegetative cover, degradation of the land's productive capacity, and the loss of an irreplaceable natural resource, which constitutes a catastrophe for agricultural production, as no agricultural intervention can fully restore its original productivity.

Arid lands are formed due to low rainfall, drought, and high temperatures, as well as human activities such as deforestation, fires, overgrazing, and intensive farming. These factors lead to water and wind erosion, reduced soil fertility, and decreased biomass, ultimately causing land degradation and desertification (FAO, 2007) [2].

Desertification describes the condition in which productive land becomes less productive due to degradation, eventually rendering it unproductive. Desertification is a serious issue that requires monitoring, control, and mitigation by the state, and international efforts should recognize it as a global problem (EOLSS).

Desertification is a global phenomenon resulting from a combination of geological, climatic, biological, and human factors that reduce the physical, chemical, and biological potential of the land in arid and semi-arid environments, which cover more than 40% of the Earth's land surface (Deichman & Eklundh, 1991). About one-third of the Earth's surface lies in arid and semi-arid regions, and more than 20% of the land in two-thirds of the world's countries is directly threatened by desertification. Desertification is a dynamic process resulting from the progression of land degradation in arid, semi-arid, and dry sub-humid areas due to the environmental characteristics of these regions, as well as improper human practices in utilizing their resources. It is considered the final stage of land degradation (UNCCD, 2014) [5].

The global area of drylands is estimated at 5.2 billion hectares, with more than 3.6 billion hectares affected by desertification to varying degrees. Approximately 1.25 billion people, or about 25% of the world's population, are threatened by desertification, which causes material losses exceeding 52 billion USD annually due to decreased land productivity, affecting 110 countries (Al-Louzi, 2008). According to Asio *et al.* (2009) [6], approximately 6 million hectares of agricultural land become unproductive each year due to degradation processes. Bini (2009) [8] indicated that 33% of the world's land surface is affected by various types of degradation, including wind and water erosion, deforestation, salinization, acidification, and chemical pollution. Low (2013) [7] reported that land degradation impacts 1.9 billion hectares of land and 250 million people. Stavi and Lal (2015) [9] noted that degraded lands cover approximately 23% of the world's surface, increasing at a rate of 5-10 million hectares per year and affecting nearly 1.5 billion people. Due to the presence of vast areas of drylands in Iraq and the evident degradation of these lands for several reasons, most notably desertification, this study was conducted to assess the state of land degradation and desertification using the MEDALUS model. This is achieved through the following:

1. Adopting soil quality indicator criteria to determine environmental sensitivity.
2. Preparing a map of environmental sensitivity to desertification and its severity levels.
3. Monitoring spatial and temporal changes using remote sensing techniques.

Materials and Methods

Study Area

As part of the field procedures, observations and field data were recorded, which play a significant role in describing the study areas through field visits. These visits aimed to determine the land-use patterns in these areas and to record information related to the effects of soil properties, which are crucial in assessing the degree of soil degradation. Several sites were selected within the administrative boundaries of Kirkuk and Erbil governorates, noting variations in their environmental, chemical, and physical properties. The lands in these areas were characterized by undulating terrain with hills, while the majority of the land was flat to gently sloping. In terms of land use, wheat, barley, and vegetables were the most cultivated crops, and the vegetative cover consisted mainly of short seasonal herbaceous plants.

After field investigation and study, the area located between longitudes 43°54'25" E and 44°03'27" E east and latitudes 34°05'58" N and 36°04'31" N north was selected. This area includes parts of the Kirkuk and Erbil plains within Kirkuk and Erbil governorates (Figure 2 and Table 1), covering a total area of approximately 460,000 hectares. Five pedons were excavated and morphologically described according to Schoeneberger *et al.* (2002) [1], and samples were taken from the representative horizons of each pedon. In addition, thirty-six surface soil samples were collected from areas surrounding each pedon, resulting in a total of sixty samples. These samples were placed in nylon bags, labeled, and transported to the laboratory for physical and chemical analyses.

A- Lab Work

Soil samples were transported to the laboratory after being placed in nylon bags and labeled according to the study objectives. This included samples from pedon horizons and surface soils surrounding the pedons. The collected samples were air-dried, sieved, homogenized, and passed through a 2 mm mesh sieve, then stored in plastic bags for the purpose of conducting physical and chemical analyses of the soil properties relevant to the study, as follows:

A- Physical Characteristics

1. **Soil Particle Size Distribution:** The volumetric distribution of soil separates (sand, silt, clay) was determined using the hydrometer method described by Gee and Bauder (1986) [10], in addition to using the textural triangle to classify soil texture.

Bulk Density: Bulk density was measured using the paraffin wax method as described by Black (1965) [11].

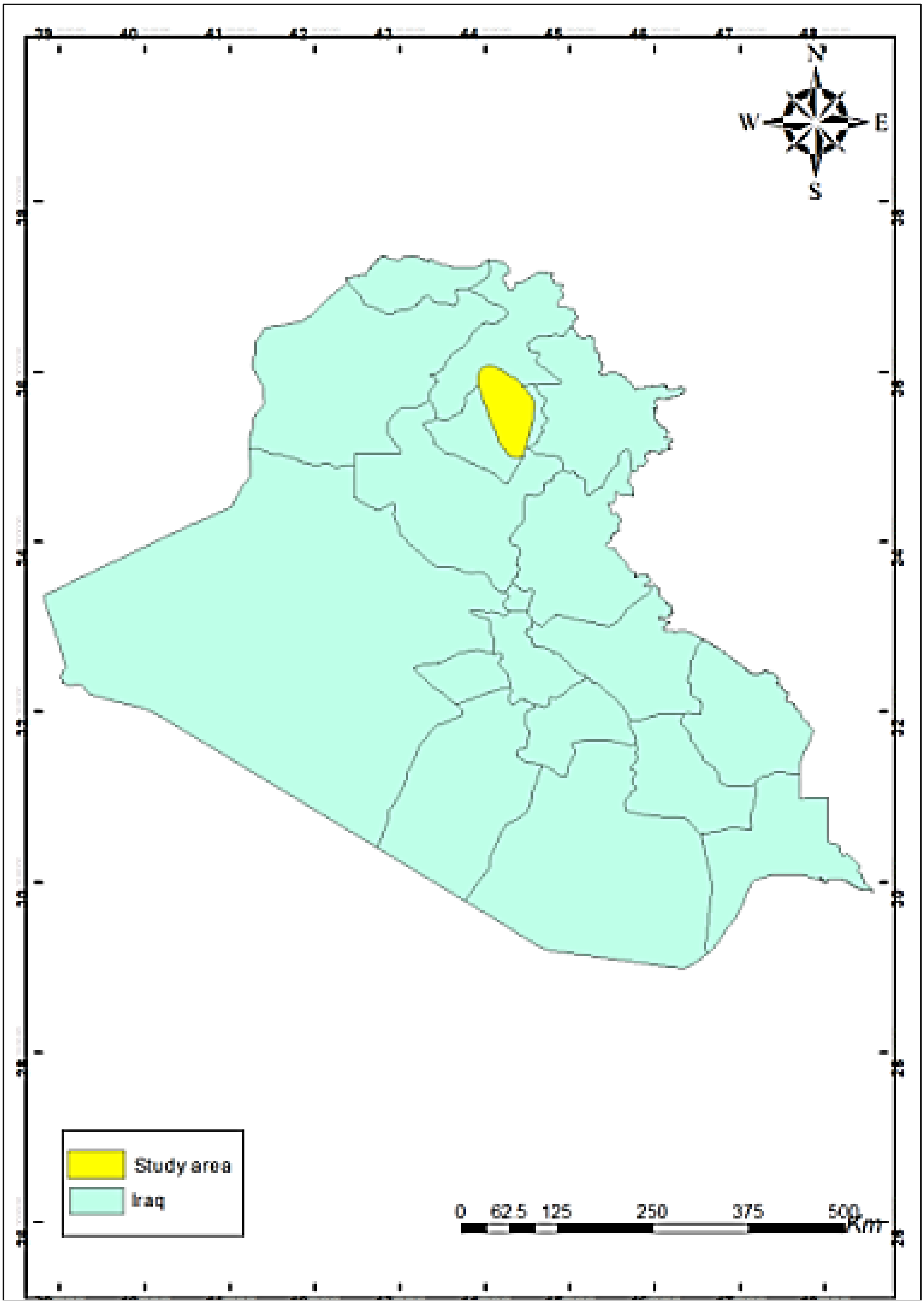


Fig 1: Iraq map showing study area.

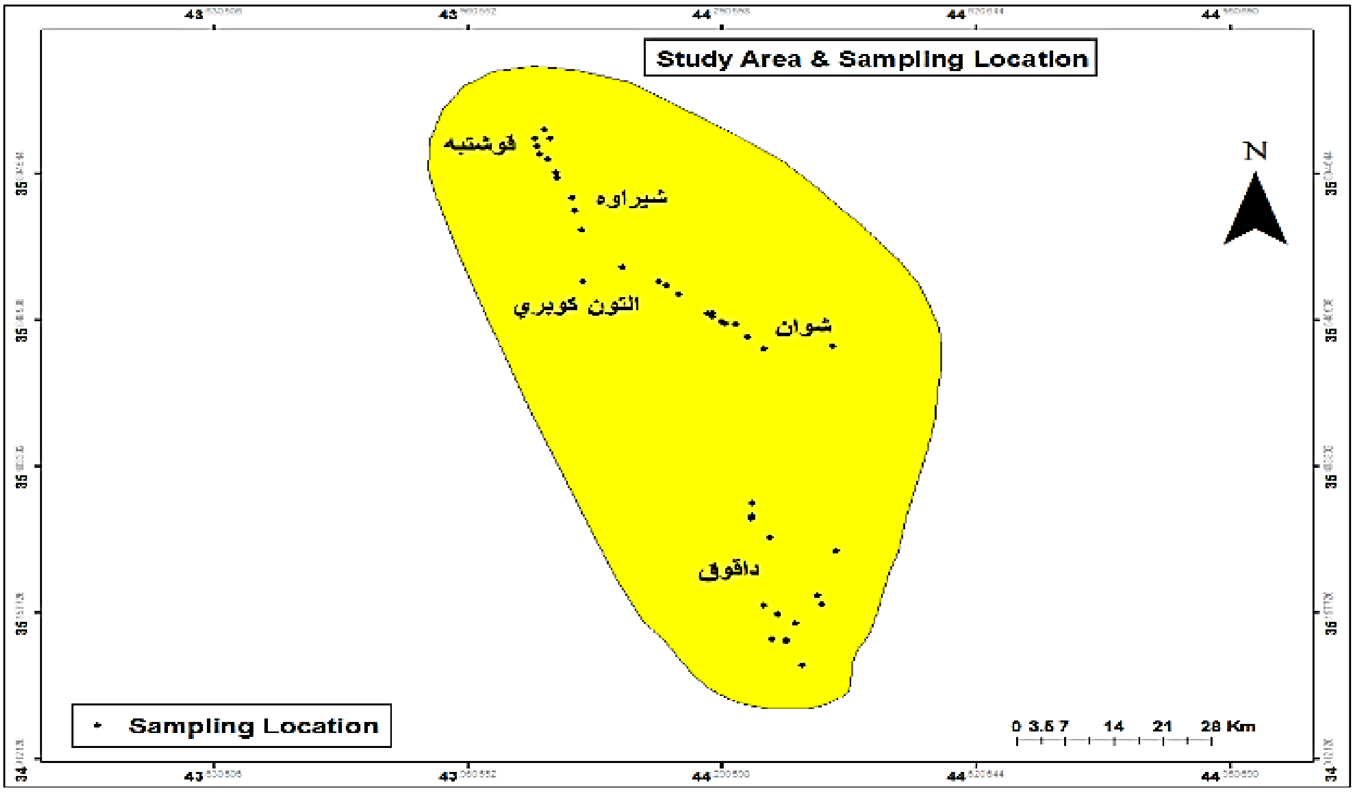


Fig 2: Study area and sampling locations.

Table 1: Coordinates of Pedon Excavation Sites (*) and Soil Sampling Locations

S	Governorate	Area	Longitude	Latitude
1.	Kirkuk	Daqouq *	44° 20' 39"	35° 10' 10"
2.	Kirkuk		44° 13' 05"	35° 42' 24"
3.	Kirkuk		44° 21' 47"	35° 00' 55"
4.	Kirkuk		44° 02' 18"	35° 08' 18"
5.	Kirkuk		44° 22' 23"	35° 06' 42"
6.	Kirkuk		44° 24' 51"	35° 11' 12"
7.	Kirkuk		44° 25' 13"	35° 10' 18"
8.	Kirkuk		44° 22' 22"	35° 06' 30"
9.	Kirkuk		44° 23' 40"	35° 04' 09"
10.	Kirkuk		44° 26' 20"	35° 15' 38"
11.	Kirkuk		44° 21' 05"	35° 16' 59"
12.	Kirkuk		44° 21' 20"	35° 06' 47"
13.	Kirkuk		44° 00' 11"	35° 20' 26"
14.	Kirkuk		44° 19' 21"	35° 19' 56"
15.	Kirkuk		44° 19' 42"	35° 19' 09"
16.	Kirkuk	Shuwan *	44° 16' 39"	35° 39' 33"
17.	Kirkuk		44° 28' 58"	35° 37' 45"
18.	Kirkuk		44° 18' 27"	35° 38' 29"
19.	Kirkuk		44° 16' 37"	35° 39' 41"
20.	Kirkuk	Al-Tun Kubri *	44° 09' 37"	35° 44' 12"
21.	Kirkuk		44° 13' 05"	35° 42' 24"
22.	Kirkuk		44° 12' 29"	35° 42' 42"
23.	Kirkuk		44° 16' 40"	35° 39' 19"
24.	Kirkuk		44° 20' 40"	35° 00' 02"
25.	Kirkuk		44° 19' 23"	35° 00' 22"
26.	Kirkuk		44° 17' 39"	35° 38' 35"

27.	Kirkuk		44° 16' 18"	35° 39' 34"
28.	Kirkuk		44° 14' 03"	35° 41' 26"
29.	Kirkuk		44° 00' 10"	35° 38' 45"
30.	Erbil	Shirawa *	44° 05' 57"	35° 49' 58"
31.	Erbil		44° 06' 33"	35° 42' 42"
32.	Erbil		44° 05' 36"	35° 51' 11"
33.	Erbil		44° 00' 27"	35° 53' 43"
34.	Erbil		44° 04' 00"	35° 57' 15"
35.	Erbil		44° 02' 51"	35° 57' 10"
ت	Governorate	Area	خطوط الطول	دائرة العرض
36.	Erbil	Qushtapa *	44° 03' 33"	35° 58' 12"
37.	Erbil		44° 00' 01"	35° 56' 00"
38.	Erbil		44° 03' 10"	35° 55' 26"
39.	Erbil		44° 03' 52"	35° 55' 36"
40.	Erbil		44° 04' 35"	35° 53' 00"
41.	Erbil		44° 06' 29"	35° 47' 11"

B- Chemical Characteristics

1. **Soil Reaction (pH):** Soil pH was measured in a soil-water suspension (1:2.5) using a pH meter, as described by Richards (1954) [12].
2. **Electrical Conductivity (EC):** Electrical conductivity was measured in a soil-water extract (1:2.5) using an EC meter and expressed in dS m^{-1}, as described by Richards (1954) [12].
3. **Soluble Ions:** Soluble ions were determined in a soil-water extract (2.5:1) as follows:

Soluble Cations

a) **Potassium (K^+) and Sodium (Na^+) ions:** Potassium and sodium ions were measured using a flame photometer (PFP7).

b) **Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) ions:** Dissolved calcium and magnesium ions were determined by titration with standard 0.01 M EDTA, according to Richards (1954) [12].

Soluble Anions

a) **Chloride (Cl^-) ions**
Dissolved chloride ions were measured by titration with 0.05 M silver nitrate, as described by Richards (1954) [12].

b) **Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-) ions:** Carbonate and bicarbonate ions were determined by titration with 0.01 M diluted sulfuric acid (H_2SO_4), according to Richards (1954) [12].

c) **Sulfate (SO_4^{2-}) ions:** Sulfate ions were determined using the turbidity method with barium chloride ($BaCl_2$) and measured with a spectrophotometer at a wavelength of 470 nm, as described by Black (1965b) [13].

3.3.2.4 Cation Exchange Capacity (CEC): Cation exchange capacity (CEC) was determined using the sodium acetate saturation method at pH 8.2, followed by alcohol washing and ammonium acetate precipitation at pH 7, according to FAO (1990) [2]. Sodium ions were measured using a flame photometer (PFP7).

3.3.2.5 Organic Matter

Organic matter in the studied soil samples was determined using the wet oxidation method according to the Smith-Weldon modification of the Walkley-Black method, as described by Abdelhadi (1986).

3.3.2.6 Calcium Carbonate

Calcium carbonate in the soil samples of the studied sites was determined using the gravimetric method, which is based on measuring the weight of CO_2 lost from the soil sample during the decomposition of calcium carbonate with HCl, as described by Richards (1954) [12].

3.3.2.7 Gypsum

Gypsum content was determined using the dilution method as described by Al-Zubaidi *et al.* (1981) [14].

C- Office Work

Desertification Assessment According to the MEDALUS Project (Kosmas *et al.*, 1999)

The assessment involves two stages. In the first stage, four indicators are calculated, including the Soil Quality Indicator, Climate Quality Indicator, Vegetation Quality Indicator, and Management Quality Indicator, providing a measure of the inherent quality of the physical environment and the human-induced stress caused by desertification (Figure 3).

Results and Discussion

1. Morphological Characteristics

The morphological description of the pedons in the study area (Tables 28-32) indicated the presence of a surface diagnostic horizon (Ochric Epipedon) and a subsurface diagnostic horizon (Calcic Epipedon), with some subsurface horizons containing high calcium content. The soils of the study area included the main horizons (A-B-C) (Schoeneberger *et al.*, 2012) [1].

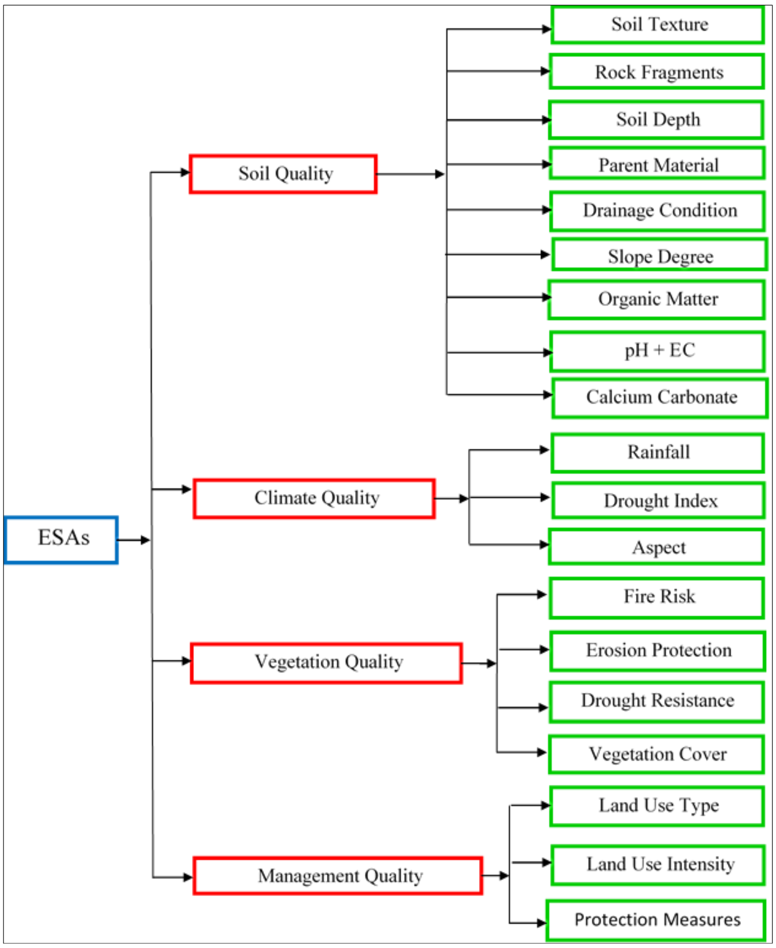


Fig 3: Indicators and Criteria Used to Identify and Map Environmentally Sensitive Areas to Desertification

The morphological description tables (28-32) showed that the dominant hue values were 10YR for all soils in the study area, which is typical for soils in arid regions. However, there was noticeable variation in value (lightness) and chroma (color saturation), attributed to soil properties, degradation, and desertification at each site. Color values ranged from 3-7 (Value) and chroma from 3-8, resulting in soil colors ranging from yellowish-brown (10YR 5/4) to very pale brown (10YR 7/4) in dry conditions, and from dark brown (10YR 3/3) to dark yellowish-brown (10YR 5/8) when wet. This variation is due to differences in calcium accumulations in some subsurface horizons, low organic matter, high clay content, dominance of certain minerals, and the level of soil degradation and desertification.

Soil texture in the pedons of the study area ranged from loamy to clay loam, silty clay loam, and clay (C-L-CL-SICL).

The dominant soil structure in most degraded soils was angular blocky and sub-angular blocky. Structure grades varied from moderate (MO) and weak to moderate (WS) to strong (ST), with structure size ranging from moderate (ME), fine (FI), very fine (VF), fine to medium (FM), and fine to coarse (FC). This variation is attributed to factors such as the nature of the parent material deposition, high-cohesion cementing materials like calcium carbonate in some horizons, and the effects of degradation and desertification in the study area.

Soil consistency varied across the study area. Morphological tables (28-32) showed that surface horizons ranged from soft (S) to slightly hard (SH), moderately hard (MH), and very hard (VH) when dry. In wet conditions, surface horizons ranged from very friable (VFR) to friable (FR) and firm (FI) for most subsurface horizons. Stickiness ranged from non-sticky (SO) to slightly sticky (SS) and moderately sticky (MS), while plasticity ranged from slightly plastic (SP) to moderately plastic (MP) and very plastic (VP). Variations in soil consistency were due to differences in soil mineral components, calcium carbonate content, and organic matter levels.

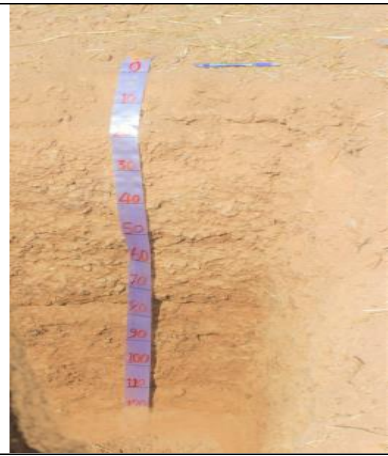
The morphological description indicated that horizon boundaries ranged from abrupt smooth to gradual wavy, reflecting soil formation processes and agricultural practices such as plowing.

Root abundance varied from common (C) to few (F) and very few (V), depending on vegetation density. Root size ranged from fine (F) to very fine (VF) in surface horizons, decreasing with depth, and roots were mainly located between soil aggregates.

Porosity varied from many (M) to common (C), moderately few (MF), and very few (VF), with pore sizes ranging from fine (F) to very fine (VF) and medium (M), and pore shapes varying between vesicular (VS) and tubular (TU). Differences in porosity and its decrease with depth were attributed to soil compaction and high calcium carbonate content.

Soil reaction (pH) analysis (Tables 35-36) showed pH values ranging from 7.3-8.3. Previous studies (Al-Zubadi, 1974; Dregne, 1976; Awad, 1986) [15] indicated that Iraqi soils are generally slightly basic, consistent with the high calcium content in pedons of the study area, ranging from slightly basic to basic

<table>
<tr><th colspan="2">Description of the stateless person</th><th colspan="5">Stateless person code: Daquq</th><th colspan="2">Field Book for Describing and Sampling Soils/V.32012</th></tr>
<tr><th>Soil series or name:</th><th>Map unit symbol:</th><th>Profile:</th><th colspan="4">Soil classification: Aridisols</th><th colspan="2">Soil moisture regime: Xeric</th></tr>
<tr><td>Described by: Burhan Nariman Nawkhas</td><td>Date: 3/10/2020</td><td colspan="2">Weather: Sunny
Air temperature: 29°C
Soil: Depth:</td><td colspan="3">Latitude: 35.1697
Longitude: 44.3442
Data source: Landsat 7, Landsat 8</td><td colspan="2">Location: Kirkuk/Daquq</td></tr>
<tr><td>Coordinate system: WGS 1984
Zone: WGS 1984 UTM Zone 38N</td><td>Topography: Level</td><td>Site code: Daquq</td><td colspan="3">Soil survey area: 460,000 hectares</td><td>Area of major land resources:</td><td colspan="2">Path:
Stop point:
Distance between points:</td></tr>
<tr><td>Landform: Flat lands</td><td>Land shape: Flat plains</td><td>Detailed characteristics:</td><td>Human-induced features:</td><td>Elevation: 210 m</td><td>Direction:</td><td>Slope (%): 2</td><td>Slope complexity:</td><td>Slope shape:</td></tr>
<tr><td>Position on the slope:</td><td colspan="2">Geology of the study area: Bay Hasan Formation</td><td colspan="2">Detailed slope:</td><td colspan="4">Physiography of the area: Undulating region</td></tr>
<tr><td>Drainage: Well-drained</td><td>Flooding:
Ponds and marshes:</td><td colspan="4">Soil moisture condition: Dry</td><td colspan="2">Permeability: Good</td><td>Land cover/usage: Cereal crops, grasses, and shrubs</td></tr>
<tr><td>Parent material: Calcareous</td><td colspan="3">Bedrock: Limestone
Type:
Fracture:
Hardness:
Depth:</td><td colspan="5">Lithologic unit:
Group:
Formation:
Member:</td></tr>
<tr><td>Erosion:
Type:
Water Degree: Slight
Type:
Wind Degree: Slight</td><td colspan="2">Water runoff:</td><td colspan="2">Surface rock fragments:</td><td colspan="4">Diagnostic horizons:
Surface horizon: Ochric Horizon
Subsurface horizon: Calcic Horizon</td></tr>
</table>

<table>
<tr><th colspan="3">Vegetation cover</th><th colspan="2">Miscellaneous field notes / Sketch</th></tr>
<tr><td rowspan="3">Symbol</td><td>Common name</td><td>Vegetation cover percentage (%)</td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td>Wheat and barley</td><td>None at present</td></tr>
<tr><td>Grasses and shrubs</td><td>10%</td></tr>
</table>

Continued - Table (2): Morphological characteristics of Daquq Bidun

S. No.	Location of the Bidun	Description methodology	Horizon	Depth (cm)	Horizon boundaries	Color				Texture	Gravel distribution	Soil structure			Soil texture				Mottling
						Dry	Color	Moist	color			Degree	Type	Size	Dry	Moist	Consistency	Plasticity	
1	Daquq	Small pit	Ap	0-15	Abrupt Smooth	10YR 5/4	YB	10YR 3/3	DB	CL	V	AS	MO	ME	S	VFR	SS	SP	
2		Small pit	AB	15-40	Gradual Wavy	10YR 6/4	LYB	10YR 5/6	YB	SiCL	N	AS	MO	ME	SH	VFR	SS	SP	
3		Small pit	Bt	40-117	Abrupt Smooth	10YR 5/6	YB	10YR4/4	DYB	C	N	AS	WS	FI	S	VFR	MS	VP	
4		Bucket auger	Ck	+117		10YR 6/4	LYB	10YR 3/4	DYB	C	N	AS	WS	FI	SH	FR	MS	MP	

S. No.	Location of the Bidun	Oxidation and reduction features	Concentrations	Pore features and surface soil aggregates	Root distribution			Pores			Soil reaction	Notes
					Abundance	Size	Location	Abundance	Size	Shape		
1.	Daquq				C	F	P	C	F	VS	7.5	
2.					N	N	N	MF	F	TU+VS	7.5	
3.					N	N	N	F	VF	TU	8.3	
4.					N	N	N	VF	VF	VS	8.1	

YB: Yellowish Brown, LYB: Light Yellowish Brown, DB: Dark Brown, DYB: Dark Yellowish Brown V: Very low, N: None, AS: Massive, prismatic, and sub-angular blocky, ME: Moderate, FI: Fine, MO: Medium, WS: Weak to moderate, S: Soft, SH: Slightly hard, VFR: Very friable, FR: Friable, SS: Slightly sticky, MS: Moderately sticky, SP: Slightly plastic, VP: Very plastic, MP: Moderately plastic, C: Common, P: Between soil aggregates, MF: Slightly medium, VF: Very fine, F: Fine, TU: Tubular, VS: Vesicular

Table 3: Morphological description of Shuwan Bidun

Parameter	Description
Description of the bidon	The symbol of the bidon: Shwan
Reference	*Field Book for Describing and Sampling Soils*, v.3, 2012
Soil series or name	—
Map unit symbol	—
Image	—
Soil classification	Aridisols
Soil moisture system	Xeric
Described by	Burhan Nariman Nawkhas
Date	10/1/2020
Weather condition	Sunny
Atmospheric height (D.H.)	27 m
Soil depth	—
Latitude	35.6594
Longitude	44.2775
Data source	Landsat 7 + Landsat 8
Location	Kirkuk / Shwan
Coordinate system	WGS 1984
Region	WGS 1984 UTM Zone 38N
Topography	Level

Site code	Shwan
Soil survey area	460,000 hectares
Area of most important land resources	—
Path / Breakpoint	—
Distance between two points	—
Land type	Flat land
Landform	Flat plains
Micro-characteristics	—
Manifestations of human action	—
Height	320 m
Direction	—
Slope (%)	3
Slope complexity	—
Slope shape	—
Location of trestle relative to slope	—
Geology of study area	Bai Hassan Formation
Fine slope	—
Physiography of area	Undulating area
Drainage	Well drained
Flood	—
Ponds and swamps	—
Soil moisture condition	Dry
Permeability	Good
Ground cover / use	Cereal crops, grasses, and bushes
Source material	Calcareous
Parent rock	Limestone
Rock type	Fractured, hard
Rock stratigraphic unit	Group: —; Formation: —; Individual: —
Erosion (Water)	Type: Water; Degree: A little
Erosion (Wind)	Type: Wind; Degree: Low
Surface rock cuts	—
Diagnostic horizons	Superficial horizon: Ochric Horizon; Calcic Horizon

Vegetation cover		
Symbol	**Common name**	**Vegetation cover percentage (%)**
	Wheat and barley	None at present
	Grasses and shrubs	%30

Miscellaneous field notes / Sketch

Continued - Table (4): Morphological characteristics of Shuwan Bidun

S	**Bidun location**	**Description method**	**Horizon**	**Depth (cm)**	**Horizon boundaries**	**Color**				**Texture**	**Gravel distribution**	**Soil structure**			**قوام التربة**				**التبقع**
						Dry	color	Moist	Color			Degree	Type	Size	Dry	Moist	consistency	Plasticity	
1	Shuwan	Small pit	Ap	0-15	Abrupt Smooth	10YR 5/4	YB	10YR 3 /4	DYB	L	F	AS	WS	VF	S	VFR	SO	SP	
3		Small pit	Bw	15-65	Gradual Wavy	10YR6/4	LYB	10YR 4/4	DYB	CL	N	AS	WS	FM	SH	FR	SS	SP	
4		Small pit	Ck1	65-95	Clear Smooth	10YR7/4	VPB	10YR 5/6	YB	L	N	AS	WS	FM	SH	VFR	SO	SP	
5		Bucket auger	Ck2	95+		10YR7/4	VPB	10YR 4/4	DYB	L	N	AS	MO	FC	MH	VFR	SO	SP	

ت	Bidun location	Oxidation and reduction features	Concentrations	Pore features and surface soil aggregates	Root distribution			Pores			Soil reaction	Notes
					Abundance	Size	Location	Location	Size	Shape		
1	Shuwan				M	F	P	C	M	TU+VS	7.3	
2					F	VF	P	C	M	TU+VS	7.7	
3					V	VF	P	MF	F	TU	7.7	
4					V	VF	P	VF	F	TU	7.7	
5					N	N	N	VF	F	TU+VS	8.0	

ت	Bidun location	Oxidation and reduction features	Concentrations	Pore features and surface soil aggregates	Root distribution			Pores			Soil reaction	Notes
					Abundance	Size	Location	Abundance	Size	Shape		
1	Shuwan				M	F	P	C	M	TU+VS	7.3	
2					F	VF	P	C	M	TU+VS	7.7	
3					V	VF	P	MF	F	TU	7.7	
4					V	VF	P	VF	F	TU	7.7	
5					N	N	N	VF	F	TU+VS	8.0	

YB: Yellowish Brown, LYB: Light Yellowish Brown, VPB: Very Pale Brown, DYB: Dark Yellowish Brown, YB: Yellowish Brown
F: Low, N: None, AS: Massive, prismatic, and sub-angular blocky, MO: Moderate, WS: Weak to moderate,
VF: Very fine, FM: Fine to medium, FC: Fine to coarse, S: Soft, SH: Slightly hard, MH: Moderately hard,
VFR: Very friable, FR: Friable, SS: Slightly sticky, SO: Non-sticky, SP: Slightly plastic, M: High, F: Low, V: Very low,
P: Between soil aggregates, MF: Slightly medium, VF: Very fine, TU: Tubular, VS: Vesicular

Table (5): Morphological description of Talon Kubri Bidun

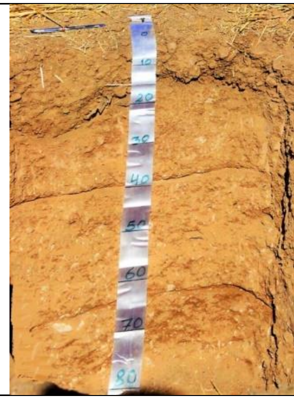
Parameter	**Description**
Description of the bidon	The symbol of the bidon: Alton Kopri
Reference	*Field Book for Describing and Sampling Soils*, v.3, 2012
Soil series or name	—
Map unit symbol	—

Image	—
Soil classification	Aridisols
Soil moisture system	Xeric
Described by	Burhan Nariman Nawkhas
Date	12/10/2020
Weather condition	Sunny
Atmospheric height (D.H.)	28 m
Soil depth	—
Latitude	35.7369
Longitude	44.1603
Data source	Landsat 7 + Landsat 8
Location	Kirkuk / Altun Kopri
Coordinate system	WGS 1984
Region	WGS 1984 UTM Zone 38N
Topography	Flat
Location code	Alton Kopri
Soil survey area	460,000 hectares
Area of most important land resources	—
Path / Breakpoint	—
Distance between two points	—
Land type	Flat land
Landform	Flat plains
Micro-characteristics	—
Manifestations of human action	—
Height	290 m
Direction	—
Slope (%)	5
Slope complexity	—
Slope shape	—
Location of trestle relative to slope	—
Geology of study area	Bai Hassan Formation
Fine slope	—
Physiography of area	Undulating area
Drainage	Well drained
Flood	—
Ponds and swamps	—
Soil moisture condition	Dry
Permeability	Good
Ground cover / use	Cereal crops, grasses, and shrubs
Source material	Calcareous
Parent rock	Limestone
Rock type	Fractured, hard
Rock stratigraphic unit	Group: —; Formation: —; Individual: —
Erosion (Water)	Type: Water; Degree: A little
Erosion (Wind)	Type: Wind; Degree: Low

Water flow	—
Surface rock cuts	—
Diagnostic horizons	Superficial horizon: Ochric Horizon; Calcic Horizon

vegetation		
The symbol	Common name	Vegetation coverage %
	Wheat and barley	currently no D
	Weeds and jungles	15%

Miscellaneous field notes / drawing



No.	Site of the Bidon	How to do the Description	Horizon	Depth (cm)	Horizon Boundary	Dry Color (Munsell)	Dry Color Code	Moist Color (Munsell)	Moist Color Code	Tissue	Spread of Gravel (Degree)	Type	Size	Soil Building	Soil Texture	Spotting (Dry)	Spotting (Moist)	Viscosity	Plasticity
20	Ton Kopri	Small pit	Ap	0-19	Gradual Wavy	10YR 4/4	DYB	10YR 3/3	DB	CL	V	AS	WS	FI	SH	VFR	SS	SP	—
21	—	Small pit	Bk	19-39	Abrupt Smooth	10YR 5/6	YB	10YR 3/6	DYB	C	F	AS	MO	FI	SH	VFR	MS	MP	—
22	—	Small pit	Ck1	39-64	Abrupt Smooth	10YR 5/4	YB	10YR 4/4	DYB	C	F	AS	MO	FI	MH	FR	MS	MP	—
23	—	Small pit	Ck2	64-79	Abrupt Smooth	10YR 5/6	YB	10YR 3/6	DYB	C	C	AS	MO	FM	MH	FR	MS	MP	—
24	—	Bucket auger	Ck3	79+	—	10YR 6/4	LYB	10YR 5/6	YB	C	M	AS	ST	ME	VH	FI	MS	MP	—

YB: Yellowish Brown, LYB: Light Yellowish Brown, DB: Dark Brown, DYB: Dark Yellowish Brown V: Very low, N: None, AS: Massive, prismatic, and sub-angular blocky, FI: Fine, FM: Fine to medium, ME: Moderate, MO: Moderate, WS: Weak to moderate, ST: Strong, SH: Slightly hard, MH: Moderately hard, VH: Very hard, VFR: Very friable, FR: Friable, FI: Firm, SS: Slightly sticky, MS: Moderately sticky, SP: Slightly plastic, MP: Moderately plastic, C: Common, V: Very low, P: Between soil aggregates, MF: Slightly medium, VF: Very fine, TU: Tubular, VS: Vesicular

Parameter	Description
Description of the bidon	The symbol of the bidon: Shirawa
Reference	*Field Book for Describing and Sampling Soils*, v.3, 2012
Soil series or name	—
Map unit symbol	—
Image	—
Soil classification	Aridisols
Soil moisture system	Xeric
Described by	Burhan Nariman Nawkhas
Date	10/18/2020

Weather condition	Sunny
Atmospheric height (D.H.)	27 m
Soil depth	—
Latitude	35.8328
Longitude	44.0994
Data source	Landsat 7 + Landsat 8
Location	Erbil / Shirawa
Coordinate system	WGS 1984
Region	WGS 1984 UTM Zone 38N
Topography	Flat
Site code	Shirawa
Soil survey area	460,000 hectares
Area of most important land resources	—
Path / Breakpoint	—
Distance between two points	—
Land type	Flat land
Landform	Flat plains
Micro-characteristics	—
Manifestations of human action	—
Height	290 m
Direction	—
Slope (%)	1
Slope complexity	—
Slope shape	—
Location of trestle relative to slope	—
Geology of study area	Bai Hassan Formation
Fine slope	—
Physiography of area	Undulating area
Drainage	Well drained
Flood	—
Ponds and swamps	—
Soil moisture condition	Dry
Permeability	Good
Ground cover / use	Cereal crops, grasses, and shrubs
Source material	Calcareous
Parent rock	Limestone
Rock type	Fractured, hard
Rock stratigraphic unit	Group: —; Formation: —; Individual: —
Erosion (Water)	Type: Water; Degree: A little
Erosion (Wind)	Type: Wind; Degree: Low
Water flow	—
Surface rock cuts	—
Diagnostic horizons	Superficial horizon: Ochric Horizon; Calcic Horizon

vegetation		
The symbol	Common name	Vegetation coverage %
	Wheat and barley	currently no D
	Weeds and jungles	12%
	thorns	3%
	The wise	5%

Miscellaneous field notes / drawing

Continued - Table (6): Morphological characteristics of Shirawa Bidun

No.	Site of the Bidon	How to do the Description	Horizon	Depth (cm)	Horizon Boundary	Dry Color (Munsell)	Dry Color Code	Moist Color (Munsell)	Moist Color Code	Tissue	Spread of Gravel (Degree)	Type	Size	Soil Building	Soil Texture	Spotting (Dry)	Spotting (Moist)	Viscosity	Plasticity
1	Shirawa	Small pit	Ap	0-12	Abrupt Smooth	10YR 5/6	YB	10YR 3/6	DYB	C	F	AS	WS	FI	SH	VFR	MS	MP	—
2	—	Small pit	BA	12-73	Abrupt Smooth	10YR 5/6	YB	10YR 3/6	DYB	C	V	AS	MO	FI	VH	VFR	MS	VP	—
3	—	Small pit	Btk	73-105	Abrupt Smooth	10YR 6/4	LYB	10YR 5/6	DYB	C	N	AS	MO	FI	SH	VFR	MS	VP	—
4	—	Small pit	Ck1	105-130	Abrupt Smooth	10YR 6/6	BY	10YR 5/6	YB	C	N	AS	ST	FI	MH	VFR	MS	VP	—
5	—	Bucket auger	Ck2	130+	—	10YR 7/4	VPB	10YR 5/8	YB	C	N	AS	ST	ME	MH	VFR	MS	VP	—

No.	Site of the Bidon	Oxidation and Reduction Manifestations	Concentrations	Surface Soil Voids and Aggregates	Root Distribution	Porosity	Soil Reaction (pH)	Notes
		Abundance	Size	The Site	Abundance	Size	Shape	
1	Shirawa	—	—	—	C	F	P	M
2	—	—	—	—	F	VF	P	VF
3	—	—	—	—	N	N	N	MF
4	—	—	—	—	N	N	N	MF
5	—	—	—	—	N	N	N	MF

YB: Yellowish Brown, LYB: Light Yellowish Brown, BY: Brown Yellowish, VPB: Very Pale Brown, DYB: Dark Yellowish Brown V: Very low, N: None, AS: Massive, prismatic, and sub-angular blocky, FI: Fine, ME: Moderate, MO: Moderate, WS: Weak to moderate, ST: Strong, SH: Slightly hard, MH: Moderately hard, VH: Very hard, VFR: Very friable, VP: Very plastic, MP: Moderately plastic, C: Common, F: Fine, P: Between soil aggregates, MF: Slightly medium, VF: Very fine, TU: Tubular, VS: Vesicular

Description of the Bidon
Symbol of the Bidon: Qushtapa
Reference: Field Book for Describing and Sampling Soils, Version 3 (2012)

Attribute	Description
Soil series or name	—
Map unit symbol	—
Image	—
Soil classification	Aridisols
Soil moisture regime	Xeric
Described by	Burhan Nariman Nawkhas
Date	October 18, 2020
Weather condition	Sunny
Atmospheric condition (D.H.)	26 m
Soil depth	—
Latitude	35.9667
Longitude	44.0592
Data source	Landsat 7 + Landsat 8
Location	Erbil / Qushtapa
Coordinate system	WGS 1984
Region	WGS 1984 UTM Zone 38N
Topography	Flat
Site code	Qushtapa
Soil survey area	460,000 hectares
Area of major land resources	—
Path / Breakpoint	—
Distance between points	—
Land type	Flat land
Landform	Flat plains
Micro-characteristics	—
Human activity manifestations	—
Elevation (Height)	400 m
Direction	—
Slope (%)	1
Slope complexity	—
Slope shape	—
Position of the trestle relative to slope	—
Geology of the study area	Bai Hassan Formation
Fine slope	—
Physiography	Undulating area
Drainage	Well drained

Flooding	—
Ponds and swamps	—
Soil moisture condition	Dry
Permeability	Good
Ground cover / Use	Cereal crops, grasses, and shrubs
Source material	Limestone
Parent rock	Limestone
Rock type	Fractured, hard
Rock depth	—
Stratigraphic unit	—
Group / Formation / Individual	Bai Hassan Formation
Erosion type (water)	Present
Erosion degree (water)	Slight
Erosion type (wind)	Present
Erosion degree (wind)	Low
Water flow	—
Surface rock cuts	—
Diagnostic horizons	Ochric Horizon, Calcic Horizon

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