

Land Use / Land Cover Impact on Soil Quality In Selected Soil of Kirkuk

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Abstract

The study area falls within the administrative boundaries of Kirkuk Governorate in northeastern Iraq, extending from 43°16'6.37"–44°43'6.58" E longitudes and 34°41'5.42"–35°51'34.49" N latitudes (Photo-figure). It includes the districts of Dibis and Daquq + sub-districts Shwan and Taza which differ according to their land-use patterns.

Soil pedons Four soil pedons were selected from four different land-use systems, including the following: (1) forest land (Pedon 1) at Dibis; (2) vegetable-crop land (Pedon 2), Taza site which had been used for growing beans and eggplants (clinical diagnosis of type Diabetes mellitus); (3) Field crop lands cultivated with wheat, barley, maize three forelements-Pedon. These included surface horizon soil samples from each pedon, selected physical and chemical properties of soils. Cornell University Soil Quality Assessment Framework was used to evaluate the soil quality according to land-use type.

Results showed a clear differences in aggregate stability of the four pedons from both land-use systems. The Soil Quality Index (SQI) values ranged from 51.54 to 61.34, all the study sites showed a moderate-high level of soil quality but variation in their performance was determinate because of both vegetation cover and land management practices. Forest soils had the greatest SQIs (61.34) among these sites and are thus, associated with better soil quality than other site types studied here. On the other hand, SQI values of vegetable-crop soils were approximately 7.08 units lower than those for forest soils (SQI value = 52.49). The SQI was the lowest in field-crop soils (51.54), indicating that these soils were affected to a greater extent by management and agricultural practices, respectively. The SQIs computed for rangelands, ranked at 52.50 and nearly equal to Soils under vegetable-crops systems indicating that the state of soil quality on Ranjaleis soils is fairly similar with respect to higher One Land-use systems

. **Keywords:** Soil Quality – Soil Health – Cornell – Land Use – Land Cover

Introduction

Soil quality is the ability of soil to provide plants with essential nutrients and function appropriately within an ecosystem in a way that sustains plant and animal productively, maintain environmental quality, support human health and habitat [6], which leads to sustainability of ecosystems. Thus, soil quality is regarded as a key player in

maintaining food security, biodiversity preservation and environmental sustainability [8]. Thus, the evaluation of soil quality among diverse land use systems has great significance because it is one of the most important worldwide issues related to sustainable agriculture and environmental quality [23].

Land use change has been shown to have direct impact on vegetation cover and soil properties affecting processes such as soil bulk density, erosion processes, nutrient balance and functional degradation of the soils. Such changes have negative impacts on soil health and the functioning of ecosystems so there is a need to assess soil quality in order to quantify the effects of land-use change[23] [6].

Numerous studies have been conducted to evaluate soil quality indices under different land-use systems[1].demonstrated that the integration of multiple soil quality indicators positively contributes to the sustainability of agroecosystem productivity. Similarly,[7] reported that the Soil Quality Index (SQI) represents a function of multiple indicators capable of integrating qualitative and quantitative information into a single value. Such indices provide practical tools for comparison and for determining whether soil quality has improved or deteriorated in response to agricultural management practices [21]. According to[2], soil quality is influenced by physical indicators such as bulk density, root depth, and soil texture, as well as chemical indicators including cation exchange capacity (CEC), electrical conductivity (EC), and soil pH. Significant relationships have been observed between these indicators and overall soil quality.

The Soil Quality Index may vary among land-use systems due to differences in the physical, chemical, and biological properties of soils [16][18] developed an SQI for agricultural lands, rangelands, and forests to assess overall soil quality across European Union countries. Their findings indicated that agricultural lands exhibited the highest SQI values, followed by rangelands and forest lands.

[3] evaluated soil quality under different land-use systems using 200 geo-referenced surface soil samples collected from agricultural, horticultural, floricultural, and plantation lands. The assessment included several indicators such as soil texture, pH, organic carbon, nitrogen, phosphorus, potassium, manganese, copper, and calcium. The results showed that plantation lands recorded the lowest SQI value (0.51), whereas agricultural lands exhibited the highest value (0.55), which was comparable to those of horticultural and floricultural lands (0.53). The study further demonstrated that agricultural lands generally performed better than plantation lands for most soil quality indicators evaluated. The authors concluded that the implementation of management practices aimed at improving soil quality is essential for achieving sustainable agricultural production

Material and Methods

1-2 Study Area

The study area is located within the administrative boundaries of Kirkuk Governorate, Iraq, extending between longitudes 43°16'6.37"–44°43'6.58" E and latitudes 34°41'5.42"–35°51'34.49" N in the northeastern part of the country. The study encompassed the districts of Dibis and Daquq as well as the sub-districts of Shwan and Taza, which differ in their prevailing land-use systems (Figure 1)

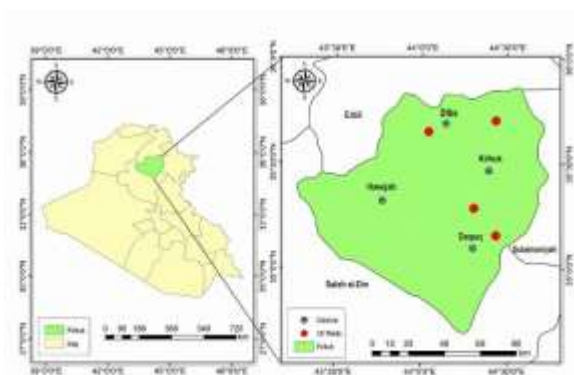


Figure (1). Map of the Study Area and Pedon Locations

One of the most important field procedures conducted in this study was the selection of pedon sites within the study area, owing to their significance in identifying land-use types and documenting the associated site characteristics. Four representative pedons were selected according to the prevailing land-use systems (Table 1). The pedons were excavated and morphologically described following the guidelines of [20]. Subsequently, soil samples were collected from the representative horizons of each pedon, yielding a total of sixteen samples. The samples were placed in labeled polyethylene bags and transported to the laboratory for selected physical and chemical analyses.

Generally, study sites were classified as level to more gently sloped with few locations where a slightly undulating topography occurred. The selected land-use types included forest land (Pedon 1), vegetable-crop land (Pedon 2), field-crop land cultivated with wheat, barley, and maize (Pedon 3), and rangeland (Pedon 4).

Table 1. Locations of the selected study pedons.

Pedon	Location	Land Use	Longitude	Latitude
1	Dibis	Forest	35°39'34"N	44°02'27"E
2	Taza	Vegetable-Crop	N40°17'35"	44°18'18"E
3	Daquq	Field-Crop	N35°9'51"	44°25'50"E
4	Shwan	Rangeland	N41°35'42"	44°26'2" E

2-2 Soil Quality Assessment

Soil quality was evaluated using the Cornell Soil Health Assessment (CASH) framework developed by Cornell University, USA. This approach is based on the selection of a set of physical and chemical indicators that reflect the soil's capacity to perform its productive and environmental functions. The evaluated indicators included soluble cations and anions, soil organic matter, calcium carbonate content, electrical conductivity (EC), soil pH, cation exchange capacity (CEC), and plant-available nutrients, including available calcium, available magnesium, available nitrogen, available phosphorus, and available potassium. In addition, several physical indicators were assessed, namely mean weight diameter (MWD), bulk density, porosity, and soil texture.

The selected indicators used for soil quality assessment are presented in Table 2.

No.	Soil Properties	Measurement Method
1	Particle size Distribution	[10]
2	Mean Weight Diameter	[25]
3	Bulk density	[5]
4	Particle density	[5]
5	Porosity	[11]
6	pH	[13]
7	EC	[13]
8	CaCO ₃	[14]
9	K ⁺	[17]
10	Na ⁺	[17]
11	Ca ⁺²	[17]
12	Mg ⁺²	[17]
13	CO ₃ ⁻	[21]
14	HCO ₃ ⁻	[21]
15	Cl ⁻	[15]
16	SO ₄ ⁻²	[5]

17	O.M	[5]
18	CEC	[9]
19	Aval NO ₃ -N	[19]
20	Aval NH ₄ -N	[19]
21	Aval P	[12]
22	Aval K	[4]
23	Aval Mg	[4]
24	Aval Ca	[4]

The measured values of the selected indicators were subsequently transformed into scores (Table 2) using the scoring functions adopted by the Cornell Soil Health Assessment (CASH) framework. Scores were based on a scale between 0 and 100 with higher scores indicating better soil quality, while decreasing scores indicate limits or degradation in certain properties of the soil. An indication affected positively soil quality had a positive value, while one badly affecting it also received its points at declining values such as salinity and sodicity.

Individual indicator scores were divided into five classes: very low (<20), low (20–40), medium (40–60) high (60–80) and very high (80–100). This categorization allowed the assessment of whether each soil property is either in a quality status and how it contributes to general functioning of soils.

After calculating the scores, CASH scoring functions were then used to scale all physical and chemical indicators measured on a continuous sub-scale from 0 (poor) to 100 (good). The Soil Quality Index (SQI) was then calculated as the arithmetic mean of the scores of all indicators included in the assessment according to the following equation:

$$SQI = \frac{S_1 + S_2 + S_3 + \dots + S_n}{n}$$

where:

SQI = Soil Quality Index.

$S_1, S_2, S_3, \dots, S_n$ = standardized scores of the evaluated soil indicators after transformation using the scoring functions adopted by the Cornell Soil Health Assessment (CASH) framework.

n = total number of indicators used in the soil quality assessment.

The resulting SQI values were subsequently classified into quality classes according to the ranges presented in Table 3. The measured values of the soil properties were converted into standardized scores ranging from 0 to 100 based on the threshold values adopted by the Cornell Soil Health Assessment system. Higher SQI values indicate an improvement in the overall soil condition and a greater capacity to perform productive and environmental functions efficiently, whereas lower SQI values reflect deterioration of soil properties and a reduced ability to sustain agricultural productivity over the long term

Table 3. Soil quality indicators and their corresponding score ranges used for evaluating the study area pedon

Properties	Unit	Very Low - 0 20	Low 40 – 20	Medium 60 – 40	High 80 - 60	Very High 100 - 80
O.M	g.kg ⁻¹	<1	2 -1	3 – 2	4 - 3	> 4
CEC		<5	5 – 10	10 - 20	20 – 40	>40
CaCO ₃	g.kg ⁻¹	>40	40 - 25	25 – 10	10 - 5	<5
pH		5>or<9	5 – 6	8 - 8.5	7.5 – 8	6 - 7.5
EC	dS m ⁻¹	>8	6 – 8	4 – 6	2 – 4	<2

Cl ⁻	Meq L ⁻¹	>30	15 – 30	5 - 15	2 – 5	<2
SO ₄ ⁻	Meq L ⁻¹	>30	15 – 30	5 - 15	2 – 5	<2
HCO ₃ ⁻	Meq L ⁻¹	>10	7 – 10	4 – 7	2 – 4	<2
K ⁺	Meq L ⁻¹	<0.1	0.1 - 0.3	0.3 - 0.6	0.6 – 1	>1
Na ⁺	Meq L ⁻¹	>40	20 – 40	10 - 20	5 – 10	<5
Mg ⁺	Meq L ⁻¹	<1	1 – 3	3 – 6	6 – 12	>12
Ca ⁺⁺	Meq L ⁻¹	<2	2 – 5	5 - 10	10 – 20	>20
M.W.D	Mm	<0.5	1.0 – 0.5	2.0 – 1.0	3.0 – 2.0	<3.0
Porosity	%	<30	30 – 40	40 - 45	45 – 55	>55
Clay	%	<5	5 – 15	15 - 30	30 – 40	40 – 50
Sand	%	>80	80 - 65	65 – 45	45 - 30	30 - 20
Silt	%	<10	20 - 10	35 – 20	50 - 35	65 - 50
Textural Class		S	LS-SL	SC-SCL-C	CL-SiL-SiCL	L
Bulk Density	Mg.m ⁻³	> 1.6	1.6 – 1.5	1.5 – 1.4	1.4 – 1.3	<1.3
A.val Ca	Cmol kg ⁻¹	<2	2 – 5	5 - 10	10 – 20	>20
A.val Mg	Cmol kg ⁻¹	<0.5	0.5 – 1	1 – 3	3 – 8	>8
A.val Na	Cmol kg ⁻¹	>5	2 – 5	1 – 2	0.5 – 1	<0.5
NO ₃ -N	Mg kg ⁻¹	<5	5 – 10	10 - 20	20 – 40	>40
NH ₄ -N	Mg kg ⁻¹	<5	5 – 10	10 - 20	20 – 40	>40
A.val P	Ppm	< 0.08	0.16-0.08	0.32-0.16	0.64-0.32	0.64>
A.val K	Cmol kg ⁻¹	<0.1	0.1 - 0.3	0.3 - 0.6	0.6 – 1	>1

Table 4. Soil Quality Rating Ranges and Scores According to the Cornell University Methodology

SQI	Assessment
> 85	Excellent
85 – 70	Good
70 – 55	Moderate
55 – 40	Poor
< 40	Degraded

Results and Discussion

Soil Quality of the Surface Horizons of the Studied Pedons

Soil Quality of the Surface Horizon (A) in Pedon 1

The mean of soil quality score reached 75.33 (Table 5) which is considered high-quality soils in other state. Soil characteristics including good chemical conditions, moderate organic matter content, a moderate level of soil reaction (pH), and low salinity levels accounted for this result. Soil pH was found to be neutral while the soil contained sufficient levels of most essential plant nutrients. On the other hand, low scores of some chemical indicators especially bicarbonate and available magnesium also indicate that there is still potential for improving soil quality based on balanced fertilization programs within a desired range through appropriate agricultural management practices.

Table 5. Soil Quality Assessment of the Surface Horizon (A) in Pedon 1

Pedon 1 / A				
Group	Indicator	Unit	Value	Scores
Physical Properties	Clay	%	24.1	52.13
	Soil Textural		Loam	100
	Bulk Density	Mg m ⁻³	1.15	100
	Porosity	%	56	100
	M.W.D	Mm	4.80	100
	Ca ⁺⁺	Meq L ⁻¹	7.8	51.2
	Mg ⁺⁺	Meq L ⁻¹	3.8	45.3
	Na ⁺	Meq L ⁻¹	2.02	100
	K ⁺	Meq L ⁻¹	0.92	76

Chemical Properties	HCO ₃	Meq L ⁻¹	11.8	20
	SO ₄ ⁻²	Meq L ⁻¹	7.23	44.46
	Cl ⁻	Meq L ⁻¹	6.2	42.4
	EC	dS m ⁻¹	1.24	100
	pH		7.15	100
	CaCO ₃	g.kg ⁻¹	35	100
	O.M	g.kg ⁻¹	5.04	100
	CEC	Cmol kg ⁻¹	29	69
Available Nutrients	Aval. Ca	Cmol kg ⁻¹	12.6	65.2
	Aval. Mg	Cmol kg ⁻¹	0.8	32
	Aval. Na	Cmol kg ⁻¹	0.35	100
	Aval. NO ₃ -N	Mg kg ⁻¹	20.45	60.45
	Aval. NH ₄ -N	Mg kg ⁻¹	15.0	50
	Aval. P	Ppm	0.320	100
	Aval. K	Cmol kg ⁻¹	2.41	100
Score				75.33
Rating				High Quality
Very High	High	Moderate	Low	Very Low

3-1 Soil Quality of the Surface Horizon (Ap) in Pedon 2

The final soil quality score was 55.95 (Table 6), classifying the soil within the moderate-quality category. This classification is a reflection of the interaction between multiple beneficial factors, including adequate soil pH, low salinity and high phosphorus availability (L), and potentially limiting influences such as higher bulk density

increased organic matter content only marginally against reduced scores for many essential plant nutrients. Hence, enhancing organic matter management practices through application of other organic amendments balanced fertilization programs fairstureestmost for aamending its quality and functionstowards building sustainable concentration directly determines the soil productive capacity potential.

Table 6. Soil Quality Assessment of the Surface Horizon (Ap) in Pedon 2

Pedon 2 / Ap				
Group	Indicator	Unit	Value	Scores
Physical Properties	Clay	%	39.1	78.2
	Soil Textural		S C	60
	Bulk Density	mg m ⁻³	1.76	20
	Porosity	%	34	28
	M.W.D	Mm	0.98	39.2
Chemical Properties	Ca ⁺⁺	Meq L ⁻¹	1.8	20
	Mg ⁺⁺	Meq L ⁻¹	2.2	32
	Na ⁺	Meq L ⁻¹	1.81	100
	K ⁺	Meq L ⁻¹	0.14	24
	HCO ₃	Meq L ⁻¹	5	46.6
	SO ₄	Meq L ⁻¹	3.11	67.4
	Cl ⁻	Meq L ⁻¹	0.4	100
	EC	dS m ⁻¹	0.58	100
	pH		7.21	100
	CaCO ₃	g.kg ⁻¹	34	32
	O.M	g.kg ⁻¹	12.0	24
	CEC	Cmol kg ⁻¹	23	63
Available Nutrients	Aval. Ca	Cmol kg ⁻¹	7.0	48
	Aval. Mg	Cmol kg ⁻¹	4.6	66.4
	Aval.Na	Cmol kg ⁻¹	0.61	64.4
	Aval. NO ₃ -N	mg.kg ⁻¹	6.21	24.84
	Aval. NH ₄ -N	Mg.kg ⁻¹	17.72	55.44

	Aval. P	Ppm	0.177	100
	Aval. K	Cmol kg ⁻¹	0.44	49.3
Score				55.95
Rating				Moderate Quality
Very High	High	Moderate	Low	Very Low

3-2 Soil Quality of the Surface Horizon (Ap) in Pedon 3

The final soil quality score was 55.42 (Table 7), classifying this soil within the moderate-quality category. This classification reflects the combined influence of several favorable and limiting factors. On the one hand, the soil is characterized by low salinity, relatively stable soil structure, and a favorable cation exchange capacity. On the other hand, its quality is adversely affected by high bulk density, elevated calcium carbonate content, and low organic matter levels. Therefore, improving soil organic matter through the incorporation of organic

residues or organic fertilizers, together with balanced nutrient management practices, could contribute to enhancing soil quality and improving its agricultural productivity in the future.

Table 7. Soil Quality Assessment of the Surface Horizon (Ap) in Pedon 3

Pedon 3 / Ap				
Group	Indicator	Unit	Value	Scores
Physical Properties	Clay	%	27.5	56.66
	Soil Textural		S C L	60
	Bulk Density	Mg.m ⁻¹	1.74	20
	Porosity	%	35	30
	M.W.D	Mm	2.70	74.02

Chemical Properties	Ca ⁺⁺	Meq L ⁻¹	2	20
	Mg ⁺⁺	Meq L ⁻¹	2.6	36
	Na ⁺	Meq L ⁻¹	2.63	100
	K ⁺	Meq L ⁻¹	0.14	24
	HCO ₃	Meq L ⁻¹	3.4	74
	SO ₄	Meq L ⁻¹	5.85	41.7
	Cl ⁻	Meq L ⁻¹	0.9	100
	EC	dS m ⁻¹	0.70	100
	pH		7.76	70.4
	CaCO ₃	g.kg ⁻¹	40.5	20
	O.M	g.kg ⁻¹	1.71	34.2
	CEC	Cmol kg ⁻¹	22	62
Available Nutrients	Aval. Ca	Cmol kg ⁻¹	7.4	49.6
	Aval. Mg	Cmol kg ⁻¹	3.6	62.4
	Aval. Na	Cmol kg ⁻¹	0.71	68.4
	Aval. NO ₃ -N	mg.kg ⁻¹	15.00	50
	Aval. NH ₄ -N	mg.kg ⁻¹	16.19	52.38
	Aval. P	Ppm	0.049	50.38
	Aval. K	Cmol kg ⁻¹	0.54	56
Score				55.42
Rating				Moderate Quality
Very High	High	Moderate	Low	Very Low

3-3 Soil Quality of the Surface Horizon (A) in Pedon 4

The final soil quality score was 51.82 (Table 8), indicating that the soil falls within the moderate-quality category. This suggests that the soil is suitable for agricultural production; however, it requires

certain improvement measures, particularly those aimed at increasing organic matter content, enhancing soil fertility, and mitigating the effects of the high calcareous content. Such practices could contribute to achieving higher levels of soil quality and agricultural productivity.

Table 8. Soil Quality Assessment of the Surface Horizon (A) in Pedon 4

Pedon 4 / A				
Group	Indicator	Unit	Value	Scores
Physical Properties	Clay	%	21.3	48.4
	Soil Textural		L	100
	Bulk Density	mg.m ⁻³	1.55	30
	Porosity	%	44	56
	M.W.D	Mm		66
Chemical Properties	Ca ⁺⁺	Meq L ⁻¹	2.2	21.3
	Mg ⁺⁺	Meq L ⁻¹	1	20
	Na ⁺	Meq L ⁻¹	1.23	100
	K ⁺	Meq L ⁻¹	0.10	20
	HCO ₃	Meq L ⁻¹	3.2	72
	SO ₄	Meq L ⁻¹	2.20	61.33
	Cl ⁻	Meq L ⁻¹	0.6	100
	EC	dS m ⁻¹	0.41	100
	pH		7.81	72.2
	CaCO ₃	g.kg ⁻¹	43.5	20
	O.M	g.kg ⁻¹	9.6	20
	CEC	Cmol kg ⁻¹	22	62
Available Nutrients	Aval. Ca	Cmol kg ⁻¹	9.2	56.8
	Aval. Mg	Cmol kg ⁻¹	2.8	58
	Aval. Na	Cmol kg ⁻¹	0.32	20
	Aval. NO ₃ -N	mg.kg ⁻¹	5.00	20

	Aval. NH ₄ -N	mg.kg ⁻¹	16.67	53.34
	Aval. P	Ppm	0.075	63.3
	Aval. K	Cmol kg ⁻¹	0.47	51.3
Score				51.82
Rating				Moderate Quality
Very High	High	Moderate	Low	Very Low

4-3 Comparison of Soil Quality among the Surface Horizons of the Studied Pedons

As illustrated in Figure 2, a clear variation in soil quality levels was observed among the different land-use systems. Forest land exhibited the highest soil quality index, recording a value of 73.10%, substantially exceeding those of the other land-use types. On the other hand, soil quality values of all additional land uses were very close to each other: vegetable-cropped land (55.95%) was at a slightly higher value than field-cropped lands (55.42%), while rangeland had clearly the lowest soil quality value at 51.82%.

The surface horizon of forest land has a high soil quality due to the advanced degree of stability for these ecosystems. The accumulation of organic residues from leaf litter and woody debris gradually decomposes which increases the soil's organic matter content, improving physical properties as well as chemical and biological characteristics. In addition, the fact that there is no intense anthropic disturbances associated with mechanical soil preparations helps maintain soil structure, an adequate pore distribution for more water retention and biological activity which positively contributes to overall soil quality.

Results showed that soil quality was significantly higher in the forest land compared to cultivated lands (vegetable and field crops), particularly while assessing physical, chemical and biological indicators. This decline is most likely associated with intensive agricultural management, reflected in the practice of repeated tillage operations that disrupt soil aggregates; therefore enhancing organic matter oxidation and nutrient depletion. Moreover, continuous harvesting depletes large amounts of nutrients from the soil system reducing its natural replenishment by surface processes and resulting in reliance on external fertilizer inputs. As a result, soil quality under these land-use systems remained in the moderate range with values approaching 55%

Rangeland soils recorded the lowest soil quality values among the studied land uses. This decline may be attributed to overgrazing, which reduces vegetation cover and leaves the soil surface more vulnerable to erosion by wind and water. The resulting deterioration in soil properties is reflected in the lower soil quality index, which reached 51.82%.



Figure 2 shows a comparison of soil quality among the surface horizons

Conclusion

1-The results revealed considerable variability in the morphological, physical, and chemical properties of the soils within the study area according to different land-use types, indicating the significant influence of both natural factors and agricultural management practices on the development and differentiation of soil characteristics

2- The soils of the study area exhibited neutral to slightly alkaline reactions, with calcareous accumulations observed in some subsurface horizons. This reflects the prevailing arid to semi-arid environmental conditions characteristic of the region.

3- The results demonstrated that different land-use types exerted a significant influence on the physical and chemical properties of the soils. Certain land-use systems were more effective in maintaining and improving soil characteristics than others, highlighting the role of land management practices in soil quality preservation

.4-The study results indicated that increased organic matter content, improved soil structure, higher porosity, and lower bulk density were among the most important factors contributing to enhanced Soil Quality Index (SQI) values.

.5- The Cornell Soil Health Assessment methodology proved to be an effective approach for evaluating soil quality and identifying the impacts of different land-use types on soil properties, making it a valuable tool for the assessment and sustainable management of land resources

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