

## CROP ROTATION'S IMPACT ON CERTAIN SOIL PROPERTIES IN DUHOK PROVINCE

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### Abstract

Crop rotation is a well-established agricultural method that entails growing various crops one after the other on the same plot of land. Soil quality is impacted by management practices throughout time. At the Agriculture College University of Duhok, an inquiry was carried out to evaluate the impact of crop rotations on the physicochemical properties of the soil. Vegetables, wheat, and fallow land were all part of the crop rotation. In four agricultural regions of Duhok City (Esmahil Ava, Khrab Dem, Agriculture College, and Shkafti), four composite soil samples at a depth of 15-30 cm were collected and sieved. Next, the NPK, SOC, SOM content, CaCO<sub>3</sub>, pH, EC, bulk density, soil texture, porosity, soil moisture content, and water-holding capacity (WHC) of the soil samples were examined. After applying crop rotation annually in four agricultural regions, the results demonstrated an effective improvement in soil macronutrients NPK in shkefti (84, 5.62, and 18.3 mg kg<sup>-1</sup>), respectively, compared to the other locations (Esmahil Ava, Khrab Dem, and College of Agriculture). The texture of the three sites is clay and only the soil in the College of Agriculture Engineering Sciences field is silty clay. The results show that there is a significant difference between the four samples collected from different locations in Duhok city. Crop rotation systems and soil management are considered the main reasons for these differences. Soils are acknowledged as slightly alkaline after results show a soil pH value between 7.7 and 7.3.

**Keywords:** Crop rotation, Physicochemical Soil properties, Soil fertility, Soil conservation, Agriculture sustainability.

## **Introduction**

Crop rotation is an important agricultural practice that involves growing different crops on the same land for a set amount of time in order to improve soil fertility, reduce pests and diseases, and increase crop yields. Crop rotations of various types are practiced in Iraq's Kurdistan Region (KRG), with many tailored to local conditions and soil types. Here are some of the most commonly used crop rotation methods; According to [1] we have many Crop Rotation Types. One-year crop rotation is the practice of planting two crops in the same field in a single year. Common examples include maize and mustard, as well as rice and wheat. Two-Year Crop Rotation: This cycle involves planting multiple crops over two years. For example, fenugreek; maize, potato, and sugarcane; and maize, peas, sugarcane, and mustard. Three-Year Crop Rotation: Planting different crops over a three-year period. Cotton, oats, sugarcane, peas, maize, rice, wheat, beans, and mustard be some examples. Crops as potatoes, legumes, brassicas, and onions/roots are planted during the four-year crop gyration cycle. Also five Year Crop Rotation (This extended cycle may admit a variety of crops, such as onions, carrots, parsnips, sweetcorn/cucurbits, mustard, potatoes, legumes, and brassicas) [2].

The practice of planting different crop sequences on the same plot of land is known as crop rotation. Emerging ecological problems with the soil could have a big impact on soil health. Interactions and relationships that span time [3]. It is a useful tactic to control weeds, pests, and diseases as well as to prevent excessive nutrient depletion, balance, maintain, and improve soil fertility and soil structure. Soil conservation is a top priority and the agricultural development program's long-term goal. There has been a lot of focus on soil management strategies that maintain soil quality and production [4]. Nonetheless, soil organic matter (SOM) is necessary for the

development and stability of soil aggregates during crop rotation. The root exudates can produce cementing agents that are highly adsorbed to inorganic minerals, which helps to retain soil aggregates [5].

According to the General Statistics Office of Vietnam 2022, rice has been the main crop in the Mekong Delta of Vietnam. Summer-autumn rice production in 2022 was 10.8 million tons, a decrease of 304.3 thousand tons from the summer-autumn paddy crop in 2021. The total area planted for the paddy crop was 1,914.7 thousand hectares, a decrease of 38.1 thousand hectares; the yield was 56.6 quintals/ha, 0.5 quintals/ha [6].

Crop rotations in rice uplands have been studied and practiced to increase soil fertility while reducing input. Local tillers apply rice-upland rotation systems, draining their rice fields after harvesting and planting an upland crop such as soybean, maize, or sesame. Rice soil quality is deteriorating as a result of prolonged submerging and the use of mineral fertilizers, which is harmful to farming sustainability. Example soft his abjection admits the decay of stable collection and the decadence of soil organic matter (SOM). Man-made fertilizers and pesticides are not permitted in organic farming practices. The elemental strategy for achieving soil health and fertility is to control pests, weeds, and diseases while too preserving organic matter and soil structure [7].

When done correctly, it can also improve soil fertility and quality, reduce soil erosion, and increase biodiversity [8]. It also increases the amounts of organic carbon in soil. When combined with low- or no-till farming techniques, this can greatly improve carbon sequestration and have a positive impact on slowing down the rate of climate change [9]. This investigation's primary goal is to assess how crop rotation affects the physicochemical soil parameters in the province of Duhok, including bulk density, soil texture, porosity,

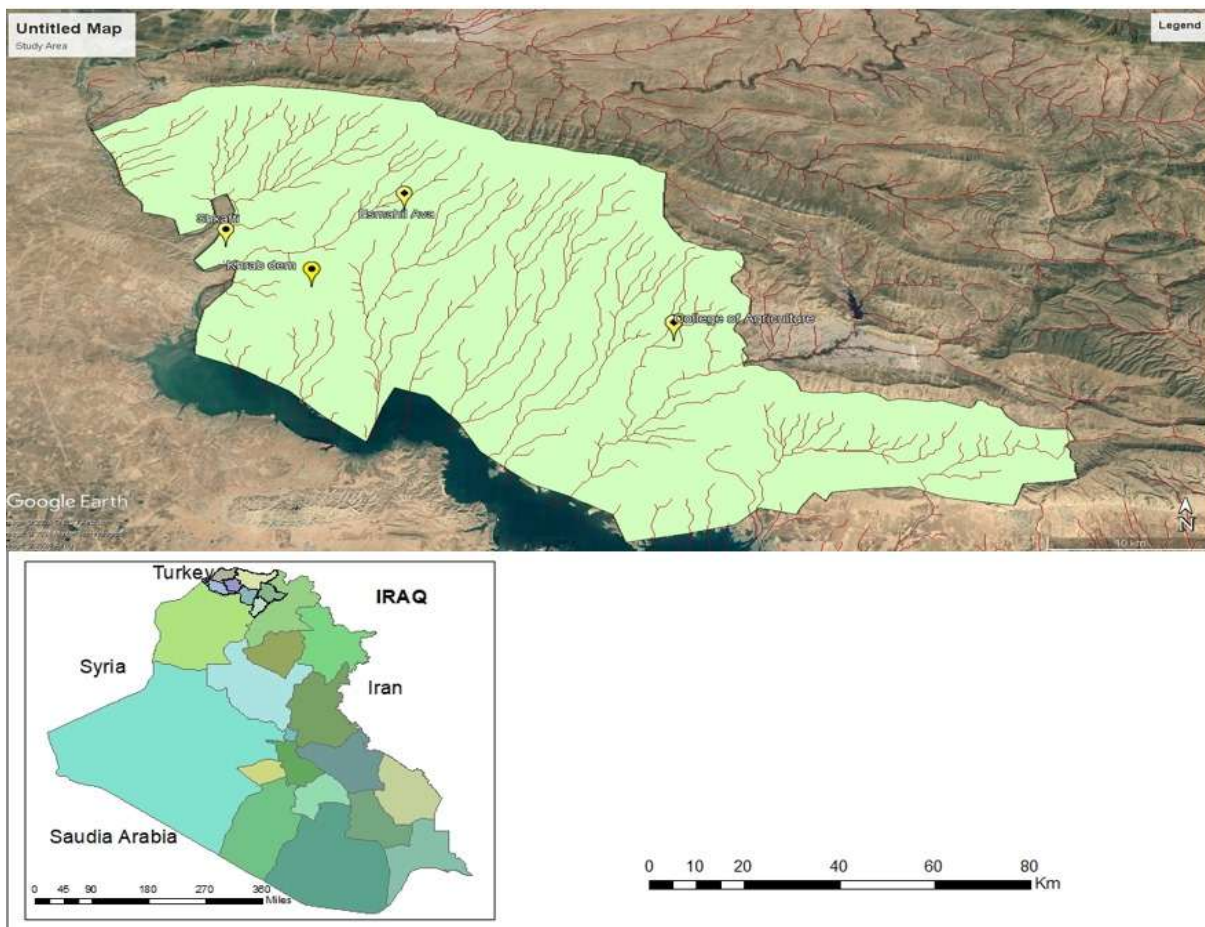
soil moisture content, NPK, SOC, and SOM content, as well as CaCO<sub>3</sub>, pH, and EC.

## Material and Methods

### 2.1 Study location

This study was carried out during the second semester of the 2023–2024 academic year

"Effect of crop rotation on some properties of soil in Duhok province. "The study examined the effects of crop rotation on various physicochemical soil characteristics in four agricultural areas (Esmahil Ava, Khrab Dem, College of Agriculture Engineering Sciences field, and Shkafti) of latitude and longitude ((36o58'03"N), (42o39'01"E); (36o54'04"N), (42o35'11"E); (36o51'32"N), (42o51'51"E), (36o56'03"N), and (42o30'20"E), respectively.



**Figure 1: Location map of the study area**

### 2.2 Sample preparation

The study was conducted in 2024, the University of Duhok's Agriculture College soil and water department laboratory was the site of this investigation. Four soil samples were collected at a depth (15-30) cm from four

different rotated agricultural areas in Duhok city.

### 2.3 Growing condition

The Esmahil Ava agriculture area was planted with wheat crops last year, but this year, efforts are being made to rotate with vegetables including tomatoes, cucumbers, and, parsley among others. On the other side, the cultivated area of the agricultural college, where the soil sample was taken from, was planted with wheat crops for three years respectively, but this year planted with broccoli plants. Khrab dem, on the other hand, was fallow land to be compared with other rotated places. Nevertheless, the Shkafti agricultural area was formerly used for wheat crop as well, and it now primarily consists of pasture land.

#### 2.4 Soil Physical properties

In this research, the standard practical procedures were followed for the physical soil properties analysis such as soil bulk density, soil texture, porosity, soil moisture content, and water holding capacity (WHC%). The determination of soil texture was analyzed through the hydrometer technique as measured by [10]. The soil bulk density and porosity of the studied soil were measured through the core method by taking the constant value of particle density (2.65 g/cm<sup>3</sup>) according to [11]. However, Soil moisture content was performed as the weight loss method (%w w) after the soil samples had been dried in an oven for 24 hours to constant weight at 105°C [12]. The WHC at saturation condition of the soil was conducted according to [11].

### Results and Discussion

Table (1, 2) shows the varied soil physicochemical properties in four Kurdistan agricultural fields that use different crop rotation strategies. The factors include soil pH, EC, organic carbon, SOM, CaCO<sub>3</sub>, and the primary nutrients (N, P, and K). A statistical analysis of the differences with the specified significance thresholds ( $p < 0.05 = *$ ,  $p < 0.01 = **$ ) suggests that there are real variations in the means. Also illustrates the differences in

#### 2.5 Soil Chemical properties

The chemical characteristics were carried out according to the standard practical procedures, the soil pH was analyzed by using the pH meter according to [13]. While the soil electrical conductivity EC was determined by an EC meter as described by [14]. The total nitrogen was determined by the Kjeldahl apparatus, potassium by flame photometer, and phosphorus by spectrophotometer according to the method suggested by [10]. Respectively, Soil organic matter (SOM) and organic carbon (OC) were measured by the Walkley and Black technique using K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> (1N) [15], and the calcium carbonate CaCO<sub>3</sub> was analyzed with a calcimeter by measuring the pressure of CO<sub>2</sub> gas produced from the reaction of soil with HCl [16].

#### 3. Statistical Analysis

The collected data were entered into SPSS software [17], for statistical analysis. Descriptive statistical measures were calculated, and one-way analysis of variance (ANOVA) along with correlation analysis was performed. Mean comparisons following ANOVA were conducted using Duncan's multiple range test [18]. In addition, SPSS was employed to generate graphical representations of the results.

some soil characteristics across different farming regions, each of them utilizes a distinct crop rotation technique. The College of Agriculture Engineering Sciences Field had the lowest pH (7.300), followed by Esmahil Ava (7.500), Khrab Dem (7.600), and Shkafti (7.700). The pH of the soil varied significantly ( $p < 0.0001$ ). These differences suggest that crop rotation in Shkafti, which includes wheat, barren lands, and okra, tends to increase soil

alkalinity as compared to other farming systems.

Electrical conductivity (EC) also showed significant differences ( $p = 0.031$ ) from  $0.080 \text{ dS/m}^{-1}$  in the College of Agriculture Engineering Sciences Field to  $0.110 \text{ dS/m}^{-1}$  in Esmahil Ava, indicating variations in soil salinity levels that may be brought on by different crop residue inputs and irrigation methods. Values for organic carbon (OC) varied significantly ( $p = 0.031$ ), ranging from 1.000% in Khrab Dem to 1.300% in Esmahil Ava. This suggests that crop rotations that include sunflower, tomato, and cucumber are associated with higher soil organic carbon contents. Similar findings were seen in soil organic matter (SOM) ( $p = 0.001$ ), with greater SOM percentages in Esmahil Ava and Shkafti (2.200% and 2.100%, respectively) than in Khrab Dem and the College Field (1.700% and 1.800%, respectively). With Khrab Dem having the highest level (10.800%), Esmahil Ava (9.700%), College Field (7.700%), and Shkafti (5.300%), the calcium carbonate ( $\text{CaCO}_3$ ) content varied considerably across sites ( $p < 0.0001$ ). These variations may have an effect on the nutrient availability and pH buffering capacity of the soil.

With Shkafti having the highest value ( $84.000 \text{ mg kg}^{-1}$ ), while the college of agriculture in second ( $83.000 \text{ mg kg}^{-1}$ ), and Esmahil Ava having the lowest ( $78.000 \text{ mg kg}^{-1}$ ), the total nitrogen (N) content varied statistically significantly ( $p = 0.001$ ). This indicates that rotations of wheat, bore, and okra may improve soil nitrogen levels more successfully than the tomato, cucumber, and sunflower system. Significant variations ( $p < 0.0001$ ) were seen for readily available phosphorus (P), with Shkafti having the greatest concentration ( $5.620 \text{ mg kg}^{-1}$ ), showing that its cropping style may be better for P availability. On the other hand, Esmahil Ava's P value was the lowest at  $4.110 \text{ mg kg}^{-1}$ . The readily available potassium (K) level, which ranged from  $14.600 \text{ mg kg}^{-1}$  in Esmahil Ava to  $18.300 \text{ mg kg}^{-1}$  in Shkafti, likewise

varied extensively between sites ( $p < 0.0001$ ). The positive influence of the wheat-bore-okra rotation on soil potassium dynamics may be seen in Shkafti's raised K level.

The findings in table (3) highlight how crop rotation techniques have a major impact on the chemical characteristics of soil, such as pH, EC, organic matter, nutrient levels, and carbonate content. While Esmahil Ava had higher salinity and organic matter but comparatively lower levels of nitrogen and phosphorus, Shkafti, which used a wheat-bore-okra rotation, consistently recorded superior nutrient availability among the sites. While the Pearson correlation coefficients between the different soils properties are displayed in table (3). It measures how strongly and in which direction pairs of variables have a linear relationship. Phosphorus and soil acidity have a moderately and strongly positive correlation ( $r = 0.631$ ,  $p < 0.05$ ), suggesting that greater soil pH may improve phosphorus availability or retention. It also exhibits moderate, non-significant positive associations with SOM ( $r = 0.303$ ), EC ( $r = 0.486$ ), and potassium ( $r = 0.496$ ), indicating that these characteristics may be more abundant in soils with higher pH.

The modest and negative association ( $r = -0.186$ ) with  $\text{CaCO}_3$  may be an indication of the carbonates' ability to buffer pH. The correlation with nitrogen is not statistically significant and is quite weak ( $r = 0.104$ ). Because of the strong and major correlation between EC and OC ( $r = 0.870$ ,  $p < 0.01$ ) and SOM ( $r = 0.869$ ,  $p < 0.01$ ), it may be inferred that soils with higher organic content have higher ionic conductivity, which may be the result of enhanced microbial activity or nutrient retention.  $\text{CaCO}_3$  ( $r = 0.045$ ), N ( $r = -0.191$ ), P ( $r = -0.020$ ), and K ( $r = -0.134$ ) all have weak, non-significant negative correlations with EC, indicating that organic content has a greater impact on EC than mineral nutrients or carbonate levels.

As would be predicted given that organic carbon is a key component of SOM, OC has a

very strong and major connection with SOM ( $r = 0.950$ ,  $p < 0.01$ ). Additionally, there is a high correlation between it and EC ( $r = 0.870$ ,  $p < 0.01$ ). It has weak and non-statistically significant associations with the following other variables: nitrogen ( $r = 0.000$ ), P ( $r = -0.056$ ), K ( $r = -0.097$ ), and  $\text{CaCO}_3$  ( $r = -0.223$ ). This implies that OC has little direct effect on the concentrations of mineral nutrients and largely affects EC and SOM. The notable negative correlation between SOM and

$\text{CaCO}_3$  ( $r = -0.327$ ) suggests that soils with higher levels of organic matter typically have lower carbonate contents. The acidifying effects of SOM decomposition could be the cause of this. In addition, there is a big and significant relationship between SOM and OC ( $r = 0.950$ ,  $p < 0.01$ ) and EC ( $r = 0.869$ ,  $p < 0.01$ ). The fact that other connections are relatively small and not statistically significant indicates that SOM influences physical features more strongly than direct nutritional levels.

**Table 1. Some Soil properties as affected by the site (with specific species of plant)**

Parameter	Sample site (Method of Crop Rotation)	Mean	± Std. Error	95% Confidence Interval		P value (Sig.)
				Lower Bound	Upper Bound	
<b>pH</b>	College of Agriculture Engineering Sciences Field (Tomato, bore and Broccoli)	7.3 <sup>d</sup>	0.01	7.27	7.32	<0.0001 **
	Esmahil Ava (Tomato, Cucumber and Sunflower)	7.5 <sup>c</sup>	0.01	7.47	7.52	
	Khrab dem (Bore soil, Grass and Bore soil)	7.6 <sup>b</sup>	0.01	7.57	7.62	
	Shkafti (Wheat, Bore and Okra)	7.7 <sup>a</sup>	0.011	7.67	7.72	
<b>EC ds/m<sup>-1</sup></b>	College of Agriculture Engineering Sciences Field (Tomato, bore and Broccoli)	0.08 <sup>c</sup>	0.00	0.06	0.09	0.031 *
	Esmahil Ava (Tomato, Cucumber and Sunflower)	0.11 <sup>a</sup>	0.00	0.09	0.12	
	Khrab dem (Bore soil, Grass and Bore soil)	0.09 <sup>bc</sup>	0.00	0.07	0.10	
	Shkafti (Wheat, Bore and Okra)	0.10 <sup>ab</sup>	0.00	0.08	0.11	
<b>OC %</b>	College of Agriculture Engineering Sciences Field (Tomato, bore and Broccoli)	1.10 <sup>bc</sup>	0.05	0.96	1.23	0.031 *
	Esmahil Ava (Tomato, Cucumber and Sunflower)	1.30 <sup>a</sup>	0.05	1.16	1.43	
	Khrab dem (Bore soil, Grass and Bore soil)	1.00 <sup>c</sup>	0.05	0.86	1.13	
	Shkafti (Wheat, Bore and Okra)	1.20 <sup>ab</sup>	0.05	1.06	1.33	

		Okra)					
<b>SOM %</b>	College of Agriculture Engineering Sciences Field (Tomato, bore and Broccoli)	1.80 <sup>b</sup>	0.05	1.66	1.93	0.001 **	
	Esmahil Ava (Tomato, Cucumber and Sunflower)	2.20 <sup>a</sup>	0.05	2.06	2.33		
	Khrab dem (Bore soil, Grass and Bore soil)	1.70 <sup>b</sup>	0.05	1.56	1.83		
	Shkafti (Wheat, Bore and Okra)	2.10 <sup>a</sup>	0.05	1.96	2.23		
<b>CaCO3 %</b>	College of Agriculture Engineering Sciences Field (Tomato, bore and Broccoli)	7.70 <sup>c</sup>	0.05	7.56	7.83	<0.0001 **	
	Esmahil Ava (Tomato, Cucumber and Sunflower)	9.70 <sup>b</sup>	0.05	9.56	9.83		
	Khrab dem (Bore soil, Grass and Bore soil)	10.80 <sup>a</sup>	0.05	10.66	10.93		
	Shkafti (Wheat, Bore and Okra)	5.30 <sup>d</sup>	0.05	5.16	5.43		

Means having different letters within each parameter are differed significantly.

<sup>ns</sup> = non-significant ( $p > 0.05$ ); \* = significant ( $p \leq 0.05$ ); \*\* = significant ( $p < 0.01$ )

**Table 2. The Macro nutrients (N, P, K) as affected by the site (with specific species of plant)**

Paramet ers	Sample site (Rotation)	(Method of Crop	Mean	± Std. Error	95% Confidence Interval		<b>P value (Sig.)</b>
					Lower Bound	Upp er Bou nd	
N mg kg <sup>-1</sup>	College of Engineering (Tomato, bore and Broccoli)	Agriculture Sciences Field	83.00a	0.66	81.46	84.53	0.001 **
	Esmahil Ava (Tomato, Cucumber and Sunflower)		78.00c	0.66	76.46	79.53	

		<b>Khrab dem (Bore soil, Grass and Bore soil)</b>	<b>80.33b</b>	<b>0.66</b>	<b>78.79</b>	<b>81.87</b>	
		<b>Shkafti (Wheat, Bore and Okra)</b>	<b>84.00a</b>	<b>0.66</b>	<b>82.46</b>	<b>85.53</b>	
<b>P</b>	<b>mg</b>	<b>College of Agriculture Engineering Sciences Field (Tomato, bore and Broccoli)</b>	<b>4.56b</b>	<b>0.03</b>	<b>4.47</b>	<b>4.64</b>	<b>&lt;0.0001 **</b>
		<b>Esmahil Ava (Tomato, Cucumber and Sunflower)</b>	<b>4.11c</b>	<b>0.03</b>	<b>4.02</b>	<b>4.19</b>	
		<b>Khrab dem (Bore soil, Grass and Bore soil)</b>	<b>4.67b</b>	<b>0.03</b>	<b>4.58</b>	<b>4.75</b>	
		<b>Shkafti (Wheat, Bore and Okra)</b>	<b>4.56b</b>	<b>0.03</b>	<b>4.47</b>	<b>4.64</b>	
<b>K</b>	<b>mg</b>	<b>College of Agriculture Engineering Sciences Field (Tomato, bore and Broccoli)</b>	<b>16.20b</b>	<b>0.05</b>	<b>16.07</b>	<b>16.32</b>	<b>&lt;0.0001 **</b>
		<b>Esmahil Ava (Tomato, Cucumber and Sunflower)</b>	<b>14.60d</b>	<b>0.05</b>	<b>14.47</b>	<b>14.72</b>	
		<b>Khrab dem (Bore soil, Grass and Bore soil)</b>	<b>15.93c</b>	<b>0.05</b>	<b>15.81</b>	<b>16.05</b>	
		<b>Shkafti (Wheat, Bore and Okra)</b>	<b>18.30a</b>	<b>0.05</b>	<b>18.17</b>	<b>18.42</b>	

*Means having different letters within each parameter are differed significantly.*

<sup>ns</sup> = non-significant ( $p > 0.05$ ); \* = significant ( $p \leq 0.05$ ); \*\* = significant ( $p < 0.01$ )

There is a significant negative relationship between  $\text{CaCO}_3$  and N ( $r = -0.749$ ,  $p < 0.01$ ), P ( $r = -0.772$ ,  $p < 0.01$ ), and K ( $r = -0.827$ ,  $p < 0.01$ ), suggesting that lower availability of these nutrients is linked to greater calcium carbonate levels. This could be the result of chemical processes that decrease nutrient solubility, such as precipitation or pH buffering effects. Furthermore,  $\text{CaCO}_3$  and SOM have a slightly negative association ( $r = -0.327$ ), which is in line with the idea that calcareous soils have less organic matter. Phosphorus ( $r = 0.784$ ,  $p < 0.01$ ) and potassium ( $r = 0.853$ ,  $p < 0.01$ ) have a strong and major relationship with nitrogen, indicating that these nutrients co-occur in productive soils. It indicates nutrient limitation in calcareous soils because of its considerable negative relationship to  $\text{CaCO}_3$  ( $r = -0.749$ ,  $p < 0.01$ ). The weak or nonexistent associations with SOM and OC suggest that mineral interactions have a greater influence on nitrogen in this dataset than organic content.

Extremely positive relationships between phosphorus and nitrogen ( $r = 0.784$ ,  $p < 0.01$ ) and potassium ( $r = 0.984$ ,  $p < 0.01$ ) suggest that these macronutrients prefer to accumulate together, maybe as a result of fertilization methods or soil fertility. The notion that carbonate-rich soils may decrease phosphorus availability is supported by the substantial negative correlation with  $\text{CaCO}_3$  ( $r = -0.772$ ,  $p < 0.01$ ). Furthermore, it has a moderately significant correlation with pH ( $r = 0.631$ ,  $p < 0.05$ ), highlighting that phosphorus solubility may be impacted by pH. The co-availability of these nutrients is shown by the particularly strong and substantial positive relationship that potassium has with phosphorus ( $r = 0.984$ ,  $p < 0.01$ ) and nitrogen ( $r = 0.853$ ,  $p < 0.01$ ). Once more, its high negative connection with  $\text{CaCO}_3$  ( $r = -0.827$ ,  $p < 0.01$ ) suggests that calcareous soils have reduced nutrient availability. There are weak and minor links with SOM, OC, and EC, besides others.

**Table 3. Correlation coefficients between the studied properties of soil**

parameters	pH	EC ds/m <sup>-1</sup>	OC %	SOM %	CaCO <sub>3</sub> %	N mg kg <sup>-1</sup>	P mg kg <sup>-1</sup>	K mg kg <sup>-1</sup>
<b>pH</b>	1	0.486	0.121	0.303	-0.186	0.104	0.631*	0.496
<b>EC ds/m<sup>-1</sup></b>	0.486	1	0.870**	0.869**	0.045	-0.191	-0.020	-0.134
<b>OC %</b>	0.121	0.870**	1	0.950**	-0.223	0.000	-0.056	-0.097
<b>SOM %</b>	0.303	0.869**	0.950**	1	-0.327	-0.059	0.067	0.004
<b>CaCO<sub>3</sub> %</b>	-0.186	0.045	-0.223	-0.327	1	-	-	-
<b>N mg kg<sup>-1</sup></b>	0.104	-0.191	0.000	-0.059	-	1	0.784**	0.853**
<b>P mg kg<sup>-1</sup></b>	0.631*	-0.020	-0.056	0.067	-	0.784**	1	0.984**
<b>K mg kg<sup>-1</sup></b>	0.496	-0.134	-0.097	0.004	-	0.853**	0.984**	1

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

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

The overall results show that there is a significant difference between four samples collected from different locations in Duhok city. Crop rotation systems and soil management are considered the main reasons for these differences. Soils are acknowledged as slightly alkaline after results show a soil pH value between 7.7 and 7.3. This observation supports [6], findings, which explain and highlight the importance and the role of soil pH in the availability of essential nutrients for

plant growth, also important for the activity of soil-beneficial microbes, and in general, soil pH directly affects soil health. Variations in pH can be caused by crop type, organic matter decomposition rates, and soil management practices as appear in figure (2). Maintaining an optimal pH range is essential because it fosters microbial processes and enhances nutrient uptake by plants, thus improving soil fertility and agricultural productivity.

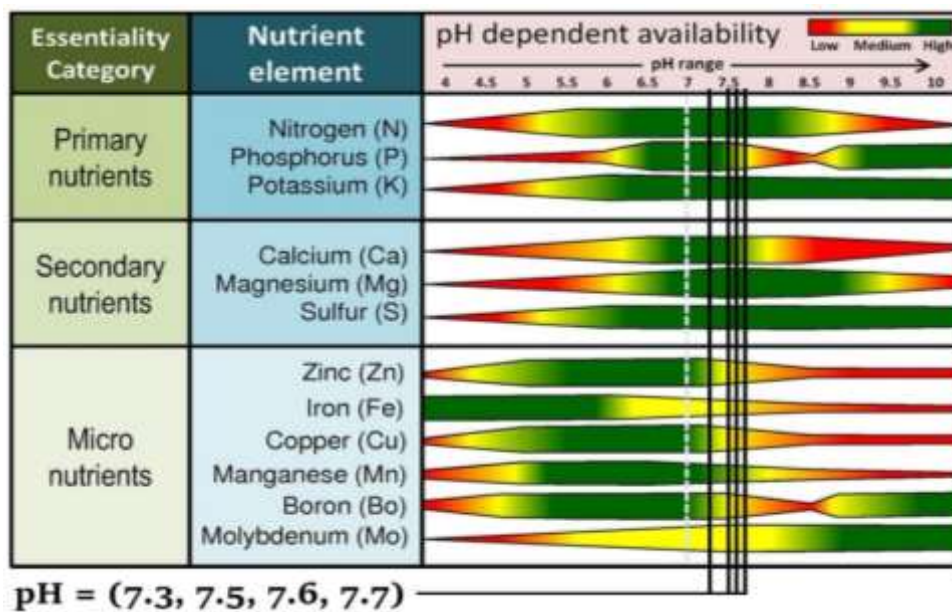


Fig. 2. The pH scale illustrating the relationship between soil pH and nutrient availability.

According to the 2018 Soil Survey Manual, non-saline Electrical Conductivity (EC) values indicating low to moderate soil salinity range from 0.08 to 0.11  $\text{ds/m}^{-1}$  (SSM,2018). Plant water intake, nutrient availability, and overall soil health are all influenced by soil salinity. The comparable work was completed [15]. EC can vary depending on soil drainage, mineral composition, and irrigation techniques [19], to maintain agricultural productivity and avoid yield losses, soil salinity must be carefully managed, especially in dry and semi-arid areas. Table 1 shows that the Organic Carbon (OC) and Soil Organic Matter (SOM) concentrations

ranged from 1.0% to 1.3% and 1.7% to 2.2%, respectively. Organic matter, an important component of soil fertility, affects nutrient cycling, soil structure, and water retention. Differences in agricultural residue can affect OC and SOM levels. The amount of calcium carbonate ( $\text{CaCO}_3$ ) in the soil ranged between 5.3% and 10.8%, influencing pH and nutrient availability. Calcium carbonate is essential if less than 5% but an increase in calcium carbonate causes a decrease in the availability of all macro and micronutrients except molybdenum.

Elevated calcium carbonate levels can cause alkaline soil, affecting plant nutrient uptake.  $\text{CaCO}_3$  concentrations can vary depending on the agricultural techniques used, weathering processes and parent materials. Controlling  $\text{CaCO}_3$  levels is critical for maximize soil pH and nutrient availability while also providing optimum conditions for plant growth. The quantities of nitrogen (N), phosphorus (P), and potassium (K) ranged from  $78 \text{ mg kg}^{-1}$  to  $84 \text{ mg kg}^{-1}$ ,  $4.11 \text{ mg kg}^{-1}$  to  $5.62 \text{ mg kg}^{-1}$ , and  $14.6 \text{ mg kg}^{-1}$  to  $18.3 \text{ mg kg}^{-1}$ , respectively. The nutrient levels (N, P, and K) differed among the sites. The development, metabolism, and general production of plants all depend on these nutrients. Our results were close to the paper [20].

Variations in nutrient levels can be related to changes in soil fertility, organic matter decomposition rates, and nutrient management strategies. Maintaining crop yields, maximizing nutrient usage efficiency, and reducing environmental effects all depend on maintaining nutrient levels. All the differences between soil chemical properties emphasize

that there are sophisticated connections in soil management techniques and crop rotation systems. In order to increase the productivity of crops and preserve soil unity, and long-term agricultural sustainability, these critical interactions required to be more understandable.

Table (4) illustrate, the soil physical properties of soil were analyzed for all four samples collected from different districts in Duhok Governorate (soil porosity, soil texture. Bulk density, water holding capacity, and soil moisture content. The results of samples show the moisture content ranging from 15.1% to 27.2%. According to a lot of research, effective soil moisture content is considered an important factor for soil fertility and water availability for microbial activity and plant growth. However, lower moisture content will affect nearly all activities in the soil, especially essential nutrient availability, microbial activities, and soil nutrient movement. Eventually, lower soil moisture content will affect crop production.

**Table 4: Physical characteristics of the soil in 4 sites where the crop rotation was applied in Duhok City.**

Sample sites	Method of Crop Rotation	Parameters	Parameters							WHC %
			Soil moisture content %	Bulk density g/cm <sup>3</sup>	Porosity %	Soil Particles			Soil Texture Type	
						Soil Percent	Clay %	Silt %		
<b>Esmahil Ava</b>	One Year Life	Tomato, Cucumbe r and Sunflowe r	26.4	1.17	56	62.7	31.1	6.2	Clay	52.94
<b>Khrab dem</b>		Bore soil, Grass	22.5	1.25	53	45.0	20.0	35.0	Clay	55.9
<b>College of Agriculture Engineering Sciences Field</b>		Tomato, bore	27.2	1.38	48	30.0	10.0	60.0	Silt y clay Loam	54.7
<b>Shkafti</b>		Wheat, Bore and Okra	15.1	1.24	53	41.3	50.0	8.7	Silt y clay	45.6

The results in Table (4) show that the bulk density ranged from 1.17 to 1.38 g/cm<sup>-3</sup>. According to this research's findings, none of the soil samples reached the high bulk density. High bulk density will affect plant growth directly and indirectly, with effects on water availability, air movement, decreased microbial activities, and even effects on nutrient availability. However, lower bulk density, ranging from near to 1.1 g/cm<sup>-3</sup>, will promote the growth of plants in a perfect way, as lower bulk density increases air movement, water movement and availability, increases microbial activities, and increases nutrient availability [21].

Optimal porosity is usually around 50%. This research's findings porosity ranged from 53 % to 56%, indicating that more than half of soil samples collected from four sites consist of pore spaces (water and air) by [22]. The findings support this research's results. Lower porosity content will have effects on water and air movement, and will also have effects on water infiltration and crop roots penetration. In the end, lower porosity content will strongly affect crop production. In contrast, ideal porosity content will increase air and water movement in soil, increase water infiltration in soil layers, and increase root penetration and distribution in soil.

Results in table (4) show that the texture in the three sites is clay and only in the soil in the College of Agriculture Engineering Sciences Field is silty clay. Soil texture is considered the main soil physical properties which impact soil nutrient availability, water soil movement, soil air movement, microbial activities, irrigation, drainage, soil structure, water retention, water holding capacity, field crop, and water availability [23]. Clay textured soil has a small particle size with

good water retention, while silty clay has a bigger particle size with lower water retention. Esmahil Ava soil required more tilling practices to make soil more available and productive. According to many research results, the other three soils with the good distribution of soil particles are favorable for growing crops [24].

Water holding capacity is considered the perfect metric for measuring and evaluating soil fertility. As there is a good content of clay particles in our four site's soils, the water-holding capacities will be high, and that is high in our research findings. Optimal water-holding capacity will be beneficial for plant growth, efficient water use, nutrient retention, soil microbial activities, root development, supports sustainable agriculture, enhances environmental protection, promotes biological health, encourages deep rooting, and even improves soil structure [22].

The soil samples collected from four different locations in Duhok governorate show the varieties of soil conditions and development. Also, the results show that Esmahil Ava soil with tomato, cucumber and sunflower crop rotation techniques, indicates much better results when compared to other locations in Duhok governorate.

Growing different crops in the same field over a number of years is known as crop rotation, and it is an essential agricultural practice. Numerous advantages of this technique, such as increased soil fertility, decreased cycles of pests and diseases, and improved water retention, have been widely acknowledged [25]. However, the text presented emphasizes broader assessments of the agricultural sector in the Kurdistan Region of Iraq (KRI) rather than concentrating on crop rotation research specifically [26].

This includes evaluating existing crop patterns, determining appropriate rotations, and assisting farmers in implementing these techniques. Crop rotation plans can also be improved through research into new crop varieties and irrigation methods, resulting in more sustainable and productive agriculture [27]. Despite the

fact that crop rotation studies are not specifically addressed, the KRI emphasizes the importance of sustainable agricultural practices. Iraq can develop more resilient and environmentally friendly farming systems by incorporating crop rotation into larger agricultural strategies [28].

## **Conclusion**

Crop rotation has a significant impact on soil physicochemical properties, according to research conducted at the University of Duhok's Agriculture College. To assess the effects of crop rotation on soil quality, the study examined a variety of parameters such as pH, electrical conductivity (EC), bulk density, soil texture, porosity, moisture content, calcium carbonate (CaCO<sub>3</sub>), nutrient levels (NPK), soil organic carbon (SOC), soil organic matter (SOM), and water holding capacity. Crop rotation practices have a significant impact on soil properties in Duhok City's four agricultural zones: Esmahil Ava, Khrab Dem, Agriculture College, and Shkafti.

Significant differences in soil pH, organic carbon content, and nutrient concentrations reflected the various management strategies used in these areas. Crop rotation methods resulted in promising improvements in soil fertility and structure, as evidenced by increased soil moisture, lower bulk density, increased porosity, and better water retention. These findings highlight the critical role of sustainable soil management in combating soil degradation and maintaining agricultural productivity.

Furthermore, the study emphasizes the importance of tailored soil management

approaches that take into account specific agricultural systems as well as local agro ecological conditions. By incorporating organic farming techniques and encouraging diverse crop rotations, stakeholders can promote long-term agricultural sustainability while effectively addressing soil health issues. Finally, the study emphasizes the importance of crop rotations in determining soil physicochemical properties and advocates for widespread adoption of sustainable soil management practices to protect soil fertility, conserve resources, and strengthen agricultural resilience in the face of changing environmental pressure.

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## **Conflict of interest**

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