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Investigation and Mapping of Some Soil Properties on the University of Baghdad Campus

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Abstract

Mapping soil characteristics is crucial to understanding the spatial distribution of those qualities and their sustainable uses; knowledge of soil fertility and agricultural yield requires an understanding of the physical and chemical characteristics, including soil acidity, electrical conductivity, and texture. This study employed interpolation techniques, Inverse Distance Weighting, to assess the spatial distribution of soil characteristics on the University of Baghdad campus in Iraq. Twenty-six soil samples were collected at 0–30 cm depth during autumn. The results revealed that sandy loam and loam were the most common textures in the study area. Soil's electrical conductivity ranged between 0.4 and 4.3 dS/m, indicating moderate to low salinity levels. Soil's pH readings did not show significant differences between sites, ranging between 7.00 and 7.11, with an average of 7.05. These results demonstrate that IDW has the potential to be a valuable tool for soil mapping, supporting precision agriculture and land management initiatives, particularly in areas with limited data. Geographic Information System approaches have proven highly effective in modeling and measuring soil characteristics, thereby providing advantages for preserving and enhancing soil health.

Keywords: GIS, Prediction, Soil map, Spatial distribution,

دراسة وترسيم خرائط بعض خصائص التربة في حدائق حرم جامعة بغداد

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الملخص

إن رسم خرائط لخصائص التربة أمر بالغ الأهمية لفهم التوزيع المكاني لتلك الصفات واستخداماتها المستدامة. تتطلب معرفة خصوبة التربة والعائد الزراعي الوعي بالخصائص الفيزيائية والكيميائية للتربة، مثل تفاعل التربةpH) ، والتوصيل الكهربائي (EC) ، والملمس. استخدمت هذه الدراسة تقنيات إحصائية جغرافية، مثل الترجيح بالمسافة العكسية(IDW) ، كنهج استيفاء لتقييم التوزيع المكاني لخصائص التربة في حرم جامعة بغداد، العراق. خلال موسم الخريف تم أخذ ستة وعشرون عينة من التربة على عمق 0–30 سم تم اختيارها بناءً على تجانس التربة. أظهرت النتيجة أن الطمي الرملي والطمي كانا نسيج التربة الشائع في منطقة الدراسة. تراوحت قيم EC للتربة من 0.4 إلى 4.3 ديسي سيمنز/ م، مما يشير إلى مستويات ملوحة معتدلة إلى

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منخفضة؛ ولوحظ أن مستويات الملوحة تزداد باتجاه نهر دجلة. لم تظهر قراءات درجة حموضة التربة pH اختلافات كبيرة بين المواقع، حيث تراوحت بين 7.00 و7.11، بمتوسط 7.05. وتُظهِر هذه النتائج أن IDW لديه القدرة على أن يكون أداة قيمة لرسم خرائط التربة، والمساعدة في مبادرات الزراعة الدقيقة وإدارة الأراضي، وخاصة في الأماكن التي لا تتوفر فيها سوى القليل من البيانات. وباستخدام استراتيجيات ومعالجات فعّالة لإدارة التربة، أثبتت مناهج نظم المعلومات الجغرافية فعاليتها العالية في نمذجة وقياس معلمات التربة، مما يوفر مزايا للحفاظ على صحة التربة وتعزيزها.

1. Introduction

Comprehension of the soil's chemical and physical characteristics and amount is decisive for reducing soil erosion, maximizing crop productivity, and maintaining environmental quality [1]. Due to their effect on soil nutrients availability and crop productivity, soil chemical and physical characteristics, including soil reaction (pH), soil electrical conductivity (EC), and soil texture, are essential for comprehending soil fertility and health [2]. Soil pH is the 'master variable' of soil chemistry because of its significant impact on many chemical reactions involving vital soil-plant nutrients [3]. Since they dictate the ideal nutrient availability, EC and PH are master variables in agricultural productivity [4]. Soil pH is a crucial indicator, as it is second-hand to predict various levels of soil chemical activity.

It is a helpful tool for determining the suitable plants for a given area, identifying if the soil reaction needs to be adjusted, and determining the nutrients amount that plants can obtain from soil [5]. The soil pH is one of the main variables that impact the availability of easily found nutrients in the soil [6]; the soil's pH shows how alkaline or acidic the soil is. The soil becomes more acidic between pH 7 and less down to 0; while moving from 7 up to 14, soil becomes more basic or alkaline [7],[8]. A soil's electrical conductivity (EC) significantly affects its salinity, which in turn impacts crop development and growth. While ions, also known as salts, appear, the mixture's EC improves. The low EC indicates that the soil mixture had weak electrical conductivity, likely due to the absence of salts. Salts become impacted by various factors, such as irrigation methods, internal soil water drainage, and the amount and timing of rainfall. The salts in the soil are reduced by rainfall, so they typically include small amounts. Evaporation extracts water from the soil, and dry conditions effectively concentrate salts. As an indicator of the quality and management of farmlands and water resources, electrical conductivity (EC) in soil and water is beneficial [9]. During Soil texture, because the mineral content of the soil is composed of three separate layers in terms of size and chemical composition (clay, silt, and sand), soil texture relates to the proportion distribution of particles of various sizes of soil (separates) [10].

Accurate mapping of these characteristics is necessary in areas where soil salinity and alkalinity pose challenges for agriculture. Soil parent material, climate, and land use are some factors that drive spatial variability in soil properties [11]. Geostatistical techniques, such as Inverse Distance Weighting, are typically used to interpolate these properties for spatial distribution maps that support precision agriculture [12]. The IDW's function, an available tool in ArcMap 10.8 software, has been used in determining soil pH and nutrient trends across fields and is further examined by [13], who demonstrated how this approach enhanced land management. In the Siliguri Sub-Division of India, [14] used IDW to produce soil pH and nutrient maps, proving its usefulness in areas with different soil parent materials and terrain. Assuming closer points have a more significant influence, IDW, a deterministic interpolation technique, weights the values of nearby sampled points to estimate values at unsampled sites [15]. Despite being straightforward and efficient, IDW has drawbacks, including sensitivity to sample distribution and a lack of consideration for spatial autocorrelation, which can occasionally make techniques like Kriging more accurate [16]. Nevertheless, IDW is widely applied in soil mapping, especially in areas with insufficient data [17]. To provide insights into the effectiveness of contributing to the understanding of soil characteristics and their spatial variability, soil texture is a crucial physical property of soil, indicating the distribution of essential soil components, such as sand, clay, and silt. These ratios are reflected in the soil, which contains particles of different sizes. A study was conducted on soil texture using the IDW technique. This technique was applied to soil texture to estimate the spatial values of soil based on known sample points [18]. The primary objective of this project is to analyze the chemical and physical properties of selected areas. Then, prepare spatial maps for these properties on the University of Baghdad campus. This map would support informed decision-making in environmental planning and land management at the University of Baghdad gardens. This study aims to estimate the status of some physical and chemical soil characteristics that have significant implications in farming production (ii), and to analyze the spatial variability.

2. Materials and methods

2.1. Study area

The study is located in the center of Baghdad, Iraq, on the campus of the University of Baghdad. It has an area of approximately 4 km$^{2.}$ The area lies approximately between a longitude of 44°21'23.8"E, a Latitude of 33°18'56.6"N, and a Longitude of 44°20'53.8"E, to a Latitude of 33°18'19.2"N. The primary criterion for selecting the management zones was the uniformity of soil within zones, as determined by chemical soil properties. Areas of individual zones were similar to those commonly used in agronomical practice.

2.2. Climate

Iraq is known for its extremely hot summers and mild winters, with maximum temperatures occurring in June, July, and August (43°C and 50°C) and in January (1°C and 8°C) [19]. The summers in Baghdad can be extremely hot, with highs of 45°C or higher in June, July, and August, due to its hot desert environment. In contrast, the annual average rainfall of Baghdad is about 154 mm during the winter; summertime rarely sees rain [20].

2. 3 Sampling procedure

Based on the green yards around the University of Baghdad campus, eleven locations were sampled using an auger for soil collection. The soil samples were collected randomly in October 2024 within each intervention site (Figure 1) at a depth of 0–30 cm using an auger tool. A handheld GPS was used to determine the geographical location of each sampling point. The spatial coordinates of samples were recorded using a GPS receiver (Garmin-GPSMAP76CSx) with an accuracy of (±3.0m). A total of 26 samples were collected and then packed in plastic bags before being sent for chemical and physical analyses at the Central Laboratory for Soil, Water, and Plant Analysis at the College of Agricultural Engineering Sciences, University of Baghdad.

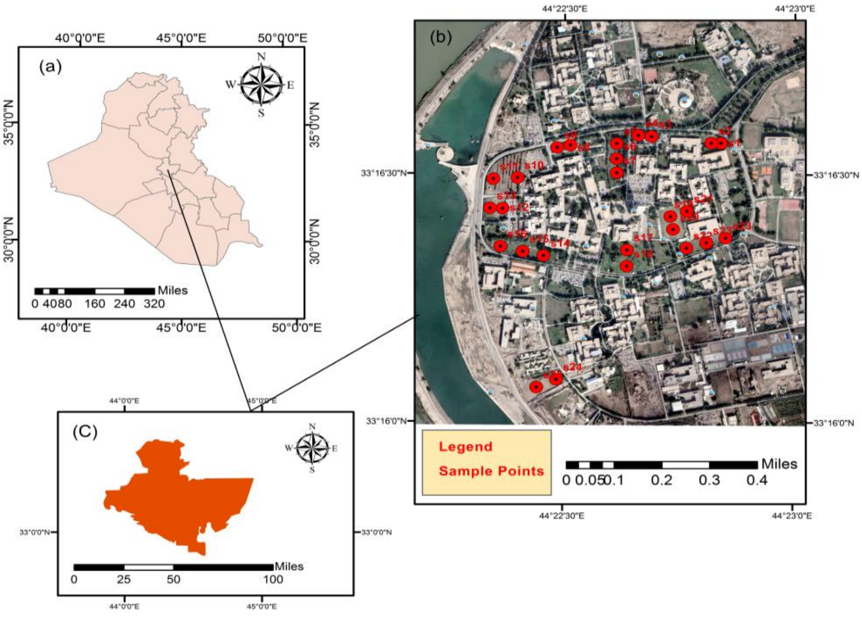
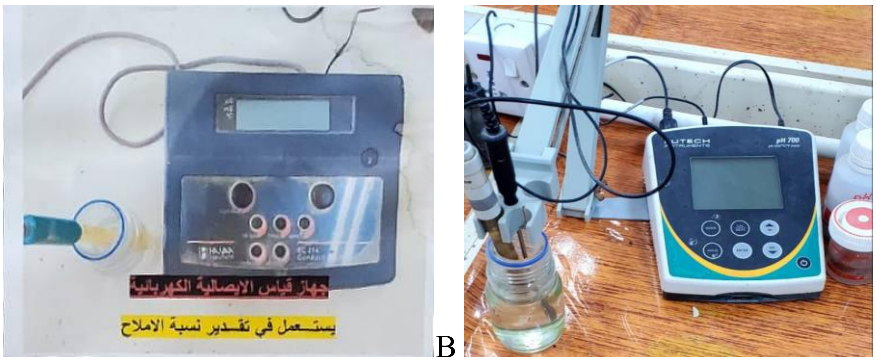


Figure 1: Sample location in the study area.

2.4. Laboratory Analysis

Composite soil samples of 500 g were air-dried, ground, and passed through a 2.0 mm sieve to separate the coarse part (gravel) from the fine part (sand, clay, and silt), then potassium chloride solution (1:1) was used with a glass electrode pH meter [21], Figure 2.

A



B

Figure 2: (a) Electrical conductivity meter, (b) pH meter.

EC was measured by the electrical method on a 1:5 aqueous extract. Such an extract has the advantage of simplicity, reducing time and cost compared to the method of saturation pulp extracts [22]. The measured values were adjusted to a temperature of 25°C. Soil texture was estimated using the pipette method given in [23]. Scientifically, soil scientists classify soils according to their salinity into five classes [24], Table 1.

Classes of salinity and EC (1 dS/m = 1 mmhos/cm;
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Table 1 Soil salinity classes based on EC (1 dS/m = 1 mmhos/cm); adapted from the NRCS Soil Survey Handbook [25].

EC (dS/m)	Salinity Class
0 < 2	Non-saline
2 < 4	Very slightly saline
4 < 8	Slightly saline
8 < 16	Moderately saline
≥ 16	Strongly saline

The average electrical conductivity of soil is 1.2 dS/m^{-1}. It ranges from 0.4 to 4.3, indicating that the area from which the results were obtained spans samples 1 to sample 14 of the study area, where the results range from 0.4 to 2.1. This suggests that the area does not have a high salinity rate [26], as shown in Table 1. The samples from the Tigris Riverside ranged in high salinity rates from 2.1 to 4.3, as shown in Table 2. Soil acidity is expressed as an important aspect of plant health, as it helps plant roots to reach many of the nutrients available in the soil, and the amount of rainfall plays an important role in soil acidity if it is a measure of soil acidity/alkalinity, and the pH value ranges between 0 and 14. If the soil acidity level is very low, it does not allow for optimal growth. Values greater than 7 indicate that the soil is alkaline, but if it is equal to 7, the soil is neutral. In the study area, the average pH of the soil ranges from 7.05, and the soil is slightly alkaline, with the highest percentage reaching 7.11. The minimum is 7.00, according to the Natural Resources Conservation Service.

Table 2: The measured values of EC and pH with their coordinates.

Sample No.	Easting m	Northing M	EC (ds/m)	PH
1	442325.5666	3682061.744	0.4	7.05
2	442293.1831	3682062.323	1	7.11
3	442091.943	3682087.189	0.9	7.08
4	442046.8375	3682091.237	0.4	7.1
5	441974.553	3682061.166	0.4	7.06
6	441974.511	3681951.891	0.4	7.08
7	441968.015	3681951.891	0.4	7.1
8	441817.8401	3682055.383	2.1	7.01
9	441773.8911	3682046.709	0.7	7.02
10	441639.7311	3681934.524	0.4	7
11	441558.1941	3681930.476	1.2	7.03
12	441589.421	3681820.603	0.8	7.11
13	441546.6286	3681821.76	2.7	7.06
14	441727.0508	3681644.229	4.3	7.04
15	441657.0794	3681659.843	0.9	7.02
16	441582.4817	3681678.926	0.8	7.05
17	442008.093	3681664.469	0.5	7.03
18	442007.5147	3681604.328	0.6	7.02
19	442154.9751	3681789.376	1	7.08
20	442163.6493	3681741.379	0.4	7.09
21	442210.4897	3681808.459	0.6	7
22	442208.7548	3681671.408	3.2	7.11
23	442275.8349	3681690.491	2.5	7.07
24	442331.876	3681710.326	0.5	7.1
25	441769.2649	3681182.765	1.6	7.05
26	441702.7632	3681153.851	2.5	7.03

2.5. GIS Analysis of Chemical Properties

2.5.1. Interpolation using IDW

Inverse Distance Weighting is most usually utilized mechanism for spatial data interpolation. Data analysis of soil properties was used to interpolate surface maps using ArcMap 10.8 software. A weighted average of known values within a specific neighborhood determines the unknown soil property values; then, those farther away. Using values from a dispersed collection of known points, the IDW method assigns values to unknown points [27] [28]. The weighted sum of the values of known locations is the value at the unknown location. This approach is utilized to estimate certain soil parameters, involving pH, EC, and texture. The IDW equation is key in creating soil characteristic maps and is essential for soil analysis. Additionally, it helps identify the area's nutrient-rich and nutrient-poor soil zones [29].

$$Z(X,Y) = \frac{\sum_{i=1}^{n}[\frac{Z_i}{d_i^p}]}{\sum_{i=1}^{n}[\frac{1}{d_i^p}]} \quad \text{……………………………..Eq.(1)}$$

Z(X,Y) is the predicted value at the sample location X,Y.

i is the number of measured sample points within the neighborhood defined.

Zi is the observed value at location i.

di is the distance between the predicted location X,Y and the measured location i.

λi is the distance-dependent weight associated with each sample point.

p is the power parameter that defines the rate of reduction of the weight as distance increases.

3. Results and Discussion

3.1 Soil texture calculator

Based on [30], the relative abundance of the three particle size classes (clay, silt, and sand) defines the soil texture. The United States Department of Agriculture has classified soil ingredients into three basic classes: silt (0.05-0.002 mm), sand (2-0.05 mm), and clay (<0.002 mm) [31]. The quantity and physical-chemical characteristics of nutrients vary according to the soil texture. The mean particle distribution of the study area soil has a 53% sand content, 34.1% silt content, and 12.8% clay content, as shown in Table 3. This suggests that the soil texture is a combination of sandy loam and loam. A soil texture triangle was used to calculate soil texture type [32]. These types of soils have a well-balanced ability to hold water, construct a stable structure, supply adequate aeration, and maintain a moderate soil temperature. Nevertheless, the more sandy or gravelly soils have an increased probability of aridity, reduced nutrient-holding capabilities, and a higher potential for nutrient leaching, including to groundwater. On the other hand, clay soils tend to be readily compressed and form a crust. Consequently, they are more complex in terms of drainage resistance and water erosion [33].

Table 3: Soil particle distribution, soil texture, and statistical description

Site No.	(gram)			Soil Texture
	Sand	Silt	Clay	
1	562	310	128	Sandy Loam
2	552	330	118	Sandy Loam
3	552	340	108	Sandy Loam
4	532	340	128	Sandy Loam
5	512	360	128	Loam
6	522	350	128	Sandy Loam
7	542	350	108	Sandy Loam
8	532	340	128	Sandy Loam
9	502	370	128	Loam
10	572	320	108	Sandy Loam
11	532	330	128	Sandy Loam
12	532	360	108	Sandy Loam
13	502	370	128	Loam
14	592	280	128	Sandy Loam
15	512	380	108	Loam
16	522	360	118	Sandy Loam
17	502	380	118	Loam
18	532	340	128	Sandy Loam
19	552	360	118	Sandy Loam
20	532	400	68	Sandy Loam
21	552	320	128	Sandy Loam
22	512	380	108	Loam
23	512	380	108	Loam
24	532	360	108	Sandy Loam
25	512	380	108	Loam
26	512	380	108	Loam
Min (%)	50.2	28.0	6.8	
Max (%)	59.2	40.0	12.8	
Mean (%)	53.0	34.1	10.8	
Sd	2.23	2.59	1.52	
Cv	4.2	7.6	14.07	

3.2. Spatial Distribution of Soil Properties

3.2.1 Spatial Soil Particle Distribution

In the field of study, the soil's 53% sand concentration indicates a sizable amount of sand. If the silt content of the soil is 34.1%, it is considered to be outstanding, and a clay content of 10.8% is regarded as modest. Given that it has a high proportion of sand (53%) and silt (34.1%) and a low proportion of clay (10.8%). Figures (3, 4, and 5) indicate that the soil texture is sandy loam. These soils are reasonably well-balanced in terms of drainage and water retention, although they are frequently sandy with a moderate proportion of clay. This soil has an average texture but tends toward sandy loam when considering the proportions of sand, silt, and clay. The sand, silt, and clay content of the soils exhibited an irregular distribution, ranging from 50.2% to 59.2%, 28.0% to 40.0%, and 12.8% to 68.0%, respectively (Figures 3, 4, and 5). Due to the significant consequences on various physical, chemical, and biological characteristics [34-35], soil texture should be considered an essential factor in land use planning, including the selection of tillage methods, crop rotation, irrigation strategies, and the quantity and type of fertilizer. Variation in the clay content of soils within the investigation area is attributed to fluctuations in the sediment load of rivers throughout the year [36]. Similar to the hypothesis on irregularity in some of the particle size components distribution, [37] exhibited uneven distribution of soil contents in an alluvial plain, and irregularity was attributed to the differences in silt content of sediments carried by the river at various periods. The reduced soil sand content toward the Tigris River can be attributed to sediment transport and deposition processes. As water flows, it holds sediments of differing sizes. Weightier and coarser particles, such as sand, tend to settle out first, while finer particles, such as silt and clay, are taken farther, resulting in a gradient where sand content declines as it moves nearer to the river.

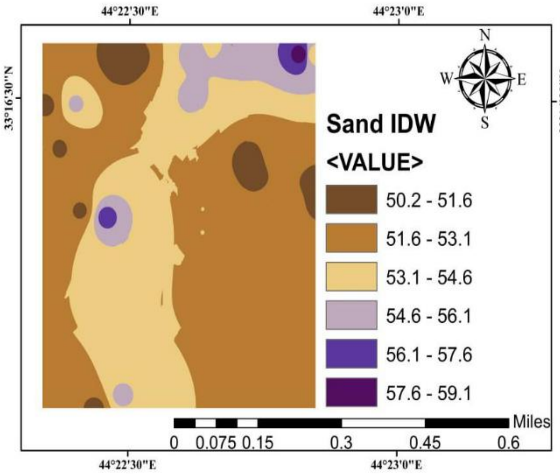
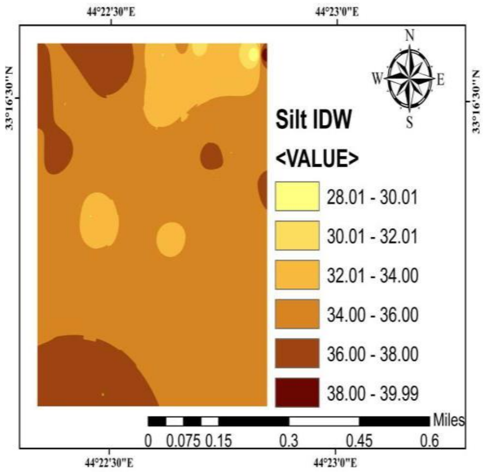


Figure 3: Interpolation analysis (IDW) of the Sand content value



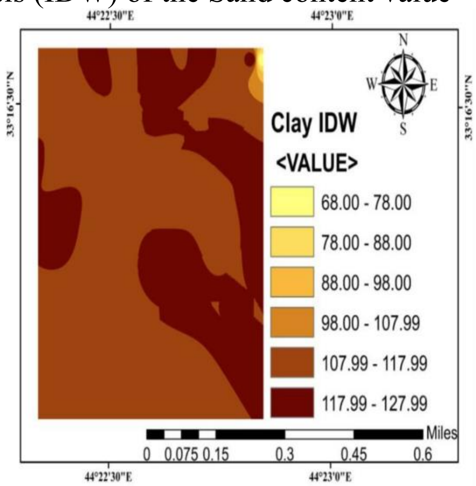
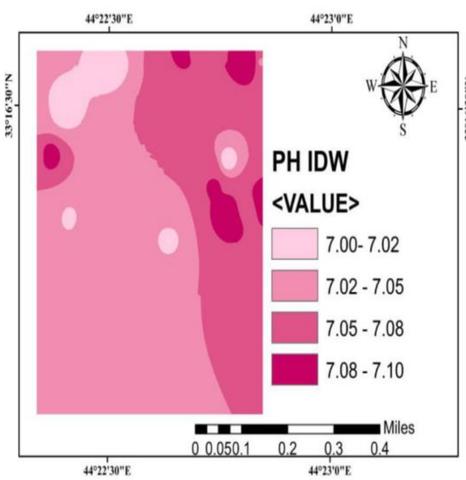


Figure 4: Interpolation analysis (IDW) of the Silt content value.

Figure 5: Interpolation analysis (IDW) of the clay content value.

According to Table (1), most of the study area can be classified as non-saline to very slightly saline soil, which is a good indicator of soil health conditions, making it perfect for most crops. However, some spots showed a slightly saline condition. Figure 6 shows that electrical conductivity (EC) follows a north-to-south gradient. Its lower value was on the north side of the region (0.40-0.95 ds/m); then, it tended to be lower in the middle, toward the river (1.5-2.1

ds/m). It was attributed to the accumulation of salts from irrigation, groundwater release, and the movement of water and dissolved salts. In many topographies, rivers are found in low-lying areas. Water from more elevated heights flows to lower areas, bringing dissolved (ions) salts. The salts concentrate in the soil as water accumulates near the river [38]. However, two spots showed up with unusually high values of EC (2.6-4.3 ds/m). A defect in the irrigation pipes has led to the salinization of this spot. Alternatively, there may be buried rubble of construction materials, or the surface layer of the soil may have been removed, resulting in insufficient thickness to drain the excess water that the plant requires, which is less than 15 cm. Figure 6 depicts the spatial distribution (interpolation maps) of EC sample points in the study area. The EC values range from 0.40 to 4.29, with a mean of 1.2. The spatial distribution of soil pH in the study area is shown in Figure 7. Generally, the soil in the study area was classified as neutral, with the lowest value at 7.11 and the highest at 7.00. Loam soil commonly has a neutral pH (6.0 to 7.0) due to its proportional formatting of sand, silt, clay, and organic matter. This balance helps with suitable drainage, nutrient availability, and buffering capability, which enables maintaining a neutral pH. Soil particle size impacts soil pH, where sand enhances soil drainage. Silt content supports soil fertility and moisture retention; soil clay content supports nutrient retention and buffering capability. The interaction between these elements prevents severe pH changes[39].



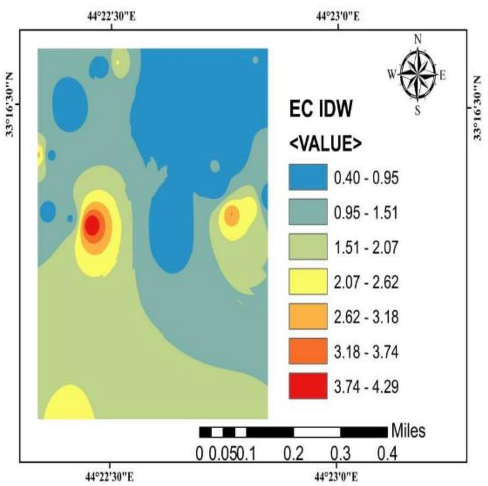


Figure 7: Interpolation analysis (IDW) of pH map. **Figure 6:** Interpolation analysis (IDW) of EC map

4. Conclusions

The investigation showed insignificant soil pH differences across the investigated locations, demonstrating uniform pH classes regardless of other soil characteristic variations. Nevertheless, meaningful soil electrical conductivity (EC) differences indicated soil salinity or nutrient scope variability. The soil texture type, characterized as loamy and sandy loam, probably contributed to these observations; soil texture and composition can impact nutrient availability, water retention, and EC classes. These results emphasize considering soil texture and EC in agricultural control, even when pH stays steady. Spots or locations with high or uncommon soil salinity content must be rechecked to prevent the issue from increasing. Finally, the additional examination could investigate the factors causing EC variability and its implications for soil health and plant growth in loamy, sandy soils. The impact of the present research is in its capacity to supply a scientific basis to enhance control of soil by illuminating the chemical and physical features of the soil in the natural areas on the University of Baghdad campus. Increasing plant health, raising the efficiency of water resource use, and decreasing salinization and environmental degradation depend on improving soil quality and studying the distribution of soil factors, such as pH, EC, and soil texture. As a recommendation, a periodic soil test must be conducted to monitor the soil reaction and salinity. Those two factors can enhance soil nutrient availability to the plants in the rootzone; otherwise, neglecting them can put the soil on the path to degradation, where reaching a hard degradation step would make restoring soil health challenging. Moreover, it recommends investigating locations with high salinity levels to find the cause, prepare solutions, and mitigate the risk.

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