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Preliminary Study on Soil Mineral Identification in Erbil Province

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Preliminary Study on Soil Mineral Identification in Erbil Province

Abstract

This article presents a preliminary study conducted to identify soil minerals within Erbil Province. Soil minerals play a crucial role in soil fertility, nutrient availability, and various soil-related processes. Understanding the mineral composition of soils is essential for effective land management, sustainable agriculture, and environmental conservation. The study area was carefully selected to represent a diverse range of soil types, geological formations, and land use practices. A systematic sampling approach was employed, ensuring adequate coverage of the study area. 80 soil samples were collected from various locations and depths, and a combination of field observations and laboratory analyses was conducted to identify and characterize soil minerals. The soil samples were examined by X-ray diffraction (XRD) method to determine the mineral composition. The identification of minerals allowed for insights into the geological origin, weathering processes, and soil formation mechanisms within the study area. The preliminary findings revealed a diverse range of soil minerals across the study area. Common mineral types, including silicates, carbonates, oxides, and clay minerals, were identified. Variations in mineral composition were observed, reflecting the influence of parent material, geology, and soil development processes. The results of this preliminary study provide a foundation for future research and more in-depth investigations of soil minerals in the study area. The mineral identification data can be utilized for land use planning, soil classification, and targeted soil management strategies

Keywords

Soil geochemistry; Soil Mineralogy; X-ray diffraction; Soil mineral identification; Erbil Province.

ORIGINAL ARTICLE

Preliminary Study on Soil Mineral Identification in Erbil Province

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Abstract

This article presents a preliminary study conducted to identify soil minerals within Erbil Province. Soil minerals play a crucial role in soil fertility, nutrient availability, and various soil-related processes. Understanding the mineral composition of soils is essential for effective land management, sustainable agriculture, and environmental conservation. The study area was carefully selected to represent a diverse range of soil types, geological formations, and land use practices. A systematic sampling approach was employed, ensuring adequate coverage of the study area. 80 soil samples were collected from various locations and depths, and a combination of field observations and laboratory analyses was conducted to identify and characterize soil minerals. The soil samples were examined by X-ray diffraction (XRD) method to determine the mineral composition. The identification of minerals allowed for insights into the geological origin, weathering processes, and soil formation mechanisms within the study area. The preliminary findings revealed a diverse range of soil minerals across the study area. Common mineral types, including silicates, carbonates, oxides, and clay minerals, were identified. Variations in mineral composition were observed, reflecting the influence of parent material, geology, and soil development processes. The results of this preliminary study provide a foundation for future research and more in-depth investigations of soil minerals in the study area. The mineral identification data can be utilized for land use planning, soil classification, and targeted soil management strategies.

Keywords: Soil geochemistry, Soil Mineralogy, X-ray diffraction, Soil mineral identification, Erbil province

1. Introduction

The study of soil mineralogy in a specific geographic area is essential for unraveling the geological influences that shape soil composition and understanding the implications for various environmental processes and land management practices. Soil minerals play a crucial role in governing soil properties, nutrient availability, water-holding capacity, and overall soil fertility. By investigating the mineralogical characteristics of soils in a given area, researchers can gain insights into the origin, formation, and transformation of soils, as well as their potential impacts on ecosystem functioning.

Previous studies have underscored the significance of soil mineralogy and its relationship with soil properties and ecosystem dynamics. For instance, the work of Brady and Weil [1] emphasized the pivotal role of soil minerals in providing essential nutrients to plants through mineral weathering and ion exchange processes. Similarly, the research by Amundson et al. [2] highlighted the importance of mineralogical composition in regulating soil carbon sequestration and nutrient cycling, which have critical implications for climate change mitigation and sustainable land management.

In the context of Erbil Province, the investigation of soil mineralogy holds particular significance due to its unique geological characteristics and environmental context. These geological factors are coupled with climatic conditions, topography, and land use practices, influence the mineralogical composition of soils within the area [3].

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To date, limited research has been conducted specifically on soil mineralogy in Erbil Province. However, studies conducted in nearby regions or with similar geological formations have provided valuable insights. For example, the study by Al-Hazaa [4] investigated soil mineralogical characteristics of the Kaista and Ora formations of north Iraq and identified kaolinite, illite, chlorite, and palygorskite form the main clay mineral assemblage while quartz, feldspar, calcite and dolomite form the non-clay fraction of the studied shales as dominant soil constituents. These findings highlight the potential for similar mineralogical patterns in Erbil Province due to shared geological origins.

The specific objectives of this research paper are twofold: firstly, to characterize the mineralogical composition of soils in Erbil Province, and secondly, to explore the relationships between soil minerals and their implications for soil properties, nutrient cycling, and land management practices. By conducting a comprehensive analysis of soil samples collected from various locations within Erbil Province, we aim to identify the predominant minerals and mineralogical assemblages present, assess their spatial distribution patterns, and examine the factors influencing their formation and distribution.

Moreover, this study will delve into the impact of soil mineralogy on key soil properties and ecosystem processes in Erbil Province.

The findings of this research will have practical implications for land managers, agronomists, and environmental practitioners in study area. By understanding the soil mineralogical characteristics and their influence on soil properties and ecosystem processes, stakeholders can develop targeted land management strategies, such as tailored soil amendments, conservation practices, or nutrient management approaches. This knowledge will contribute to sustainable land use planning, soil fertility management, and environmental conservation efforts in Erbil Province.

2. Methodology

2.1. Study area

Geographically, Erbil Province is situated in the northern part of Iraq, bordered by Turkey to the north and Iran to the east and is bounded by latitudes 35.42172 N and 37.32381 N and longitudes 43.35408 E to 44.97378 E. It covers an area of approximately 15,074 square kilometers and is characterized by diverse topography. The region features plains, hills, and mountains, offering a variety of landscapes for study and analysis (Figure 1). The climate of Erbil Province is classified as a continental climate, with hot summers and cool winters. The average annual temperature ranges from around 14 °C–22 °C, with the hottest months being July and August. The region experiences relatively low precipitation. Precipitation is variate and majority of rainfall occurring during the winter months; as a whole, the arid zone receives rainfall less than 250 mm while the dry semi-humid zone receives 900-1000 mm and over (Keya, 2020).

Erbil Province is known for fertile soils and its rich agricultural potential. The region supports a wide range of crops, including wheat, barley, fruits, and vegetables. Livestock farming is also prevalent in the area [5]. The agricultural practices and land use patterns in Erbil Province make it an interesting study area for examining soil properties, nutrient dynamics, and sustainable agricultural practices.

2.2. Lithological soil types

The lithology of Erbil Province is characterized by a diverse range of geological formations and rock types. The region's geology is shaped by its location within the larger geological framework of the Zagros Fold-Thrust Belt, which is known for its complex tectonic history and diverse lithological units. Erbil Province encompasses a variety of lithological formations that have been deposited over millions of years. These formations include sedimentary, metamorphic, and igneous rocks (Figure 2b). The lithological composition of Erbil Province provides valuable insights into the geological history, tectonic processes, and environmental conditions that have shaped the region over time ([6]). Understanding the lithology of the area is important for various geological studies, including geological mapping, mineral exploration, and understanding the hydrogeological characteristics of the region.

The soils of Erbil Province exhibit a diverse range of characteristics influenced by factors such as parent material, topography, climate, and land use practices. The region's soils support agricultural activities and have implications for land management and environmental sustainability [7]. While specific soil types may vary across the province, several general soil groups can be identified [8]: **Chernozem** soils are characterized by a dark, fertile topsoil layer rich in organic matter. These soils are typically found in the plains and low-lying areas of Erbil Province. Chernozem soils are highly productive and support a wide range of crops. **Calcisols** are soils with a high concentration of calcium carbonate (lime) accumulation. They form in arid or semi-arid regions where evaporation exceeds

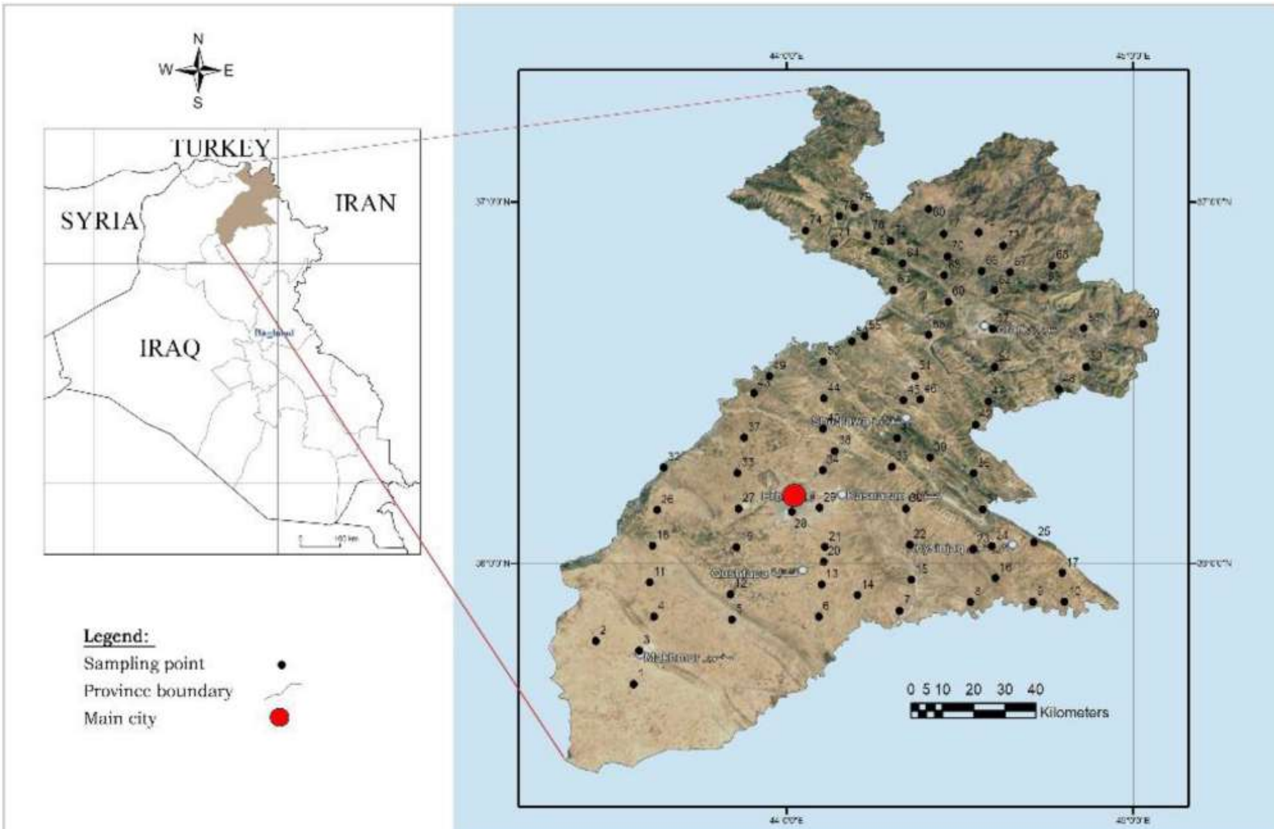

Figure 1. Location map of Erbil Province and 80 sampling points.

precipitation, leading to the concentration of carbonates. Calcisols are often found in drier areas of Erbil Province. **Leptosols** are shallow soils that occur on steep slopes or rocky terrains. They have a limited soil profile and are found in hilly and mountainous regions within Erbil Province. Leptosols are often associated with areas of erosion and provide unique challenges for agriculture. **Vertisols** are clay-rich soils that exhibit high shrink–swell properties. They have a high clay content and form deep cracks when dry. Vertisols can be found in various parts of Erbil Province and pose challenges for soil management due to their tendency to swell and shrink with changes in moisture. **Regosols** are young and undeveloped soils characterized by a limited soil profile. They often occur in eroded or recently deposited areas, such as alluvial plains, riverbanks, and floodplains. Regosols are typically found in areas with recent geological activity. Figure 2 a shows soil taxonomy of study area [9].

2.3. Soil sampling

The current study encompasses 80 sampling points and strategically are distributed across the region. The selection of these 80 sampling points takes into account various factors such as land use patterns, soil taxonomy and lithological condition. The survey methodology involves collecting soil samples from each of the designated sampling points. Trained soil experts and technicians carry out the collection process, following standardized protocols to ensure consistency and accuracy.

The collected soil samples were then analyzed in laboratory settings using a range of techniques and equipment. These analyses provided crucial data on soil mineralogy. In addition, these analyses provided crucial data on important soil properties, including texture, gypsum content, P, Ca, Mg, Na, K and SO_4 (Table 1).

Laboratory analysis methods were: particle size using the hydrometer method; Soluble Na and K in the saturation extract was determined by flame photometer; Soluble Ca and Mg in the saturation extract was Determined by EDTA Titration; Available P extracted by Olsen method and was determined using the spectrophotometer; Available K was extracted with ammonium acetate and was determined using the flame photometer.

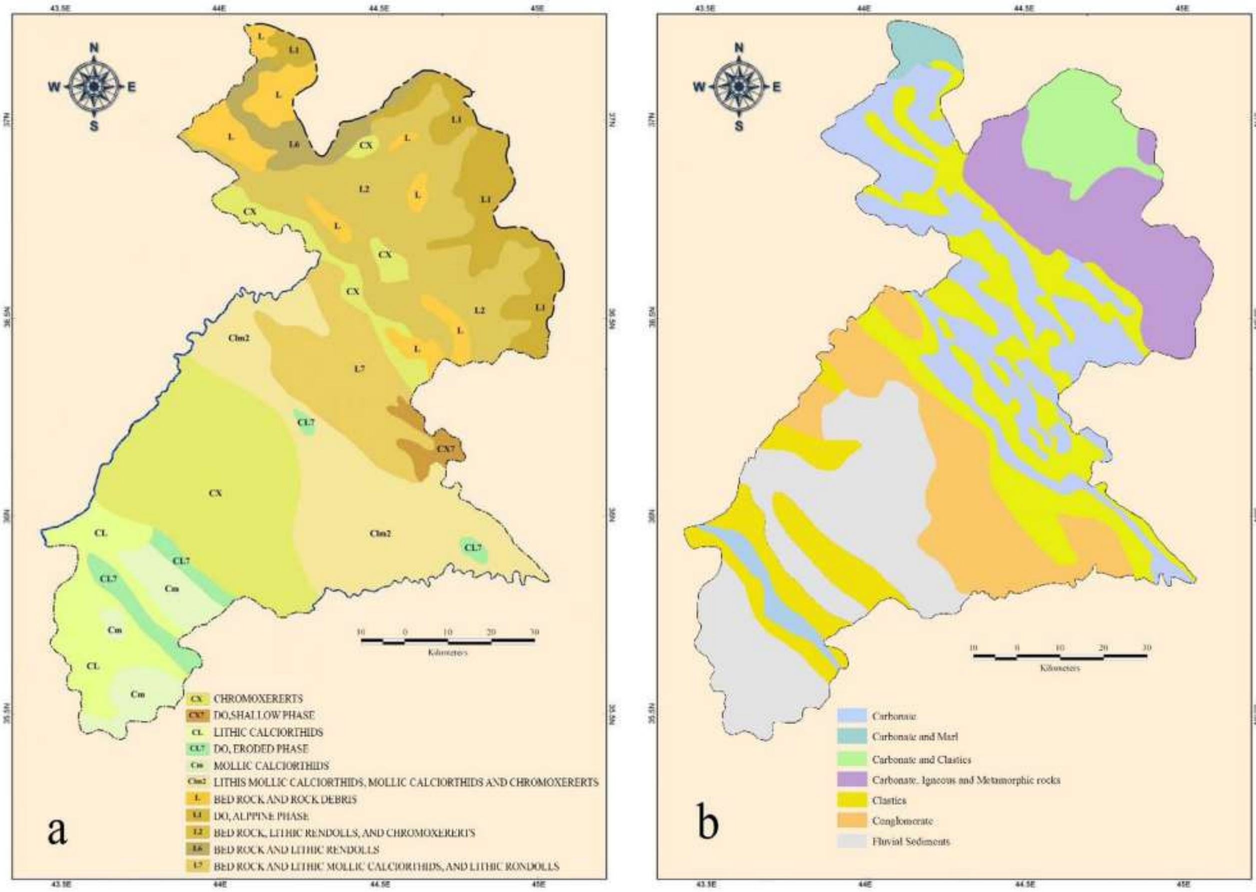

Figure 2. Soil taxonomy classification map and Lithological map of the exposed formations. (After [10]).

Table 1. Some selected soil properties for 80 samples in the study area.

#	Location	Longitude	Latitude	Clay	Silt	Sand	P	Gypsum	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SO_4
1	Baqrt	43.55902	35.66436	16	54	30	14.5	0.0	11.0	12.0	5.7	0.8	8.1
2	Kabaruk	43.45019	35.78393	20	42	38	7.0	0.0	13.0	11.0	11.5	0.5	9.1
3	Makhmur	43.57537	35.7578	20	40	40	20.5	0.0	13.0	11.0	4.4	1.6	8.6
4	Dushwan	43.61779	35.85174	16	14	70	23.9	17.9	9.0	14.0	8.2	0.7	20.1
5	Dibagah	43.84225	35.84365	28	52	20	1.9	0.0	2.0	3.0	1.6	0.0	4.6
6	Omarawa	44.09289	35.85114	36	54	10	3.6	0.0	3.2	2.0	0.6	0.0	5.9
7	Awmal	44.32612	35.86784	14	16	70	2.1	0.0	2.0	0.8	0.3	0.0	2.9
8	Kani Lala	44.53051	35.89177	36	46	18	5.0	0.0	1.2	1.6	0.3	0.0	2.2
9	Kanirash	44.71095	35.89234	24	22	54	5.7	0.0	6.0	6.0	2.4	0.2	2.8
10	Alyasa Sur	44.8012	35.89251	36	46	18	9.0	0.0	1.6	1.2	0.4	0.1	3.0
11	Malaqra	43.60528	35.94635	28	40	32	3.7	12.2	9.0	7.0	5.4	0.0	12.4
12	Dibagah	43.83819	35.91351	26	60	14	3.7	0.0	2.8	1.2	0.6	0.1	2.4
13	Dola Bakra	44.10125	35.94058	26	56	18	11.7	0.0	3.6	1.6	0.4	0.1	3.9
14	Azyana	44.20473	35.91139	20	20	60	7.2	0.0	1.2	1.2	0.3	0.0	1.2
15	Merga	44.36093	35.95314	14	54	32	4.8	0.0	1.2	2.4	0.3	0.1	0.9
16	Kwna Gwrg	44.60266	35.9585	40	46	14	8.4	0.0	3.0	4.0	0.4	0.1	4.2
17	Shiwashan	44.79547	35.97281	38	44	18	11.2	0.0	2.8	1.6	0.6	0.0	2.5
18	Awena	43.61334	36.04776	32	52	16	9.8	0.0	3.0	6.0	1.4	0.2	5.9
19	Sorbash	43.85595	36.04396	32	62	6	13.3	0.0	6.0	5.0	4.0	0.5	8.3
20	Qushtapa	44.10758	36.00347	30	52	18	23.3	0.0	2.8	1.6	1.3	0.1	1.0
21	Sardasht	44.11019	36.04419	22	54	24	15.9	0.0	4.0	2.0	0.0	0.1	2.6
22	Banimaran	44.35524	36.05107	20	28	52	4.5	0.0	1.6	0.8	0.4	0.0	1.0
23	Shiwashok	44.53833	36.0379	36	48	16	20.0	0.0	7.0	5.0	1.9	0.2	7.2
24	Shila	44.59232	36.04658	50	40	10	1.7	0.0	0.8	1.6	1.2	0.0	0.3
25	Sewasan	44.71398	36.05734	24	46	30	6.9	0.0	2.0	1.2	0.4	0.0	4.1
26	Hawerah	43.62715	36.1468	40	50	10	7.1	0.0	4.0	1.2	1.8	0.1	5.5

(*continued on next page*)

Table 1. (continued)

#	Location	Longitude	Latitude	Clay	Silt	Sand	P	Gypsum	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SO_4
27	Jmka	43.86159	36.15007	42	44	14	8.8	0.0	4.0	1.6	1.7	0.1	3.6
28	Grdarasha	44.01569	36.14224	32	60	8	12.7	0.0	2.4	0.8	0.9	0.1	1.6
29	Hiran City	44.0956	36.15292	30	56	14	9.2	0.0	4.0	1.6	0.8	0.1	3.2
30	Smaqa Shirin	44.3438	36.15035	32	36	32	1.9	0.0	1.2	0.8	0.3	0.0	0.9
31	Senan	44.56561	36.14792	40	34	26	3.2	0.0	2.0	1.2	0.3	0.0	0.7
32	Khabat	43.64638	36.26442	33	39	28	10.7	0.0	4.0	1.6	1.2	0.2	1.3
33	Qalatga	43.85814	36.24934	44	38	18	4.7	0.0	2.0	3.0	0.7	0.1	2.0
34	Shaways	44.10399	36.25705	44	28	28	12.9	0.0	4.0	3.0	1.9	0.1	2.0
35	Gomaspan	44.30381	36.26668	46	52	2	8.6	0.0	1.6	2.0	0.3	0.1	2.3
36	Nazanin	44.53977	36.24773	47	35	18	16.4	0.0	1.6	1.2	0.2	0.1	1.6
37	Bar Hushtr	43.87813	36.34696	47	49	4	2.8	0.0	1.2	2.0	0.4	0.0	1.5
38	Malla Omar	44.13901	36.31002	37	41	22	4.2	0.0	2.0	1.2	0.3	0.1	2.5
39	Sulawk	44.41425	36.29255	12	8	80	5.0	0.0	2.8	2.0	0.2	0.1	2.9
40	Qeremukyan	44.10599	36.37112	45	35	20	4.5	0.0	1.6	1.6	0.3	0.0	3.0
41	Qala sng	44.3187	36.3453	54	36	10	6.1	0.0	3.0	2.0	0.2	0.0	5.5
42	Balisan	44.5454	36.38267	48	42	10	11.6	0.0	2.0	0.8	0.2	0.0	1.2
43	Darashakran	43.90615	36.46944	49	47	4	39.2	0.0	15.0	8.0	1.6	0.6	9.5
44	Sarsul	44.10714	36.45534	36	50	14	2.5	0.0	1.2	1.2	0.4	0.0	2.4
45	Khatibyan	44.33743	36.45038	55	31	14	4.5	0.0	4.0	2.0	0.2	0.0	1.9
46	Mamajalka	44.38578	36.45252	53	39	8	5.8	0.0	3.6	0.8	0.4	0.1	1.4
47	Malakan	44.58192	36.44743	45	37	18	9.1	0.0	4.0	3.0	0.2	0.1	6.1
48	Warte	44.78563	36.48053	57	27	16	6.4	0.0	5.0	1.0	0.3	0.1	5.3
49	Garwdalalan	43.95073	36.51678	43	33	24	13.0	0.0	5.0	1.0	0.5	0.1	6.2
50	Shekh Turab	44.10623	36.55784	27	23	50	1.4	0.0	1.2	0.8	0.2	0.0	0.5
51	Bawyan	44.37104	36.51768	53	43	4	2.6	0.0	2.4	1.6	0.3	0.1	2.5
52	Akoyan	44.59998	36.54157	61	27	12	8.4	0.0	7.0	2.0	1.4	0.3	4.1
53	Wallze	44.8645	36.54249	49	33	18	2.5	0.0	2.0	2.0	0.2	0.0	1.1
54	Chira	44.18808	36.61328	39	27	34	1.1	0.0	1.6	1.6	0.5	0.0	2.6
55	Barbyan	44.22617	36.62775	21	25	54	2.4	0.0	1.6	1.6	0.2	0.1	1.4
56	Sreshma	44.41013	36.63108	33	25	42	1.5	0.0	1.6	1.2	0.2	0.0	1.6
57	Barzewa	44.59502	36.64817	55	39	6	2.9	0.0	0.8	0.8	0.2	0.0	0.6
58	Delza	44.8569	36.64941	37	21	42	7.9	0.0	4.0	4.0	0.4	0.1	3.9
59	Haji Omran	45.02844	36.66165	45	29	26	5.7	0.0	1.2	0.8	0.2	0.1	0.3
60	Mazne	44.46702	36.72275	41	51	8	1.9	0.0	1.6	0.8	0.2	0.0	0.1
61	Shivadze	44.30838	36.75627	51	47	2	1.1	0.0	1.2	1.6	0.2	0.1	1.0
62	Kazhak	44.60033	36.75449	17	7	76	9.3	0.0	0.8	2.0	0.2	0.1	0.0
63	Dere	44.7423	36.76258	21	47	32	41.6	0.0	2.4	0.8	0.2	0.1	2.0
64	Mergasor	44.335	36.82936	35	31	34	8.3	0.0	1.6	0.4	0.2	0.1	0.1
65	Dara	44.45435	36.79592	39	51	10	1.7	0.0	1.2	0.8	0.2	0.0	0.6
66	Nekawa	44.56237	36.80792	27	23	50	7.0	0.0	1.2	0.8	0.2	0.1	0.2
67	Sidakan	44.64455	36.8043	15	9	76	5.8	0.0	1.2	1.2	0.3	0.0	1.1
68	Bni Rashkin	44.76598	36.82407	27	37	36	10.7	0.0	2.4	2.0	0.2	0.1	1.8
69	Goratu	44.25554	36.86316	31	41	28	25.8	0.0	3.2	1.2	0.2	0.1	2.9
70	Girkal	44.46423	36.84825	43	31	26	12.2	0.0	1.2	0.8	0.2	0.0	0.8
71	Rezan	44.13819	36.88568	28	48	24	10.5	0.0	1.6	0.8	0.2	0.0	0.9
72	Bedod	44.30055	36.89114	10	16	74	1.5	0.0	1.2	2.0	0.2	0.0	0.9
73	Darhol	44.62501	36.87797	16	8	76	8.7	0.0	1.6	0.8	0.3	0.1	0.3
74	Barzan	44.05503	36.92015	30	34	36	2.2	0.0	0.8	1.6	0.1	0.0	0.8
75	Kani Bota	44.15217	36.96031	42	40	18	5.4	0.0	2.0	1.6	0.2	0.1	1.7
76	Aysha Kor	44.23447	36.90651	28	36	36	1.8	0.0	1.6	2.0	0.2	0.0	1.8
77	Kolaka	44.45389	36.91091	40	28	32	3.0	0.0	1.6	1.2	0.2	0.1	2.6
78	Shushin	44.55433	36.915	18	16	66	7.5	0.0	3.2	1.2	0.3	0.1	3.0
79	Dudamara	44.19662	36.98335	38	50	12	5.5	0.0	2.0	1.2	0.2	0.0	2.2
80	Barmiza	44.4104	36.97912	36	42	22	2.0	0.0	0.8	1.2	0.2	0.0	1.6

(Clay, Silt, Sand and Gypsum per %), (P per ppm), (Ca, Mg, Na, K and SO_4 per meq/L).

3. Results and discussion

The mineralogical study of the study area revealed a diverse range of minerals present in the samples collected. A comprehensive analysis using X-ray diffraction (XRD) method allowed for the identification and quantification of the mineral phases [11]. The results showed the presence of several key minerals, including but not limited to quartz, feldspar, mica, and calcite. Table 2 (Appendix) illustrates the chemical formulae and ICDD card numbers of presents the abundances of major mineral phases in the samples.

According to the X-ray diffractogram of soil samples, the dominant minerals (Major Phase) were Quartz, Calcite, Albite, Palygorskite, Illite, Muscovite - Illite and Smectite Group. In the Minor Phase, Potassium Feldspar, Chlorite, Kaolinite, Dolomite were found, which were sometimes different in the samples. These findings are consistent with [4,12]'s studies. Additionally, Gypsum was found as trace phase in southern soils. Figures 3 and 4 illustrate the X-ray diffractogram of samples based on soil taxonomy (Figure 2a).

It was worth noted that Hematite was encountered in sample number 2, 16, 21, 22, 25, 26, 34, 35, 58, 60 and 68. Likewise, Goethite was observed in samples 19, 23 and 71. Also, Augite was seen in samples 68−71 and 75−79 which are located in northern parts of study area.

The identified minerals in the study area provide insights into the geological processes and environmental conditions that have influenced the formation and composition of the studied samples. The prevalence of quartz, feldspar, and mica indicates the dominance of primary minerals derived from the parent rock materials [13]. These minerals are commonly found in igneous and metamorphic rocks, suggesting a significant contribution from these rock types to the study area's mineralogical composition [14].

The presence of calcite suggests the influence of secondary processes such as weathering and hydrothermal alteration. Calcite is often associated with carbonate-rich environments and can result from the dissolution and precipitation of carbonates in the geological history of the area. The relative abundance of calcite may reflect the influence of specific hydrological conditions or depositional environments [15].

The mineralogical data obtained from this study can also provide insights into the potential economic significance of the area. For instance, the presence of specific minerals with economic value, such as sulfides or rare earth elements, could indicate potential mineral deposits worth further exploration and assessment.

Soil minerals that are easily weathered, also known as primary minerals, undergo chemical and physical alterations when exposed to weathering processes [16]. Feldspars, Olivine, Amphiboles, Carbonates and Sulfides are some examples of soil minerals that are prone to weathering. These processes can lead to the formation of secondary minerals and the release of elements and ions into the soil. Feldspars contain K, Ca and sometimes Na; Olivine, releases Mg and Fe; Amphiboles are rich in Fe, Mg, and Ca; Carbonates, can contribute Ca and Mg; Sulfides, contain S [17,18].

In other hand, soil minerals that are resistant to weathering, also known as secondary minerals, are typically formed from the weathering of primary minerals [19]. These secondary minerals often have more stable structures in the soil environment. Quartz, Gibbsite, Iron and Aluminum Oxides and Kaolinite are some examples of soil minerals that are resistant to weathering [20,21]; Moore and Reynolds, 1997). Quartz is a highly stable mineral and is considered inert in terms of nutrient supply to plants. Gibbsite is relatively insoluble and does not provide significant nutrients to plants. Iron and aluminum oxides, such as hematite and goethite, are also generally not sources of plant nutrients. Kaolinite is a clay mineral with a relatively stable structure and low cation exchange capacity.

4. Conclusions

By conducting a comprehensive analysis of soil samples collected from various locations within Erbil Province, we aim to identify the predominant minerals and mineralogical assemblages present, assess their spatial distribution patterns, and examine the factors influencing their formation and distribution.

Moreover, this study will delve into the impact of soil mineralogy on key soil properties and ecosystem processes in Erbil Province.

This preliminary study on soil mineral identification in Erbil Province has provided valuable insights into the composition of soil through the utilization of X-ray diffraction (XRD) technique. According to the X-ray diffractogram of soil samples, the dominant minerals (Major Phase) were Quartz, Calcite, Albite, Palygorskite, Illite, Muscovite - Illite and Smectite Group. In the Minor Phase, Potassium Feldspar, Chlorite, Kaolinite, Dolomite were found, which were sometimes different in the samples.

These findings contribute to our understanding of the area's geology, provide insights into potential economic mineral resources, and lay the groundwork for future investigations and geological assessments.

It is important to note that the mineralogical study is subject to limitations and uncertainties. The results are based on a representative set of samples collected from specific locations within the given area, and variations in mineralogy may exist at smaller scales. Additionally, the identification and quantification of minerals are influenced by the analytical techniques employed and the accuracy of mineral standards used for comparison.

Figure 3. X-ray diffractogram of A6: Omarawa, A27: Jmka and A42: Balisan (Chromoxererts), A31: Senan and A38: Mala Omar (Do, Shallow Phase), A1: Baqrt and A2: Kabaruk (Lithic Calciorthids), A4: Dushwan and A5: Dibagah (Do, Eroded Phase), A3: Makhmur and A11: Malaqra (Mollic Calciorthids) and (A15: Merga (Lithis Mollic Calciorthids, Mollic Calciorthids and Chromoxererts).

Figure 4. X-ray diffractogram of A49: Garwdalalan (Lithis Mollic Calciorthids, Mollic Calciorthids and Chromoxererts), A47: Malakan and A73: Darhol (Bed Rock and Rock Debris), A53: Wallze and A68: Bni Rashkin (Do, Alppine Phase), A57: Barzewa, A71: Rezan and A77: Kolaka (Bed Rock, Lithic Rendolls, and Chromoxererts), A75: Kani Bota and A79: Dudamara (Bed Rock and Lithic Rendolls) and A39: Sulawk and A51: Bawyan (Bed Rock and Lithic Mollic Calciorthids, and Lithic Rondolls).

5. Recommendations

It's important to note that these soil groups provide a general overview, and within Erbil Province, there may be variations and subtypes of these soil groups. Detailed soil surveys, analysis, and mapping specific to different regions within Erbil Province would provide more accurate and comprehensive information on the soil types, properties, and their distribution. These studies are crucial for effective land management, sustainable agriculture, and environmental conservation in the region.

Conflicts of interest

The authors declare no conflict of interest.

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Appendix

Table 2. Chemical formulas and ICDD cards numbers of the found mineral phases

Mineral Phases	Chemical Formula	ICDD card numbers
Quartz	SiO_2	33–1161
Calcite	$CaCO_3$	05–0586
Albite	$NaAlSi_3O_8$	09–0466
Potassium Feldspar	$KAlSi_3O_8$	*19–932*
Dolomite	Ca Mg (CO_3)2	36–0426
Chlorite	(Mg, Fe)6(Si, Al)4O_{10}(OH)8	29–0701
Kaolinite	$Al_2Si_2O_5(OH)_4$	29–1488
Smectite	Ca0.2(Al, Mg)2Si4$O_{10}(OH)_2$, xH_2O	02–038
Palygorskite	(Mg, Al)5(Si, Al)8O_{20}(OH)2, 8H_2O	21–0958
Hematite	Fe_2O_3	33–0664
Illite	(K, H_3O) $Al_2Si_3AlO_{10}(OH)_2$	26–0911
Augite	$Ca(Fe,Mg)Si_2O_6$	24–0203
Goethite	FeO(OH)	29–0713
Gypsum	$CaSO_4$, $2H_2O$	33–0311
Amphibol group	$Ca_2(Fe.Mg)_4Al(Si_7Al)O_{22}$, $(OH)_2$	45–1371
Muscovite-Illite	$KAl_2Si_3AlO_{10}(OH)_2$	26–0911
Vermiculite	$(Mg, Al)_3(Si, Al)_4O_{10}(OH)_2$,$4H_2O$	34–0166
Mica	K(Mg,Fe)3(Al,Fe)$Si_3O_{10}(OH)_2$	26–0911

ICDD: The International Centre for Diffraction Data.

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