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Impact of forest trees on the soil reflectance and their relation of soil oxides in Sherawa village, Erbil government- Iraq

ABSTRACT

Soil reflectance spectroscopy has become a pioneering technique for quantifying soil properties that provide data for soil classification and digital soil mapping studies. This work was conducted with the aim to analyze the spatial variability of soil spectrometric properties between surface and subsurface soil under three land use patterns namely; pine, barren land and oak in Sherawa village, northeast Iraq.

Soil samples were collected from the three land types at two depths: surface soil at 0–15 cm and subsurface soil at 15–30 cm in duplicates totaling 6 collected soil samples. The elemental composition and mineral phases of soils were determined by X-ray fluorescent XRF and X-ray diffraction (XRD) respectively for qualitative and quantitative characterization. Magnesium oxide (MgO) was highest detected concentration in the surface soil layer reaching 34.16%, 36.75%, and 33.63%, respectively for pine, barren land and oak compared to 41.57%, 38.54%, 33.94% of the respective concentration in the subsurface soil layer samples of pine, barren and oak. Whereas, calcium and iron were the lowest percentages of pine in the surface and subsurface soil layer samples by (2.19%, 4.85%, 3.39%, and 4.55%, respectively). At the same time as, the percentages of oak in the surface and subsurface soil layer samples were (2.24%, 4%, 2.99% and 4.93%, respectively).The results indicate that the use of spectrometric analysis of soils in the field or in the laboratory can positively enhance soil characterization and typification surveys. Moreover, the influence of the silicates near 1400 nm by Al or Mg-OH and OH group were very apparent in the SWIR spectral regions of oak and pine in the subsurface soil. The results also showed the differences in soil color and reflectance between surface soil samples and subsurface surface soil for all site locations. Further studies are proceeding for more investigation at larger scale concerning analyzing the spatial variability of soil spectrometric properties with depth under different land use patterns.*.*

1. INTRODUCTION

The combined optical properties of the soil including the color and spectral reflectivity characteristics of the soil (Glass, 2013) are one of the current fields in the application of remote sensing and GIS techniques in the field of soil sciences (Paningbatan Jr, 2002), geology (Sreekanth and Debarup, 2016), and agriculture (Tola et al., 2019). However, the optical properties of the soil depend on the relationship between incident radiation and reflected radiation from the soil surface (Curnel, 2014), which are controlled by many characteristics and factors, including soil moisture

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(Mulders, 1987), soil texture (Ben-Dor et al., 2010), quality and quantity of clay minerals (Irwin et al., 1997) and other attributes, which are directly and significantly affected by the type of vegetation (Pang et al., 2019) and agricultural processes (Gonet et al., 2008), climate (temperature, rains. etc.) (Karmakar et al., 2016), and parent minerals of soil (Egli et al., 2008).

Soil is one of the most significant natural resources for crop production, which provides water and nutrients for plant growth (Hamad et al., 2018). Soil is a mixture of varying amounts of inorganic matter i.e. primarily crystalline minerals (Hill, 1994; Sen, 2009), organic matter (i.e. plant roots, decaying plant residues, and soil organisms) (Stoops et al., 2018), water, and air (Acharya et al., 2014). In the composition of the soil, some of the main elements are present depending on the nature of the process. Chemical reactions, water imbibition and drainage, colloid filtration, and contaminant adsorption are different processes that affect the soil surface particles (Hillel and Hatfield, 2005).

Soil color property is considered as one of the most important characteristic of soil (Hillel and Hatfield, 2005). The soil color and spectral reflection are among the most important characteristic of the soil optical properties (Hill, 1994). In this context, color is one of the most visible soil properties. Changes in soil color notes the eye before anything else (Gupta et al., 2008), which can specify the structure and mineral composition of the soil (Nyle and Ray, 2009). Moreover, light colored soils are more reflective and absorb heat less than the dark soils do regardless of moisture content. In other words, well drained dark colored soils absorb larger proportions of sun heat than do light colored ones (Kains, 2013).

Furthermore, when the moist soil dries up, the particles are grouped together by negative pressure or adsorption that arise in the pore water. Thus, the soil as a whole shrinks and decreases in size that make cracks among surrounding soil elements (Hillel and Hatfield, 2005), which in turn is an undesirable matters for both agricultural and engineering uses (Anderson et al., 1982).
Reflection information is used to determine the material according to the nature of the reflection spectrum they provide. More information can be gained from more wavelength measurement charts (Ben-Dor et al., 2008).

The specific wavelengths regions in soils across the SWIR spectral region and electronic transitions in atoms across the Vis-NIR determines the optical activity of chemical chromophores. Chemical chromophores are those parts of a molecule that are responsible for soil color (Ben-Dor et al., 2008). The reflectance of the soil in the region of visible and near infrared is a function of the soil composition (Brown et al., 2006).

Many scientists have studied the correlations between the different bands of the electromagnetic spectra and spectral reflectance data in order to better understand the complex soil components. According to Stoner and Baumgardner (1981) and Coleman and Montgomery (1987) the presence of organic matter has a strong influence on soil reflection, which greatly affects the color of the soil and generally decreases over the entire short wave region. Moreover, the first spectral database of American soils was created by Stoner and Baumgardner (1981). Thus, in the early 1980s the near infrared reflectance (NIR) started to investigate the organic matter of soils (Chabrillat et al., 2013; Xu et al., 2019).
Almost, all short waves solar radiation in the optical field from (300 nm to 2500 nm) incident on soil surface is either absorbed or reflected, and only a little of it is transmitted (Dwivedi, 2017).

Generally, published literature point out that when a band occurs near 1000 nm, is due to Mg, Fe, and silicates, if it occurs at 1400 nm is due to the fundamental stretch with usually Al or Mg – OH. If it occurs at 2200 nm and 2300 nm it is due to Al and Mg, respectively (Hunt, 1977; Hunt and Ashley, 1979; Krohn and Altaner, 1987; Clark et al., 1990).

The objective of this paper is to investigate the soil color and soil reflectance characteristics by calculating (RGB) values from Munsell charts and correlating those values to soil geochemistry and type of vegetation.

2. MATERIALS AND METHOD

2.1. Study area

The study area was conducted at three sites located in Sherawa village 30 km northeast Erbil city at very large scale, Figure 1. The GPS device (model: GARMIN-GPSMAP-64s) was used to obtain the exact coordinates of the three study points. The latitude and longitude coordinate of pine soil were $36^0 24'22.07''$N and 44° $16'05.27''$ E, for barren soil were $36^o 24'26.24''$N and $44^o 16'11.44''$ E, while for oak soil were $36^o 24'17.26''$N and $44^0 16'$ $29.66''$E.
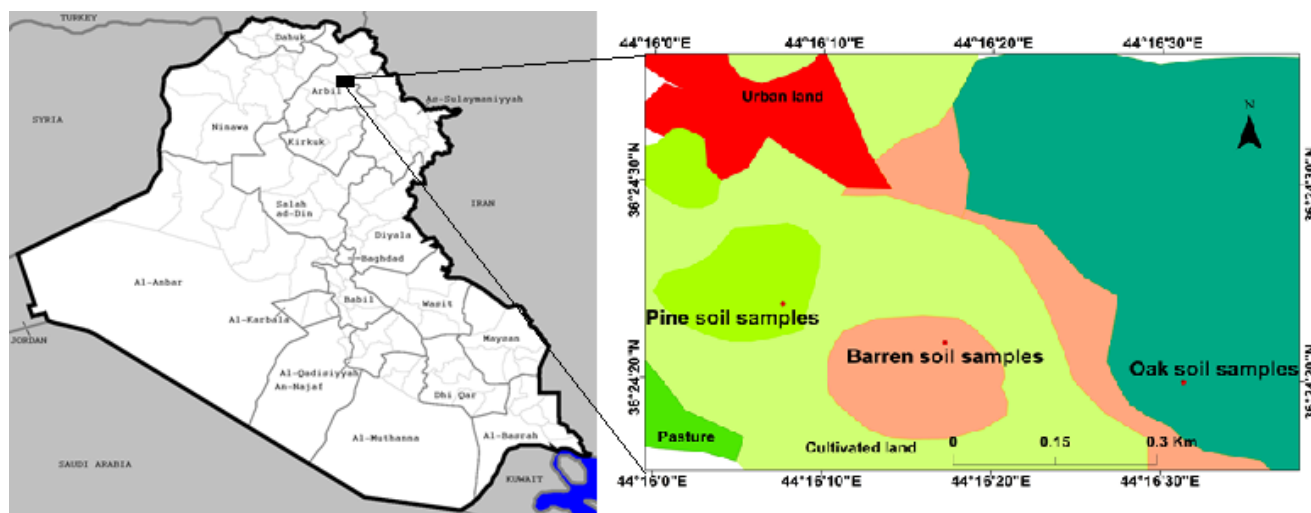

Figure 1. Maps of the study area showing its location in Iraq- Erbil governorate- Sherawa village in black spot.

2.2. Soil sampling

Three neighboring sites aligned sequentially with a distance of 250 meters between each, were chosen in this work from Sherawa village area. Each one is located within the three different land use types, i.e., pine, barren land and oak soil samples, Figure 2. Soil sampling was carried out in September 2019 from each of the three land use types and they were collected from one spot at every sampling plot within the land use. Totally, six soil samples were taken at two depths: 0–15 cm (surface soil layer) and 15–30 cm (subsurface soil layer) using soil auger.

Figure 2. The spatial distribution for three sample plots; pine (left), barren land (middle) and oak (right) in Sherawa village.

The soil was sampled by removing the litter and vegetation layers and then collecting approximately 1 kg of soil down to two depths at 15 and 30 cm. The soil analyses were performed

in the laboratory of the Scientific Research Centre of Soran University. Soil samples were sieved and dried before analysis.

The Geochemical analyses of the samples were carried out on Pan-Analytica powder diffractometer model for mineral phases assessment and XRF model for elemental composition at the Scientific Research Center (SRC) Soran University and the soil reflectance characterization and measurement of reflectance values were determined on spectroradiometer (The FieldSpec® 3) at remote sensing center at Mosul University. The RGB color values and soil color were determined using Munsell Soil Color Charts under wet and dry conditions. The wavelength range of ASD FieldSpec Spectrometer is from 350 nm to 2 500 nm.

2.3. Soil Spectroscopy {This Part is Methodology not our results, we cannot move it under result section}

Reflection information is used to determine the material according to the nature of the reflection spectrum they provide. However, more information can be gained from more wavelength measurement charts. The specific wavelengths regions in soils across the SWIR spectral region and electronic transitions in atoms across the Vis-NIR determines the optical activity of chemical chromophores. Chemical chromophores are those parts of a molecule that are responsible for soil color. Figure 3 represents a typical soil spectrum with directly known chromophores, which illustrates the physical and chemical features. For instance, iron oxides and organic matter appear in the Vis – NIR region, while in the SWIR region the water molecules in hygroscopic water can be observed in 1425 nm and 1925 nm. Thus wavelength may vary depending on the structure, shape, and the purity of the minerals (Chabrillat et al., 2019).
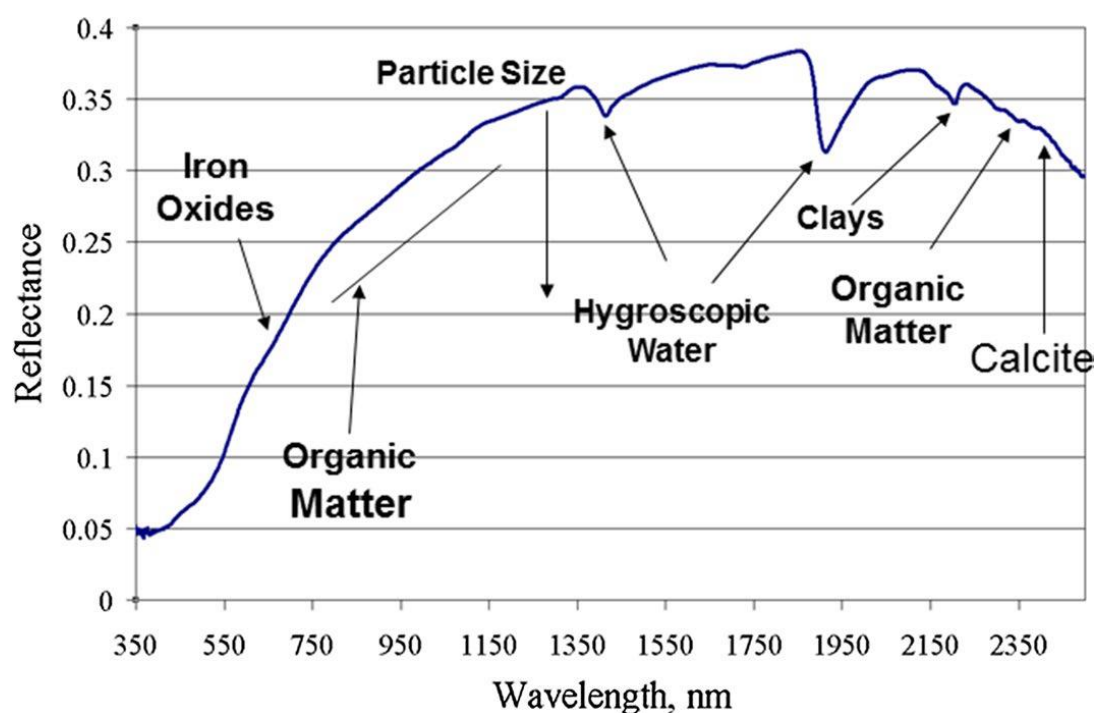

Figure 3. A soil spectrum (Haploxeralf) that represents the major chromophores in soils, after (Ben-Dor et al., 2008).

3. RESULTS
3.1. Variations in soil properties with depth
3.1.1. Soil Analysis and Oxides Percentage Distribution

Table 1 shows the minimum, maximum, mean concentrations and standard deviation in percent for elements magnesium oxide (MgO), aluminum oxide (Al_2O_3), silicon dioxide (SiO_2), Iron, and calcium of all 6 soil samples, which collected at three different sites. Percentages increased in magnesium oxide concentrations in subsurface sample soils were more than those on surface soils samples.

Table 1. The concentrations in percentages and basic statistical parameters (mean, min and max) of elements at three sites of the investigated surface soil layer and subsurface soil layer samples in Sherawa.

Sample	Layer cm	MgO	Al_2O_3	SiO_2	Calcium	Iron
Pine - surface soil	0-15	34.1619	12.8888	8.5544	2.1958	4.8537
Pine-subsurface soil	15-30	41.5718	14.3957	19.9748	3.3927	4.5577
Barren- surface soil	0-15	36.7583	14.5617	24.2981	3.8398	3.9571
Barren-subsurface soil	15-30	38.5437	14.5511	23.7135	5.2041	3.7781
Oak- surface soil	0-15	33.6343	13.4742	11.8531	2.2458	4.0084
Oak-subsurface soil	15-30	33.9435	13.0363	31.8745	2.9919	4.9325
Mean	0-15	36.4355	13.8179	20.0447	3.3116	4.3479
Minimum	15-30	33.6343	12.8888	8.5544	2.1958	3.7781
Maximum	0-15	41.5718	14.5617	31.8745	5.2041	4.9325
SD	15-30	3.1672	0.7767	8.6096	1.1269	0.4968

The comparison of the concentrations of the investigated surface soil layer samples at (15 cm) depth of the three land cover classes is illustrated in Figure 4. Magnesium oxide has the highest value in barren land 36.75% followed by pine 34.16% and Oak by 33.63%. However barren soil contains the highest rate of MgO, Al_2O_3, SiO_2 and calcium by 36.75%, 14.56%, 24.29% and 3.8 % respectively.

	Pine	Barren	Oak	Mean	Minimum	Maximum	SD
MgO	34.1619	36.7583	33.6343	34.8515	33.6343	36.7583	1.6722
Al2O3	12.8888	14.5617	13.4742	13.6415	12.8888	14.5617	0.8489
SiO2	8.5544	24.2981	11.8531	14.9018	8.5544	24.2981	8.30284
Calcium	2.1958	3.8398	2.2458	2.7604	2.1958	3.8398	0.935
Iron	4.8537	3.9571	4.0084	4.273	3.9571	4.8537	0.5034

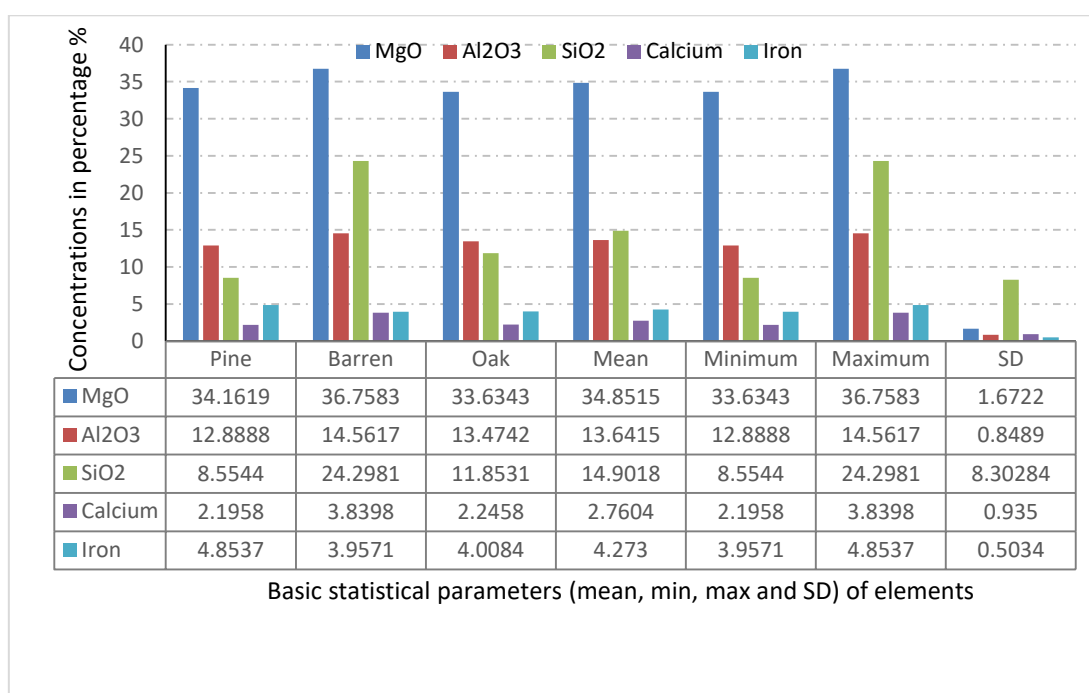Basic statistical parameters (mean, min, max and SD) of elements

Figure 4. The concentrations in percentage of elements at three different sites of the investigated surface soil layer samples at (15 cm) depth in Sherawa.

Pine soil surface contains 34.16%, 12.88%, 8.55%, and 2.19% of MgO, Al_2O_3, SiO_2 and calcium respectively. While oak comprises 33.75%, 13.47%, 11.85%, and 2.24% of MgO, Al_2O_3, SiO_2 and calcium respectively. Iron is the only element that has lowest values by 3.95% compared with pine and oak by 4.85% and 4.00%, respectively.
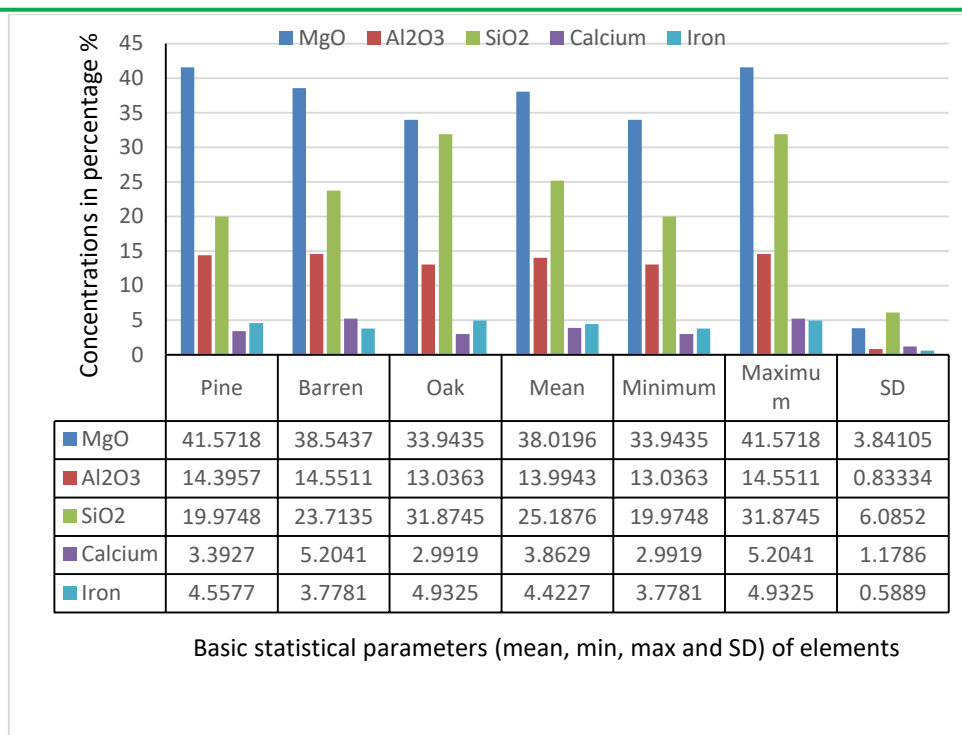
Figure 5. The concentrations in percentage of elements at three different sites of the investigated subsurface soil layer samples at (30 cm) depth in Sherawa.

In terms of subsurface soil layer samples at 30 cm, the percentage of magnesium oxide was the highest (41.57%) under pine and the lowest (33.94%) under oak land. Silicon oxide was the highest (31.87%) under oak land cover and lowest (19.97%) under pine soil, while barren subsoil layer was (23.71%) of aluminum oxide. Calcium and Iron were the lowest percentages of pine, barren and oak subsurface soil layer samples by (3.39%, 5.20%, 2.99% and 4.55%, 3.77% and 4.93, respectively), Figure 5. This could be due to chemical and elemental variations.

3.1.2. Effect of trees Canopy in Soil Color

The essential colors in dry condition differ from wet condition. Soil color samples under wet conditions are darker than dry soil samples do for all three color values (RGB) as shown in Table 2.

Table 2. Soil color (RGB) values of dry and wet soil samples in Sherawa area.

Sample	Layer cm	Wet Samples			Dry Samples		
		Essential Colors			Essential Colors		
		R	G	B	R	G	B
Pine - surface soil	0-15	195	178	145	131	107	81
Pine-subsurface soil	15-30	208	191	170	141	113	83
Barren- surface soil	0-15	207	179	159	186	143	114
Barren-subsurface soil	15-30	202	167	133	147	118	92
Oak- surface soil	0-15	172	143	123	131	98	83
Oak-subsurface soil	15-30	190	163	144	130	98	84

Concerning the surface soil color under dry condition, pine has pale brown color (10YR6/3), light brown (7.5YR6/3) for barren land, and (10YR5/3) yellowish brown for oak. Subsurface soil surface colors were also pale brown (10YR6/3), light brown (7.5YR6/4) and yellowish brown (10YR5/3) for pine, barren, and oak soil samples, respectively. Thus there were no changes of colors under dry condition Table 3. This, could be related to the pores that are mainly filled with air under dry condition (Ramesh et al., 2019).

Table 3. Hue, Value, Chroma, and color of representative soil samples from Sherawa under dry condition.

Sample	Dry samples	Color of samples based on Munsell Soil Color Chart
	HUE/Value/Chroma of sample	
Pine –surface soil	10YR6/3	Pale brown
Pine-subsurface soil	10YR6/3	Pale brown
Barren- surface soil	7.5YR6/3	Light brown
Barren-subsurface soil	7.5YR6/4	Light brown
Oak- surface soil	10YR5/3	Yellowish brown
Oak-subsurface soil	10YR5/3	Yellowish brown

On other hand, soil sample surface colors under wet conditions in lab revealed that pine has brown color (10YR4/3), barren brown color (7.5YR5/3), and oak has dark yellowish brown color (10YR4/4). Whereas, soil sample subsurface colors were dark grayish brown (10YR4/2), brown (7.5YR5/3) and dark yellow (10YR4/3) for pine, barren, and oak, respectively, Table 4.

Table 4. Hue, Value, Chroma, and color of representative soil samples from Sherawa under wet condition.

Sample	Wet samples	Color of samples based on Munsell Soil Color Chart
	HUE/Value/Chroma of sample	
Pine - surface soil	10YR4/3	Brown
Pine-subsurface soil	10YR4/2	Dark grayish brown
Barren- surface soil	7.5YR5/3	Brown
Barren-subsurface soil	7.5YR5/3	Brown
Oak- surface soil	10YR4/4	Dark yellowish brown
Oak-subsurface soil	10YR4/3	Dark brown

4. DISCUSSION

The results indicated as shown in the tables and curves shape of spectral properties to a clear differences between the surface and subsurface layers of the chosen sites. This is due to a variation in the organic matter content in higher quantities in the surface soil layer than the subsurface layer, as a result of the vital activity of microorganisms, and also to the roots of the plants and leaves decomposed on the surface. This is consistent with what has been supposed by many studies (Ben-Dor and Banin, 1990; Ben-Dor and Banin, 1995; Karmakar et al., 2016; Pang et al., 2019).

The results also indicated the occurrence of variances and differences in the color values RGB, reflection values (%R), and the curves of the spectral reflective properties between the chosen study sites, oak and pine trees compared to the barren lands that were free from vegetation. The reason for this is due to the apparent effect of contrast and the difference in the chemical components and their concentrations according to the XRD and XRF investigations for soil and the observation of the effect of the magnesium concentration on the color characteristics. As well as vegetation and its components affect the contrast and the difference in the characteristics.

Concerning the essential colors of all surface soil and subsurface soil samples, it can be observed that the essential colors in wet circumstances are higher than all samples in dry circumstances, Figure 6. This could be due to the incorporation of leaf litter to soil, which affects soil colors only under wet condition for pine, oak, and barren soil. Additionally, it could also be related to the influencing the leaf litter on the nutrients and polyphenols of soil during reaction with water. Moreover, the colors in Table 3 under dry conditions are unchanged; while color changes are observed for wet soil samples except for barren soil in Table 4.

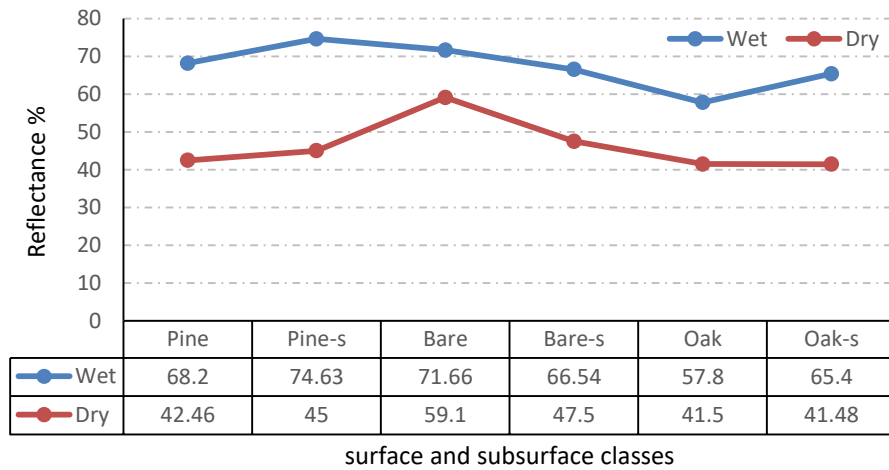| surface and subsurface classes	Pine	Pine-s	Bare	Bare-s	Oak	Oak-s
Wet	68.2	74.63	71.66	66.54	57.8	65.4
Dry	42.46	45	59.1	47.5	41.5	41.48

Figure 6. Essential colors of representative surface soil and sub- soil surface samples from Sherawa clay soils under dry and wet conditions.

Subsurface barren land has the highest reflection in the NIR region at around 1700 nm, while the lowest reflection is represented by surface soil pine at 350 nm. Thus, the intensity of the reflection decreases due to the strong absorption of soil organic matter (Soltani et al., 2019) and increases significantly after removal of organic soil (Stafford, 2007), Figure 7.

It is clear that the entire spectrum decreases with the increase of the soil water content, therefore every object on the surface of the earth has its unique spectral reflectance (Bartholomeus et al., 2008).

1: Sub-surface Barren land   2: Sub-surface Pine   3: Sub-surface Oak
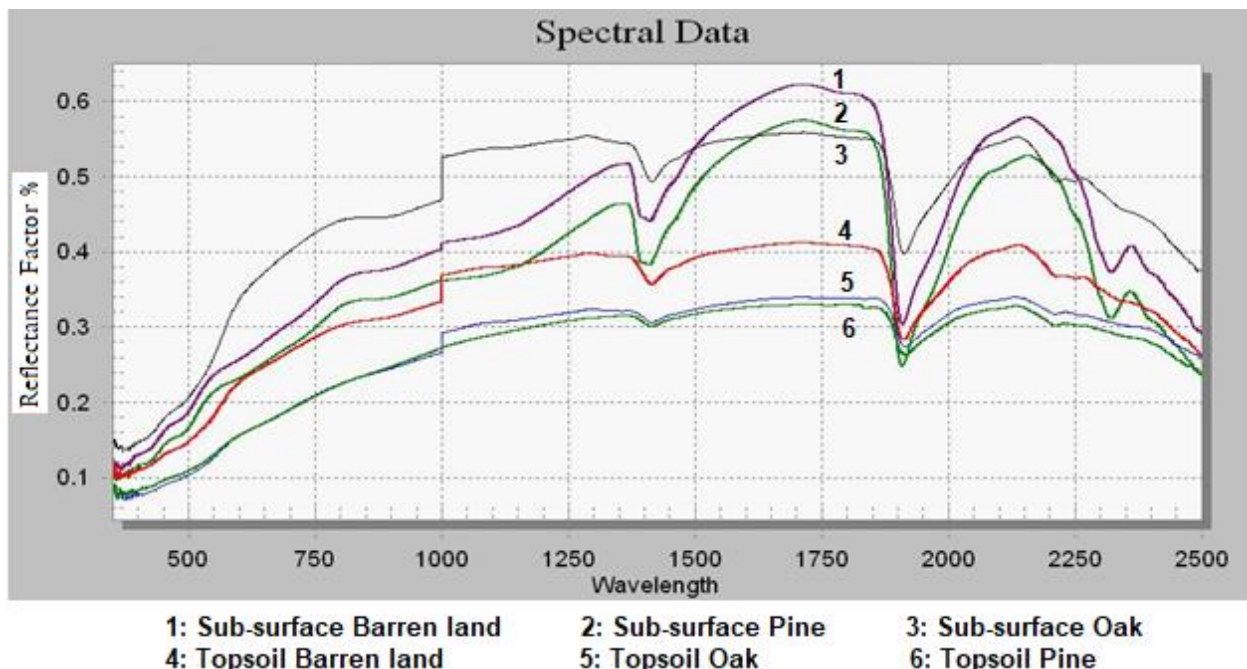4: Topsoil Barren land   5: Topsoil Oak   6: Topsoil Pine

Figure 7. A laboratory spectral reflectance curves of surface and subsurface layer soil samples, representing all three surface soil and subsurface soil samples of pine, barren land, and oak. Absorption features around 1000 nm by Mg and Fe. Silicates around 1400 nm by Al or Mg – OH. Also, the major peaks at 1900 nm, which they are attributed to OH group, and absorption features around 2200 nm and 2300 by Al and Mg, respectively.

The electromagnetic energy covers the VIS (400–700 nm), NIR (700–1100 nm), and SWIR (1100–2500 nm) spectral regions. Generally, the original reflectance curves of surface soil and sub-surface bands in the range, 350-2500 nm in the current work were almost parallel but not similar in all properties, with some sharp absorption features by vibrational processes.

Two strong absorption features can be observed at 1400 nm and 1900 nm in the NIR-SWIR region. A moderate and weak absorption features due to clay minerals 2200 nm, carbonate 2300 nm or primarily minerals are shown in the general view, which is an agreement with Ben-Dor et al. (2008) and Banin and Amiel (1970).

In addition, Figure 7 illustrates also the absorption peak of surface soil and subsurface soil layer samples that exists at three different regions in the studied 350~2500 nm wavelength range. The absorption peak of surface soil and subsurface soil layer samples are attributable to absorption molecule of water by leaves and belongs to MID-IR wavelength. Moreover, due to the effect of OH- in soil minerals, there were three absorption bands with different absorption intensities in the vicinity of 1000 nm, 1400 nm and 1900 nm. Thus, each of the curves in Figure 7 represents a certain value of soil reflectance. In the range of 1900 ~ 2500 nm, the reflectivity curve increases rapidly and then decrease.

In the present work and from Figure 7, the first overtone features is noticeably shown and occurred at 1000 nm. Furthermore, the most common natural materials occurring in this range is due to the presence of iron and the presence of water or OH groups in the visible-near infrared region, identified Hunt (1977). He also detected a very broad absorption region of Mg, Fe and Silicate near 100 nm. Secondly, the absorbed band near 1400 nm is due to the first overtone of the OH stretch, or due to combination bands of the fundamental stretch with usually Al or Mg – OH. Hunt (1977) identified that when there is water, hydroxyl features appear, that's why the evidence for OH occurs often than evidence for any other group in the spectra of terrestrial materials.

Thirdly, the greater (absorption band intensity – spectral contrast) appears at 1900 nm, which strongly related to molecular water (Hunt and Salisbury, 1971; Aines and Rossman, 1984). Therefore, the presence of silicon-oxygen near 1900 nm can be determined as there are groups of the OH. Lastly, the combination ranges in the 2000 nm region that include the basic OH position appear in pairs. Aluminum and magnesium are two common elements that typically appear near 2200 nm 2300 nm (Hunt, 1977),

In the current study, iron oxides and organic matter can be observed in the range of VIS – NIR, while in the SWIR region the hygroscopic water is illustrated in 1425 nm and 1925 nm, which agrees with Ben-Dor et al. (2008). Moreover, higher levels of iron oxides was found in the curves of the profile with a lower intensity of reflectance and the presence of organic matter in surface and subsurface of all soil samples, mainly in the 350–850 nm range, and this agrees with Ben-Dor et al. (2008).

5. CONCLUSIONS

This work shows that the selected soil properties vary with depth in color and element distributions among different land-use types, and specified the effect of all vegetation, tree type, forests, and the nature of chemical soil characteristics on the optical properties of the studied soil. The possibility of utilizing GIS-RS using spectroradiometer in studying changes in vegetation and soils and making future maps for that is a recommended option. Differences and variances in color, reflectivity, and reflective curves were observed between the surface and sub-surface layers, and under the studied species. In addition to the difference between one site and another compared to the barren lands.

Finally, it could be concluded that the soil at the study area contain major and minor element of metals. The concentration of the major and minor element oxides has been noticed with the change in depth. Thus, soil color and spectral reflectance are considered of the most important optical soil properties, and finally the wavelength may vary depending on the structure, shape, and the purity of the minerals.

CONFLICTS OF INTEREST
The authors declare that they have no conflicts of interest.

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تاثير نوع الغطاء النباتي في الخواص البصرية ومحتوى الأكاسيد لبعض الترب في قرية شيراوا محافظة أربيل

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الخلاصة

معرفة الخواص الأنعكاسية الطيفية للتربة اصبحت مهمة و فعالة في تحديد و تفسير الكثير من صفات التربة التي يعتمد عليها في عمليات مسح وتصنيف التربة ورسم خرائط التربة الرقمية. تهدف الدراسة الى تحليل و معرفة تأثيرالتغايرالمكاني في الخواص الأنعكاسية للتربة وفي الطبقة السطحية وتحت السطحية لمناطق ذات غطاء نباتي مختلف، حيث شملت المواقع المختارة أراضي مزروعة بأشجار الصنوبر وأخرى مزروعة بأشجارالبلوط وأراضي جرداء بدون غطاء نباتي للمقارنة في قرية شيراوا في محافظة أربيل شمال شرق العراق. تم استحصال نماذج تربة ممثلة من الطبقة السطحية (صفر – 15 سم) وتحت السطحية (15– 30 سم) من كافة المواقع المختارة، وتم اجراء التحاليل والقياسات عليها لتقدير مكونات العناصر الكيمياوية و أكاسيد التربة بأستخدام جهاز الأشعة السينية الفلورنسية (XRF) والتركيب المعدني بأستخدام جهاز حيود الأشعة السينية (XRD).

أشارت النتائج الى أن اعلى نسبة من الأكاسيد الحديد في الطبقة السطحية كان أوكسيد المغنيسيوم حيث تراوحت نسبتها (34.16%، 36.75% و 33.63%) في أراضي الصنوبر والجرداء وأراضي زراعة البلوط على التوالي. في حين كانت النسبة في الطبقة التحت سطحية (41.57%، 38.54% و 33.94%)على التوالي لنفس المواقع المذكورة. ووجد بأن نسبة العناصر الأخرى مثل الكالسيوم والحديد في أراضي الصنوبر كانت قليلة مقارنة بنسبة أوكسيد المغنيسيوم في كلا الطبقتين السطحية وتحت سطحية (3.39%، 2.99% و 4.55%، 4.93%) على التوالي. في نفس الوقت، نسبة العناصر الكالسيوم والحديد في أراضي زراعة البلوط في كلا الطبقتين السطحية وتحت سطحية كانت أيظا قليلة وعلى التوالي(2.24%، 4% و 2.99%، 4.93%).

وأكدت الدراسة على أن استخدام التقنيات والأجهزة الحديثة في رسم وحساب منحنيات الخواص الأنعكاسية الطيفية للتربة سواء في الحقل أو المختبر تساعد وتساهم بشكل كبير في عمليات مسح و تصنيف التربة. وأظهرت النتائج الى وجود اختلافات في لون التربة والأنعكاسية بين الطبقة السطحية و تحت سطحية في المواقع المدروسة ويعود السبب في ذلك الى الأختلاف و التباين في محتوى المادة العضوية في الطبقات السطحية. وتوصي الدراسة بزيادة الأهتمام والتحريات والبحوث والدراسات في هذا المجال لمساحات أوسع وتحت أغطية نباتية مختلفة مثل اراضي المحاصيل والمراعي والغابات وغيرها.

الكلمات المفتاحية: الخواص الطيفية والجيوكيميائية ؛ الأنعكاسية الطيفية؛ الغطاء النباتي ؛ لون التربة ؛ أكاسيد الحديد