# SPECTRAL SIGNATURE IDENTIFICATION OF LAND COVER IN FADAK FARM /KARBALA GOVERNORATE AND EVALUATION OF ITS SUITABILITY FOR DATE PALM CULTIVATION

**K. M. Taha** **A. I. Hamad**
**Researcher** **Prof.**
**Dept. Desert. Combat, Coll. Agric. Engin. Sci., University of Baghdad. Iraq.**
khalda.taha2310m@coagri.uobaghdad.edu.iq abdalghafor.ibrahim@coagri.uobaghdad.edu.iq

## ABSTRACT

**The study aims to evaluate the lands of Fadak Farm and their suitability for palm trees cultivation. An area of 2,000 dunams was selected as the study site .It is located in Karbala Governorate between longitudes 43°51'44" and 43°35'16" E and latitudes 32°43'56" and 32°42'59" N. Sentinel-2A satellite imagery was used, Two pedons were identified—one in a cultivated area and the other in an uncultivated -with 40 surface soil samples collected. These samples were analyzed in the laboratory.The spectral signature of the existing land cover in the farm was determined. The reflectance values for date palm trees were 5252 in the green band, 4440 in the red band, and 6280 in the near-infrared band, covering 12% of the surface area. Newly planted date palms had reflectance values of 4708(green), 5196(red), and 6160 (near-infrared), covering 25% of the area. Barren lands covered 43% of the area, with reflectance values of 4804, 5700, and 6180 in the green, red, and near-infrared bands, respectively. Water bodies showed reflectance values of 1349 (blue), 1534 (green), 1532 (red), and 1830 (near-infrared), covering 10% of the area. Built-up areas also covered 10%, with reflectance values of 8504, 7468, and 6904 for the green, red, and near-infrared bands, respectively .The results indicated that all the covers in Fadak Farm showed the highest reflectance in the near-infrared band. The results showed two levels of suitability for date palm cultivation: moderately suitable S2 and marginally suitable S3 .**

**Keywords: sentinel-2a, green band, red band, near-infrared band, blue band.**
***Part of The M.Sc. thesis for the 1st author.**



## تحديد البصمة الطيفية للغطاء الارضي في مزرعة فدك / محافظة كربلاء وتقييم صلاحيتها لزراعة النخيل

**خالدة مقدام طه** **عبد الغفور ابراهيم حمد**
**باحثة** **استاذ**

## المستخلص

**تهدف الدراسة الى تقييم اراضي مزرعة فدك وملائمتها لزراعة اشجارالنخيل . اختيرت كمنطقة دراسة بمساحة 2000 دونم اذ تقع في محافظة كربلاء بين خطي طول "44 `51 °43 و"16 `35 °43 شرقا ودائرتي عرض "56 `43 °32 و"59 `42 °32 شمالا تمت الاستعانة بالمرئية الفضائية Sentinel–2A، تم الكشف عن بيدونين احدهما في منطقة مزروعة واخرئ غير مزروعة، مع جلب عينات سطحية لتغطي 40 عينة ، حللت العينات مختبريا ، بعدها تم تحديد البصمة الطيفية للغطاء الارضي الموجود في المزرعة اذ بلغت انعكاسية النخيل 5252 في الحزمة الخضراء و 4440 في الحزمة الحمراء و 6280 في الحزمة القريبة من الحمراء الذي يغطي ( 12% ) مساحة سطحية في حين بلغت انعكاسية النخيل المزرع حديثا 4708في الحزمة الخضراء و5196 في الحزمة الحمراء و6160 في الحزمة القريبة من الحمراء وغطت مساحة (25%) اما الاراضي الجرداء غطت مساحة (43% ) وبلغت انعكاسيتها في الحزم الخضراء والحمراء والقريبة من الحمراء 4804 و 5700 و 6180 علئ التوالي اما المياة فابدت انعكاسية في الحزمة الزرقاء1349 و 1534 في الحزمة الخضراء و 1532 في الحزمة الحمراء و1830 في الحزمة القريبة من الحمراء واذ غطت مساحة (10% ) في حين غطت الابنية مساحة (10% ) وابدت انعكاسية 8504 و7468 و 6904 للحزم الطيفية الخضراء والحمراء والقريبة من الحمراء علئ التوالي . اشارت النتائج ان جميع الاغطية في مزرعة فدك ابدت اعلئ انعكاسية في الحزمة القريبة من الحمراء. اظهرت نتائج ملائمتها لزراعة النخيل بوجود صنفين من الملائمة ملائم معتدل S2 وملائم هامشي S3.**

**الكلمات المفتاحية: القمرسنتنل2، الحزمة الخضراء، الحزمة الحمراء، الحزمة القريبة من الحمراء، الحزمة الزرقاء.**

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## INTRODUCTION

Land suitability assessment is one of the fundamental pillars of land use planning. Various criteria have been developed for this purpose, including the land suitability evaluation framework of the Food and Agriculture Organization (FAO). Suitability is considered as a function of both land and crop requirements, and it is a measure of the degree of compatibility between the characteristics of a land unit and the requirements of a specific crop. The analysis of land suitability aims to achieve sustainable and optimal land use, ensuring efficient use of resources to meet the growing demand for food(11,22,26).Remote sensing techniques plays an effective role in supporting fieldwork and enhancing the land evaluation process by performing various classifications on the spectral bands of the study area (5). One of the most important tools used to monitor and assess changes in land use and land cover types is Geographic Information Systems (GIS), due to their high accuracy and efficiency (19). Using Remote sensing to distinguish ground features through spectral reflectivity (10), the objectives are as follows:

1- monitor the land cover of Fadak Farm using remote sensing technologies.

2- identify the key land characteristics that affect palm cultivation.

3- achieve Goals 12 and 13 of the Sustainable Development Goals (SDGs).

## MATERIALS AND METHODS

**Location of the study area:** The Fadak Palm Farm Project, affiliated with the Holy Al-Abbas Shrine, was selected for this study**.**The study area is located in the western part of the Holy Karbala Governorate, along the road connecting Karbala to the Ain Tamr district, west of Karbala city. The total area of the farm is 2,000 dunums, and it extends between the longitudes 43°51'44" and 43°35'16" East, and the latitudes 32°43'56" and 32°42'59" North. The farm is situated approximately 20 km from the city center of Holy Karbala, as shown in Figure 1. The annual rainfall in the study area is 6 mm, and the average annual temperature is 23.8°C. The average maximum temperature is 39°C, while the average minimum temperature is 0°C .

**Office and field work**

The satellite imagery from Sentinel-2A was downloaded from the official website of the European Space Agency (ESA) on September 4,2024.The portion corresponding to the study area was then extracted from the raw image based on the coordinates of the study area using ArcMap 10.8. This was done using the Clip tool available in the Arc Toolbox. Subsequently, the sampling locations were identified on the Sentinel-2A image. Several field visits were conducted to the study area to observe the nature of the land and identify the dominant vegetation cover. Another visit was carried out on September 5, 2024, to collect soil samples. The geographical coordinates of the study area were determined using a Garmin GPS MAP 64 Global Positioning System (GPS) device. Sampling coordinates were recorded in the (N/E) format. Soil samples were collected using an auger, taking surface samples to a depth of 30 cm from 40 different sites, ensuring coverage of the entire study area. Additionally, two soil profiles were identified—one in a cultivated area and the other in a non-cultivated area—and were described according to the Soil Survey Staff (2017) guidelines.

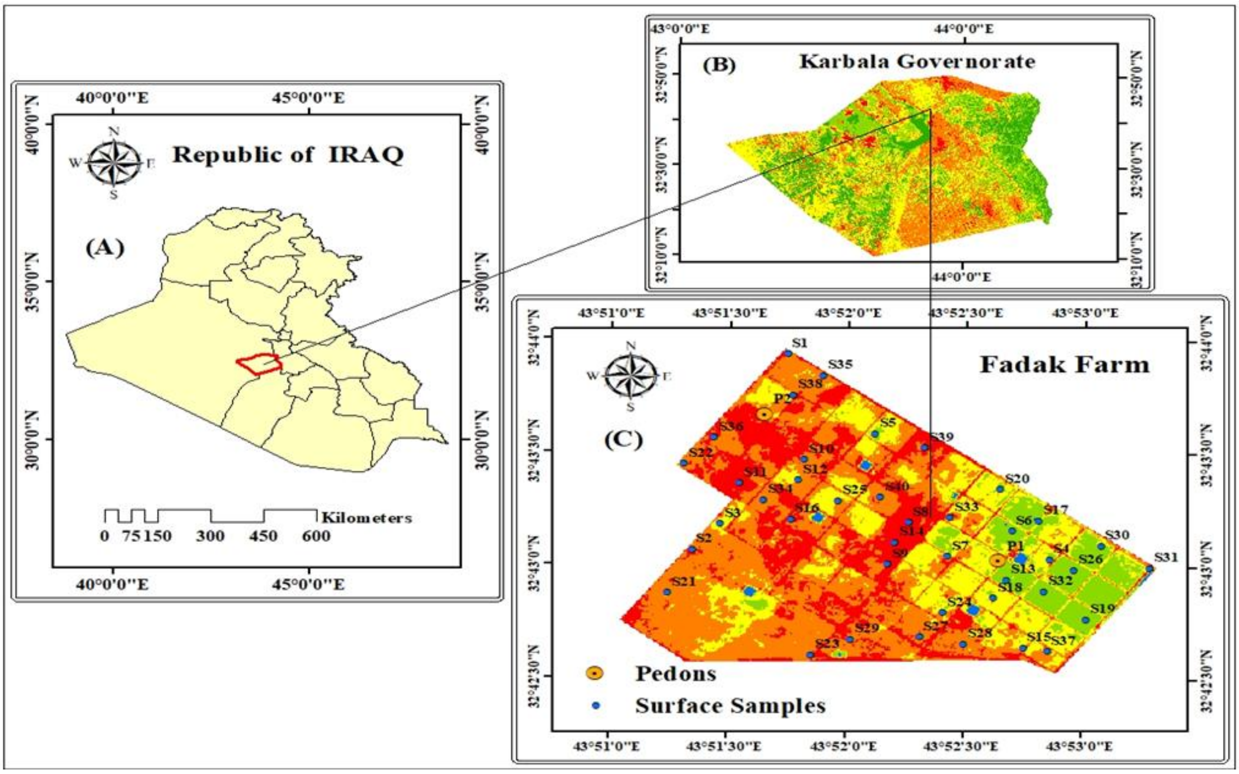


**Figure 1. The study area A,B,C.**

**Laboratory Work**

After collecting the soil samples from the identified horizons and surface layers, they were placed in nylon bags, labeled, air-dried, crushed using a wooden hammer, and sieved through a 2 mm mesh. The samples were then transferred to the laboratory for physical and chemical analyses. The particle size distribution was determined using the hydrometer method. Chemical analyses included determining electrical conductivity (ECe), organic matter, lime content, and calcium sulfate (gypsum), Apparent CEC, Organic Carbon, and Exchangeable sodium percentage (ESP). All soil analyses were carried out at the Desertification Control Laboratory, College of Agricultural Engineering Sciences, University of Baghdad.

**Determining the Spectral Signature of Land Cover Using Visible and Near-Infrared Bands:** The spectral signature was determined by calculating the spectral reflectance of the study area using ERDAS IMAGINE 2014. The bands used from the extracted satellite image were:

Band 2: Blue
Band 3: Green
Band 4: Red
Band 8: Near-Infrared (NIR)

Reflectance values were recorded for various land cover types including bare soil, cultivated areas, buildings, water bodies, and vegetation cover.

**RESULTS AND DISCUSSION**

**Morphological Description:** The morphological characteristics of the pedons in the study area varied. The results of the morphological description showed that the soil color for all horizons, in both dry and moist conditions, had a hue value of 10YR, except for horizon (Cy) in the first pedon (P1), where the hue was 5Y. This indicates the presence of reducing conditions in this horizon and water accumulation for more than six months per year. The value (lightness) ranged between 6–8 in the dry state and 4–7 in the moist state. The chroma (color intensity) ranged between 3–8 in both conditions. The results also indicated that the soil texture ranged between Sandy Loam (28.6%) and Loamy Sand (71.4%), indicating a dominance of coarse-textured soils. This dominance is attributed to the interaction between geomorphological processes and pedogenic processes (12). The soil structure varied between massive in the first pedon (horizons Cy1 and Cy2) and structureless in all horizons of the two pedons. This is attributed to the high sand content in the soils under study. Morphological examination of soil consistency under the three moisture conditions (dry, moist, and wet) revealed the following:

-In the dry state, consistency ranged from loose to extremely hard.

-In the moist state, consistency ranged from loose to extremely firm.

-In the wet state, based on stickiness and plasticity, all horizons were non-sticky and non-plastic. This is due to the low clay content of the studied soils (23).

The morphological description of soil pores, based on abundance, size, and type, showed variation in quantity from very few to common and many, with a predominance of very few, followed by common, while many appeared in only one horizon. Pore sizes ranged from very fine to medium, with medium being the dominant class. This is attributed to the coarse texture and high sand content. As for the type, pores were either tubular or interstitial. Root distribution was denser in the surface horizons, ranging in quantity from very few to many, and in size from very fine to medium. Regarding the boundary topography between soil horizons, two types were observed:

-Smooth, which dominated in most horizons (80% occurrence)

-Wavy, with 20% occurrence.

The variation in boundary nature between horizons is mainly attributed to the intensity and nature of soil translocation processes and their impact on the horizon boundaries(8) during the study of gypsiferous soils in the North Kut project.

-Pedon No :p1
-Location: Karbala Governorate / Fadak Farm
-G.P.S: (°39 47' 94" E –36° 20' 483 " N)
-Soil classification: Typic Haplogypsids
-Natural Vegetation: Suaeda aegyptiaca
-Cynodon dactylon
-Climate: Arid
-Parent material: Calcareous Gypsiferous
-Salinity: Very slightly saline soils
-Ground water depth : very deep
-Drainage: Well
-Land use: Date palm
-Date of examination: 5/9/2024

-Pedon No :p2
-Location: Karbala Governorate / Fadak Farm
-G.P.S: (39° 32' 58" E – 36° 21' 685" N)
-Soil classification: Typic Calcigypsids
-Natural Vegetation: *Stipagrostis*
*-plumosa (L.)، Atriplex halimus*
-Climate: Arid
-Parent material: Calcareous Gypsiferous
-Salinity: Very slightly saline soils
-Drainage: Well
-Ground water depth : very deep
-Land use: Abandoned
-Date of examination: 5/9/2024

**Table 1. Morphological Description in pedon 1**

| Horizon | Depth / cm | Description |
|---|---|---|
| Ay | 0-28 | Pale brown 10YR(6/3) dry, olive 5Y(5/6) moist; loamy sand, structure less, loose, non sticky, non plastic, few medium interstitial pores, few medium roots; many accumulation of gypsum; few cementation of gypsum; clear smooth boundary. |
| Cy1 | 28-65 | Pale yellow 10YR (7/4) dry, pale olive 10 YR (6/4) moist, few fine faint brownish yellow 10 YR (6/8) mottles; loamy sand; massive, slightly hard dry, friable moist, non sticky, non plastic; few medium and coarse tubular pores; no roots; many accumulation of gypsum; few fine gravel; diffuse wavy boundary. |
| Cy2 | 65-100 | Pale olive 5Y (6/4) dry, olive 5Y (5/4) moist, few medium faint brownish yellow 10YR (6/8) mottles; loamy sand; massive, extremely hard dry, extremely firm moist, non sticky, non plastic; common fine tubular pores; no roots; many accumulation of gypsum; few fine gravel. |

**Table 2. Morphological Description in pedon 2**

| Horizon | Depth / cm | Description |
|---|---|---|
| Ay | 0-48 | Light yellowish brown 10 YR (6/4) dry, dark yellowish brown 10 YR (4/4) moist; few medium faint yellow 10 YR(8/6) mottles; loamy sand; structure less, loose, non sticky, non plastic; many medium interstitial pores; many fine and very fine roots; many accumulation of gypsum; few fine gravel; clear smooth boundary. |
| Cy1 | 48-73 | Very pale brown 10 YR(8/3) dry, very pale brown 10 YR (7/3) moist, common fine faint yellow 10YR (8/6) mottles; loamy sand; structure less, loose; non sticky, non plastic; common fine and medium interstitial pores; few very fine roots; many accumulation of gypsum; common fine gravel; clear smooth boundary. |
| Cy2 | 73-104 | Yellow 10 YR (7/6) dry, yellowish brown 10 YR (5/6) moist, few fine faint brownish yellow 10 YR (6/6) mottles; sandy loam; structure less, loose, non sticky, non plastic; very few fine and very fine tubular pores; very few very fine roots; many accumulation of gypsum; common medium gravel; clear smooth boundary. |
| Cy3 | 104-140 | Brownish yellow 10 YR (6/8) dry, yellowish brown 10 YR (5/8) moist, common coarse prominent yellow 10 YR (7/6) mottles; sandy loam; structure less, loose ,non sticky, non plastic, few fine and medium tubular pores; no roots; many accumulation of gypsum. |

**Table 2. Morphological Description in pedon 2**

**Physical Properties**

**Particle Size Distribution:** Table (3) shows that the dominant soil texture in the study area is Sandy Loam, except for the first pedon, where the texture was Sandy in horizons (Ay) and (Cy1), and Loamy Sand in horizon (Cy2). Sand is the dominant soil fraction in the study area, indicating a low water-holding capacity of the soil (14), followed by silt and then clay.In the first pedon, sand particles were predominant, with contents ranging from 552 to 912 g kg$^{-1}$. It was observed that the sand content increased with depth. As for clay particles, their content ranged between 28–40 g kg$^{-1}$,while silt content ranged between 60–420 g kg$^{-1}$.In the second pedon, sand was also dominant, ranging from 572 to 692 g kg$^{-1}$, while clay content ranged between 48–180 g kg$^{-1}$, and silt ranged from 128 to 380 g kg$^{-1}$. The variation in particle content among the horizons of the second pedon is attributed to differences in the sedimentation periods.The particle size distribution also varied among surface soil samples. Sand particles were dominant due to the depositional characteristics of the desert environment in the study area (2), followed by silt and then clay. Sand content ranged from 547 to 676 gkg$^{-1}$, with samples 19 and 34 having the lowest sand content, while sample 1 had the highest. Clay content ranged from 28 to 122 g kg$^{-1}$. Sample 31 showed the highest clay content, while sample 4 had the lowest. Silt content ranged from 204 to 423 g kg$^{-1}$, with sample 34 having the highest silt content, while samples 1 and 26 had the lowest, as illustrated in Figure (A), Figure (B), and Figure (C).

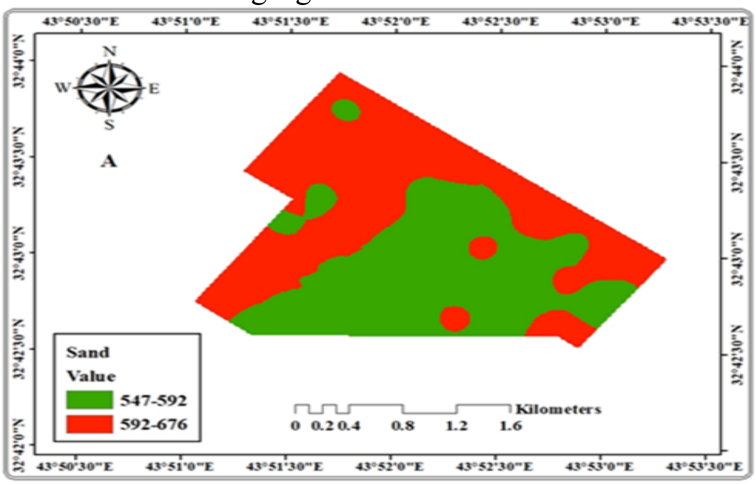


**Figure A. Spatial distribution of sand fraction in the study area**

**Table 3. Physical and chemical properties of soil pedons and surface samples**

| No. | Depth cm | Soil Texture g $Kg^{-1}$ Clay | Silt | Sand | Tex. Class | Ece dS $m^{-1}$ | OM g $Kg^{-1}$ | CaCO3 g $Kg^{-1}$ | CaSO4 g $Kg^{-1}$ | Apparent CEC Cmol(+).$Kg^{-1}$.clay | O.C g $Kg^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | 0-28 | 28 | 420 | 552 | S | 7.2 | 6.2 | 234 | 546 | 1.64 | 3.57 |
| P1 | 28-65 | 28 | 60 | 912 | S | 7.2 | 5.9 | 217 | 562 | 1.53 | 3.40 |
| P1 | 65-100 | 40 | 136 | 824 | LS | 6.8 | 4.8 | 199 | 585 | 2.45 | 2.77 |
| P2 | 0-48 | 88 | 240 | 622 | SL | 6.4 | 4.9 | 265 | 602 | 4.81 | 2.83 |
| P2 | 48-73 | 180 | 128 | 692 | SL | 7.2 | 4.2 | 212 | 611 | 19.32 | 2.42 |
| P2 | 73-104 | 48 | 380 | 572 | SL | 5.2 | 3.9 | 221 | 633 | 17.46 | 2.25 |
| P2 | 104-140 | 128 | 250 | 672 | SL | 4.8 | 3.5 | 206 | 643 | 19.65 | 2.02 |
| S1 | 30 | 120 | 204 | 676 | SL | 2 | 3.2 | 251 | 600.2 | 18.5 | 1.85 |
| S2 | 30 | 84 | 264 | 652 | SL | 2.8 | 3.6 | 251 | 593 | 1.41 | 2.08 |
| S3 | 30 | 48 | 360 | 592 | SL | 2.4 | 6.1 | 230.3 | 562 | 17.12 | 3.52 |
| S4 | 30 | 28 | 421 | 551 | SL | 4.8 | 7 | 242 | 550.2 | 1.55 | 4.04 |
| S5 | 30 | 88 | 240 | 672 | SL | 5.6 | 6.1 | 234 | 563 | 1.64 | 3.52 |
| S6 | 30 | 120 | 205 | 675 | SL | 1.2 | 7.2 | 230.7 | 560.2 | 19.27 | 4.16 |
| S7 | 30 | 85 | 264 | 651 | SL | 2 | 6.4 | 241 | 563 | 3.65 | 3.70 |
| S8 | 30 | 49 | 360 | 591 | SL | 5.6 | 3.1 | 268 | 600.1 | 2.59 | 1.79 |
| S9 | 30 | 29 | 421 | 550 | SL | 6 | 3.2 | 265 | 603 | 1.45 | 1.85 |
| S10 | 30 | 89 | 241 | 670 | SL | 4.2 | 3.5 | 250.4 | 600.8 | 1.73 | 2.02 |
| S11 | 30 | 121 | 205 | 674 | SL | 4.12 | 3.6 | 259 | 596 | 17.12 | 2.08 |
| S12 | 30 | 85 | 265 | 650 | SL | 4.4 | 6.5 | 250.8 | 550.2 | 1.42 | 3.75 |
| S13 | 30 | 49 | 361 | 590 | SL | 6 | 7.37 | 234 | 557 | 4.85 | 4.26 |
| S14 | 30 | 29 | 422 | 549 | SL | 3.2 | 3.2 | 267 | 608 | 1.61 | 1.85 |
| S15 | 30 | 89 | 241 | 670 | SL | 3.6 | 3.6 | 251 | 595 | 17.8 | 2.08 |
| S16 | 30 | 121 | 206 | 673 | SL | 5.6 | 3.8 | 255 | 592 | 15.6 | 2.19 |
| S17 | 30 | 86 | 265 | 649 | SL | 5.2 | 7 | 230.3 | 562 | 2.48 | 4.04 |
| S18 | 30 | 50 | 361 | 589 | SL | 2.4 | 6.1 | 243 | 571 | 3.43 | 3.52 |
| S19 | 30 | 31 | 422 | 547 | SL | 1.6 | 7.2 | 230.7 | 553 | 1.58 | 4.16 |
| S20 | 30 | 89 | 241 | 670 | SL | 2.8 | 6.4 | 243 | 568 | 17.35 | 3.70 |
| S21 | 30 | 121 | 205 | 674 | SL | 1.2 | 3.1 | 261 | 600.4 | 18.42 | 1.79 |
| S22 | 30 | 85 | 265 | 650 | SL | 2.8 | 3.2 | 260.3 | 601 | 17.26 | 1.85 |
| S23 | 30 | 49 | 361 | 590 | SL | 2.4 | 3.5 | 264 | 606 | 1.57 | 2.02 |
| S24 | 30 | 29 | 422 | 549 | SL | 3.2 | 3.6 | 254 | 595 | 3.33 | 2.08 |
| S25 | 30 | 89 | 241 | 670 | SL | 1.6 | 6.5 | 251 | 560.2 | 1.58 | 3.75 |
| S26 | 30 | 121 | 204 | 675 | SL | 4 | 7.37 | 230.7 | 550.6 | 19.22 | 4.26 |
| S27 | 30 | 86 | 265 | 649 | SL | 4.4 | 3.2 | 250.1 | 594 | 17.53 | 1.85 |
| S28 | 30 | 50 | 361 | 589 | SL | 5.2 | 3.6 | 260.3 | 596 | 2.52 | 2.08 |
| S29 | 30 | 30 | 422 | 548 | SL | 4.8 | 3.8 | 265 | 600.2 | 1.77 | 2.19 |
| S30 | 30 | 90 | 242 | 668 | SL | 4.4 | 7 | 230.3 | 556 | 1.58 | 4.04 |
| S31 | 30 | 122 | 206 | 672 | SL | 4 | 6.1 | 243 | 560.1 | 18.35 | 3.52 |
| S32 | 30 | 86 | 266 | 648 | SL | 5.2 | 7.2 | 230.2 | 553 | 3.65 | 4.16 |
| S33 | 30 | 50 | 362 | 588 | SL | 4.8 | 6.4 | 260.1 | 570.2 | 18.68 | 3.70 |
| S34 | 30 | 30 | 423 | 547 | SL | 6 | 3.1 | 235 | 600.8 | 18.48 | 1.79 |
| S35 | 30 | 90 | 242 | 668 | SL | 2 | 3.2 | 250.1 | 606 | 3.55 | 1.85 |
| S36 | 30 | 122 | 207 | 671 | SL | 1.2 | 3.5 | 250.4 | 600.7 | 19.24 | 2.02 |
| S37 | 30 | 87 | 266 | 647 | SL | 2.8 | 3.6 | 266 | 590.1 | 18.3 | 2.08 |
| S38 | 30 | 51 | 362 | 587 | SL | 3.2 | 6.9 | 234 | 565 | 1.69 | 3.98 |
| S39 | 30 | 88 | 265 | 647 | SL | 3.2 | 4.9 | 267 | 593 | 3.67 | 2.83 |
| S40 | 30 | 53 | 360 | 587 | SL | 2.4 | 5 | 253 | 570.1 | 2.6 | 2.89 |

**Chemical Properties**

**Electrical Conductivity:**The results show in Table (3) indicate that both Pedon 1 and Pedon 2 fall within soils of low electrical conductivity. The reason for the low electrical conductivity values in Pedon 1 is attributed to the fact that the area is cultivated, and irrigation practices have contributed to the leaching of soil salts, causing them to move downward into deeper soil layers. The electrical conductivity values for Pedon 1 ranged between 6.8–7.2 dS·m$^{-1}$. In Pedon 2, the values ranged between 4.8–6.4 dS·m$^{-1}$, which can be attributed to the soil texture, as sand particles dominate. Furthermore, the region is characterized by high permeability due to the coarse texture (6). As for the surface soil samples, they also fall within non-saline soils, with values ranging between 1.2–7.2 dS·m$^{-1}$. The low values can also be attributed to the dominance of sand particles as well as rainfall during the winter season, which helped leach salts from the surface layer. Figure 2 shows that there are two classes of soil salinity the study area.

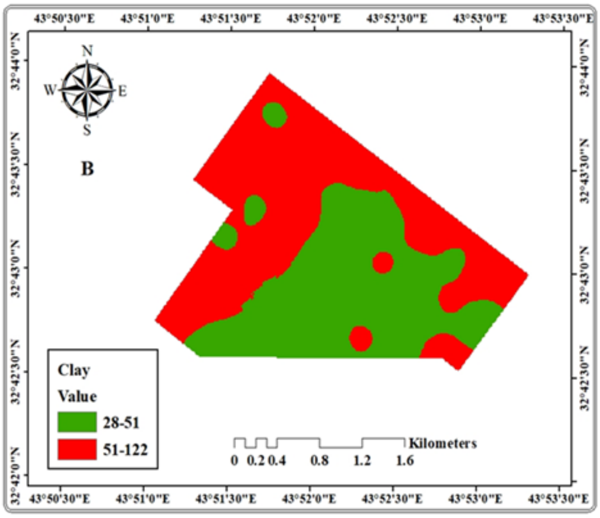


**Figure B. Spatial distribution of clay fraction in the study area**

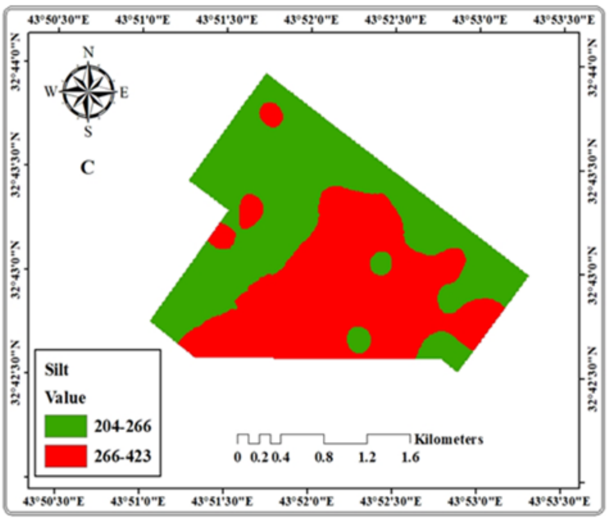


**Figure C. Spatial distribution of silt fraction in the study area**

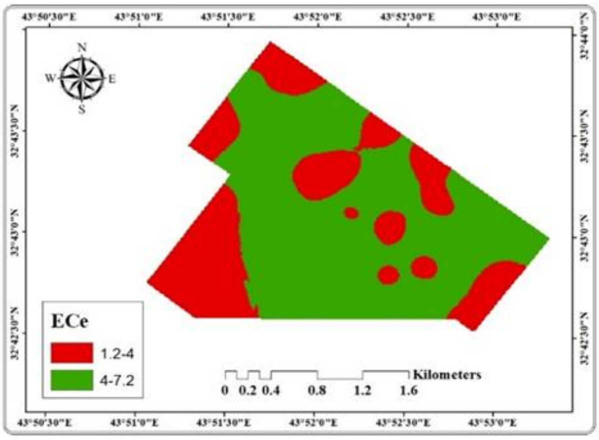


**Figure 2. Spatial distribution of electrical conductivity values in the study area**

**Organic Matter**

The results in Table (3) show that the highest values of organic matter were recorded in the surface horizon of Pedon 1, ranging between 4.8–6.7 g·kg$^{-1}$. This is due to its location in a cultivated area. It was also observed that organic matter content decreases gradually with depth in P 1, due to agricultural activities(3). In Pedon 2, organic matter values ranged between 3.5–4.9 g·kg$^{-1}$, which is attributed to the fact that the land is not agriculturally exploited, the dominance of sand particles, large pore sizes, and high temperatures in the region (15), all of which enhance the oxidation and rapid decomposition of organic matter in the soil (20) Regarding surface soil samples, the organic matter content is generally low, ranging between 3.1–7.37 g·kg$^{-1}$. Figure 3 illustrates the spatial distribution of organic matter values in the study area. The class with the largest spatial coverage had values between 3.1–3.8 g·kg$^{-1}$, covering 244.6806 hectares and representing 46.37058% of the total study area. This class includes sample sites 1, 2, 8, 9, 10, 11, 14, 15, 16, 21, 22, 23, 24, 27, 28, 29, 34, 35, 36, and 37.It is followed by the range 3.8–5 g·kg$^{-1}$, which covered an area of 121.826 hectares, representing 23.08783% of the study area, including sample sites 39, 40, and Pedon 2. The next class, with organic matter content between 6.1–7.37 g·kg$^{-1}$, occupied 93.43217 hectares, representing 17.70678% of the study area. This class includes sample sites 4, 6, 7, 12, 13, 17, 19, 20, 25, 26, 30, 32, 33, 38, and Pedon 1.The class with the smallest coverage represented values between 5–6.1 g·kg$^{-1}$, covering 67.72461 hectares, accounting for 12.83481% of the total area, and includes sample sites 3, 5, 18, and 31.

**Carbonate Minerals ($CaCO_3$)**

The results in Table (3) show the content of calcium carbonate in the soil pedons of the study area. In Pedon 1, values ranged between 199-234 g $kg^{-1}$, while in Pedon 2, calcium carbonate values ranged between 206-265 g $kg^{-1}$. As for the surface soil samples, values ranged between 268 - 230.2g $kg^{-1}$. It is evident that calcium carbonate levels increased in most soils of the study area, which is attributed to the calcareous nature of the parent material .The content of calcium carbonate decreases with depth in both Pedon 1 and Pedon 2.This is likely due to prevailing climatic conditions, such as low rainfall and the limited solubility of calcium carbonate (1). The results in Figure 4 indicate the presence of two classes of calcium carbonate minerals in the study area. Class C3 occupies the largest area, within the range of 240–260 g $kg^{-1}$, covering 380.1526 hectares, which constitutes 72.00871% of the total study area. This class corresponds to the locations of samples:1, 2, 8, 9, 10, 11, 12, 14, 15, 16, 21, 22, 23, 24, 25, 27, 28, 29, 33, 34, 35, 36, 37, 39, 40, and P2. Other classes like C1, C4, C5, and C6 were not detected in the laboratory analysis results. Meanwhile, Class C2 occupied the smallest area, ranging between 230–240 g $kg^{-1}$, covering 147.7733 hectares, which is 27.99129% of the total area. This class includes samples:3, 4, 5, 6, 7, 13, 17, 18, 19, 20, 26, 30, 31, 32, 38, and P1.

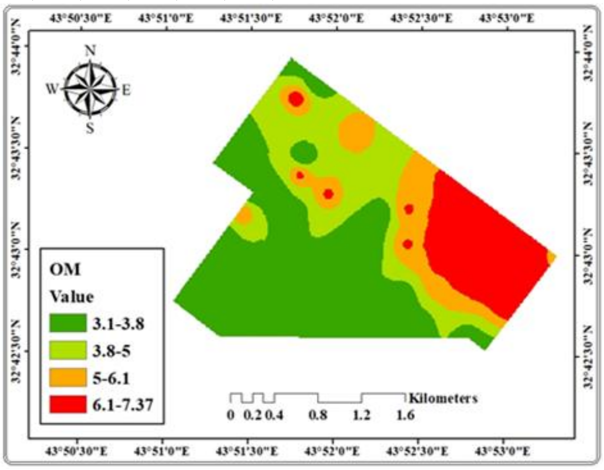


**Figure 3. Spatial distribution of organic matter values in the study area**

**Gypsum ($CaSO_4 \cdot 2H_2O$)**

The results in Table (3) show an increase in calcium sulfate content, which is attributed to the gypsiferous nature of the parent rocks. In surface soil samples, calcium sulfate content ranged between 550.2–608 g $kg^{-1}$. In Pedon 1, values ranged between 546–585 g $kg^{-1}$, and in Pedon 2, between 602–643 g $kg^{-1}$. The gypsum content in the surface soil samples ranged between (55.02-608%).The content of calcium sulfate was lower in Pedon 1, which is likely due to agricultural practices that reduce gypsum content in the soil (5). It is also noted that the calcium sulfate content increases with depth in both pedons. This is attributed to irrigation and rainfall causing gypsum leaching from surface horizons, followed by re-precipitation in sub-surface horizons, leading to higher gypsum accumulation in those horizons. This(13).Figure 5 illustrates the spatial distribution of calcium sulfate content in the study area's soils. Based on classification (25), three classes of calcium sulfate were identified: Class G8, within the range 571–608 g $kg^{-1}$, occupies the largest area of 272.0511 hectares, which is 51.52294% of the total area. This class corresponds to the locations of samples: 1, 8, 9, 10, 11, 14, 21, 22, 23, 24, 27, 28, 29, 34, 35, 36, 37, 41, and Pedon 2.Class G7, within the range 568–571 g $kg^{-1}$, covers 140.0622 hectares, or 26.52595% of the area, and includes samples:18, 33, 40. Class G6, within 546–568 g $kg^{-1}$, occupies the smallest area of 115.9061 hectares, representing 21.95111% of the study area.It includes samples: 3, 4, 5, 7, 12, 13, 17, 19, 20, 25, 26, 30, 31, 32, 38, and Pedon 1.

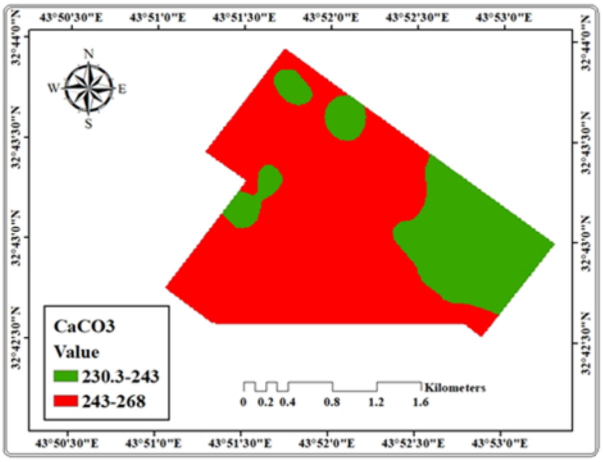


**Figure 4. Spatial distribution of carbonate minerals in the study area**

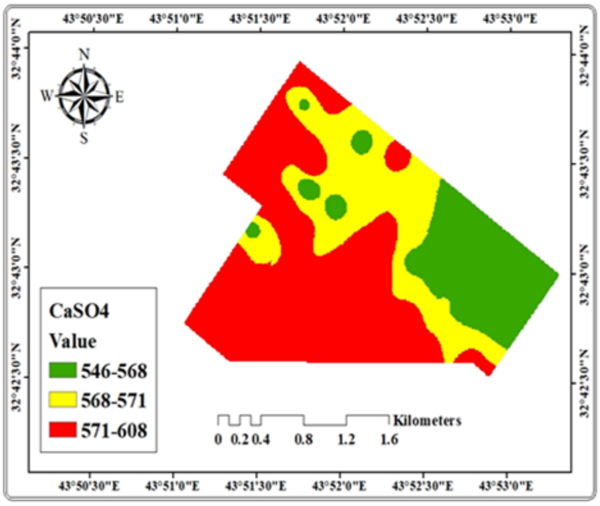


**Figure 5. Spatial distribution of calcium sulfate in the study area**

**Apparent CEC:** The results in Table (3) show a general decrease in Apparent Cation Exchange Capacity (CEC) values across the study area. This is attributed to the dominance of the sand fraction in the soil texture, which is coarse, and the low proportion of the clay fraction. Additionally, the high content of calcium carbonate and calcium sulfate in the soils of the study area negatively affects the Apparent CEC. With their increase, the soil's capacity to retain cations decreases. (21). There is an inverse relationship between calcium sulfate and Apparent CEC, as an increase in calcium sulfate content at the expense of other soil components such as clay and organic matter leads to a decline in Apparent CEC (24). Another reason for the low Apparent CEC values is the low organic matter content in most of the soils in the study area. In the surface samples, Apparent CEC values ranged between 1.41–19.27 cmol $kg^{-1}$ clay. In the first pedon, values ranged between 1.64–2.45 cmol $kg^{-1}$ clay, while in the second pedon, they ranged between 4.81–19.65 cmol $kg^{-1}$ clay.

**Organic Carbon:** The results in Table (3) indicate a decrease in organic carbon values in most of the soils in the study area. This decline is attributed to the prevailing climatic conditions in the region, specifically low rainfall and high temperatures. These factors significantly affect the rate of organic matter decomposition in the soil (4). The values of organic carbon in the surface samples ranged between 1.79–4.26 g $kg^{-1}$, while in the first pedon, they ranged between 2.77–3.57 g $kg^{-1}$, and in the second pedon, between 2.02–2.83 g $kg^{-1}$. It is observed that organic carbon values decrease with depth in both pedons P1 and P2.

**Exchangeable sodium percentage (ESP)**

The Exchangeable Sodium Percentage (ESP) values were very low, all being less than 1%, indicating that the soils are non-saline. Therefore, the indicator value was 100%.

**Spectral Signature:** The highest near-infrared spectral reflectance from the barren lands was observed in sample S1, reaching 6180, due to the high content of calcium sulfate in the soil. The lowest reflectance was recorded in sample S15, with a value of 4876, because the land is irrigated .As for the red band reflectance from barren lands, the highest value was in sample S14, reaching 5700, due to the high calcium sulfate content in this sample. Soils with a high percentage of calcium sulfate are characterized by a light color, which reflects more radiation, thus increasing reflectance (17,18,27). The lowest red band reflectance was in sample S15, with a value of 4232.In the green band, the highest spectral reflectance from barren lands was 4804 in sample p2, because sand particles dominate the soil, which implies wide pores and air-filled spaces between the soil particles, along with low moisture content. Therefore, soil reflectance is high, as there is a direct relationship between sand content in the soil and its spectral reflectance: as the sand fraction increases, the reflectance increases.Meanwhile, the lowest reflectance in the green band was 3328 in sample S15.table 4 and Figures 6,7, and 8 illustrate the spectral reflectance values of the near-infrared, red, and green bands reflected from the barren lands.

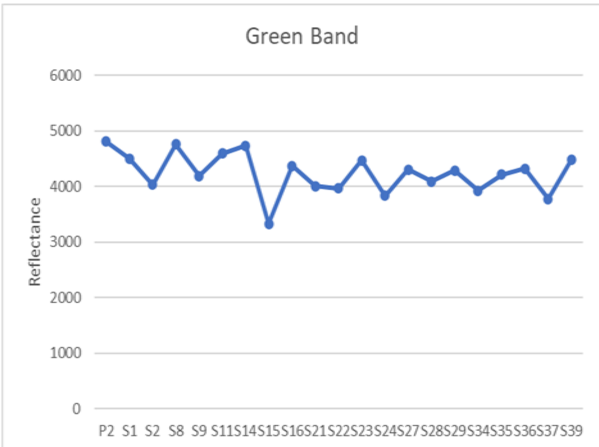


**Figure 6. Spectral reflectivity of the green band reflected from barren lands**

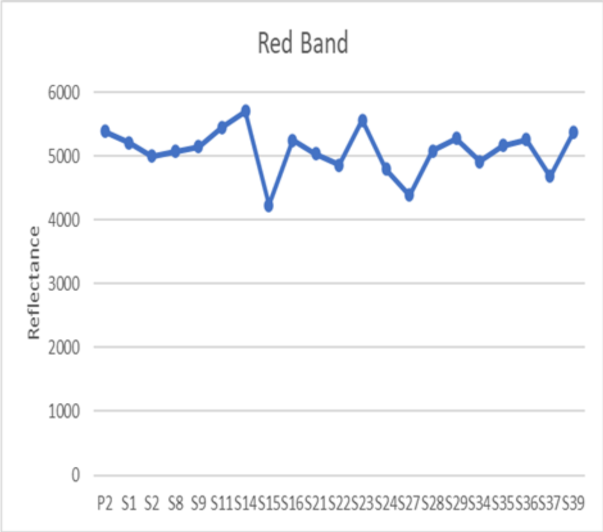


**Figure 7. Spectral reflectivity of the red band reflected from barren lands**

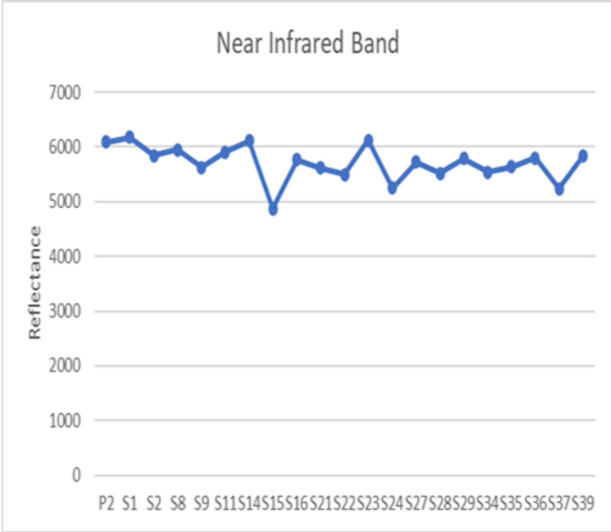


**Figure 8. Spectral reflectance of the near-red band reflected from barren lands.**

**Table 4. Spectral reflectance values of the near-red, red, and green bands reflected from barren lands**

| Spectral reflectivity of barren lands | | | |
|---|---|---|---|
| NO. | B3 | B4 | B8 |
| P2 | 4804 | 5580 | 6092 |
| S1 | 4504 | 5532 | 6180 |
| S2 | 4030 | 5096 | 5848 |
| S8 | 4760 | 5072 | 5948 |
| S9 | 4188 | 5144 | 5624 |
| S11 | 4588 | 5448 | 5912 |
| S14 | 4736 | 5700 | 6116 |
| S15 | 3328 | 4232 | 4876 |
| S16 | 4372 | 5252 | 5764 |
| S21 | 4002 | 5040 | 5616 |
| S22 | 3962 | 4864 | 5500 |
| S23 | 4464 | 5560 | 6128 |
| S24 | 3830 | 4792 | 5248 |
| S27 | 4300 | 4388 | 5728 |
| S28 | 4088 | 5080 | 5516 |
| S29 | 4284 | 5280 | 5792 |
| S34 | 3922 | 4912 | 5544 |
| S35 | 4212 | 5164 | 5636 |
| S36 | 4320 | 5256 | 5796 |
| S37 | 3776 | 4684 | 5236 |
| S39 | 4476 | 5372 | 5828 |

While the highest reflectance in the near-infrared band for newly planted palm trees was 6160, which was reflected from sample S20, the reason for the high values of near-infrared reflectance is that the newly planted palm trees are in good condition. Therefore, the reflectance of radiation from the palm leaves was high, and due to the high calcium carbonate content in them, the reflectance was also high. On the other hand, the lowest reflectance, 4916, was in sample S3, due to the high organic matter content in the soil and the low electrical conductivity value, which leads the soil to appear darker in color, thus reducing reflectance compared to sample S33.Meanwhile, the highest reflectance in the red band was in sample S40, reaching 5196,The reason for this high reflectance value is the increase in calcium carbonate content. The lowest reflectance, 2120, was in sample S17, and the reason for the decrease in reflectance values is the high organic matter content, along with a decrease in both electrical conductivity and calcium carbonate contents.As for the green band, the highest reflectance was in sample S31, reaching 4708, while the lowest reflectance was in sample S17, reaching 2666. The reason for this decline is the high organic matter content.Table (5), along with Figures (9),(10),and (11), illustrate the spectral reflectance values for the near-infrared, red, and green bands reflected from the newly planted palm trees.

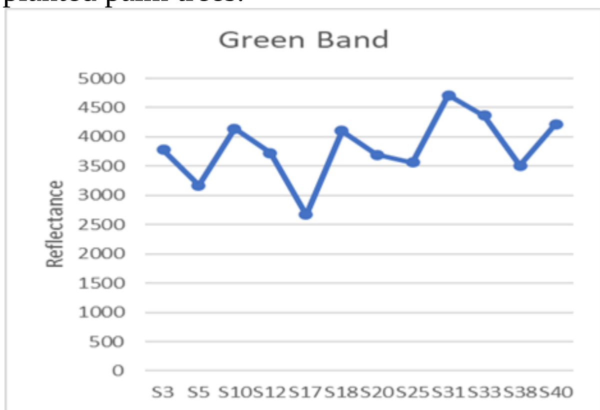


**Figure 9. Spectral reflectivity of the green band reflected from newly planted palm**

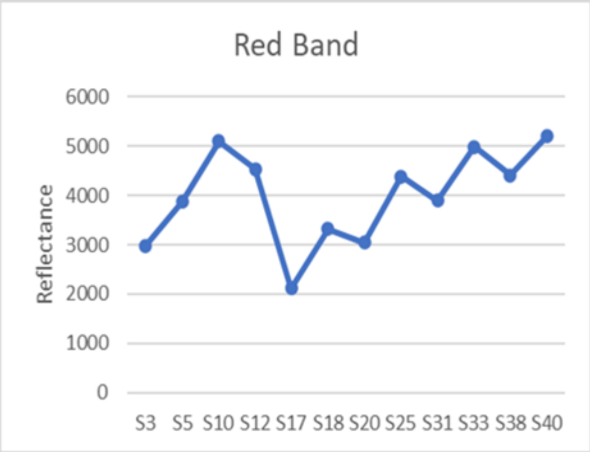


**Figure 10. Spectral reflectance of the red band reflected from a newly planted palm trees**

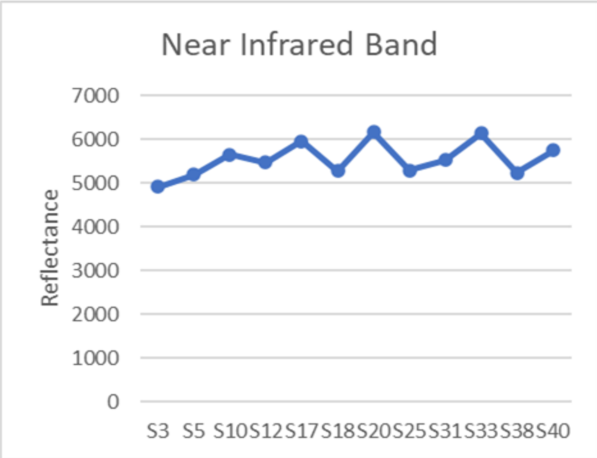


**Figure 11. Spectral reflectance of the near-red band reflected from newly planted palm trees**

**Table 5. Spectral reflectance values of the near-red, red, and green bands reflected from newly planted palm trees.**

| Spectral reflectivity of a newly planted palm trees | | | |
|---|---|---|---|
| **No.** | **B3** | **B4** | **B8** |
| S3 | 3776 | 2980 | 4916 |
| S5 | 3172 | 3866 | 5192 |
| S10 | 4144 | 5096 | 5648 |
| S12 | 3724 | 4540 | 5472 |
| S17 | 2666 | 2120 | 5964 |
| S18 | 4104 | 3322 | 5276 |
| S20 | 3692 | 3038 | 6160 |
| S25 | 3564 | 4388 | 5292 |
| S31 | 4708 | 3900 | 5524 |
| S33 | 4364 | 4984 | 6140 |
| S38 | 3510 | 4408 | 5232 |
| S40 | 4220 | 5196 | 5748 |

Table (6) and Figures (12), (13), and (14) shows the spectral reflectance values reflected from palm trees planted during the early years of the farm's establishment .The highest reflectance in the near-infrared band was 6280, recorded in sample S7, due to the high calcium carbonate content.The lowest reflectance, 5216, was observed in sample S32, attributed to low electrical conductivity and high organic matter content in the soil, which in turn leads to the absorption of the incoming radiation (7). In the red band, the highest reflectance was 4440 in sample S7, while the lowest reflectance was 2080 in sample S26, due to the high organic matter content. As for the green band, the highest reflectance was 5252 in sample S7, and the lowest was 2376 in sample S26. The high reflectance values of the samples in the near-infrared (NIR) band compared to the red band are due to the good and healthy condition of the plant leaves. Healthy foliage reflects more in the NIR band and less in the red band (9).

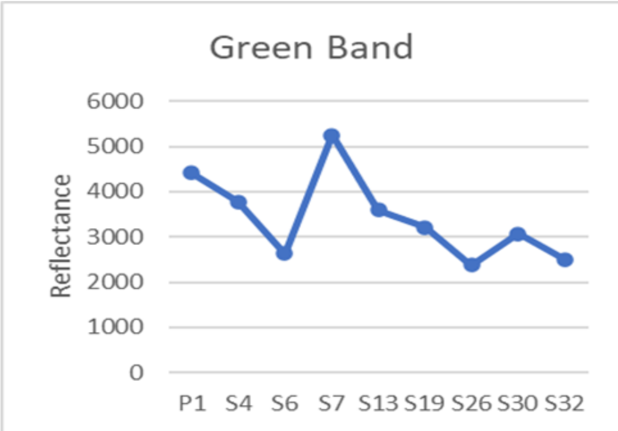


**Figure 12. Spectral reflectivity of the green band reflected from palm trees**

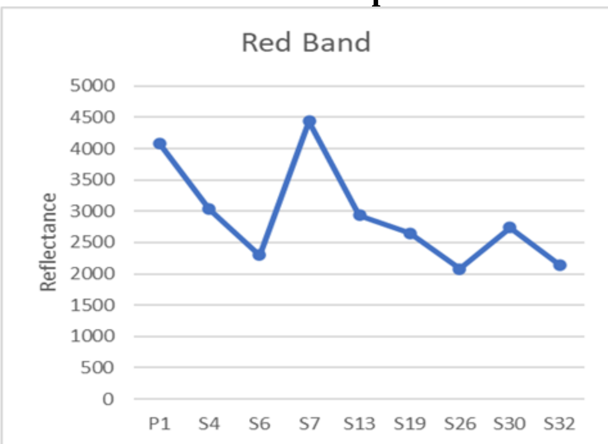


**Figure 13. Spectral reflectance of the red band reflected from palm trees**

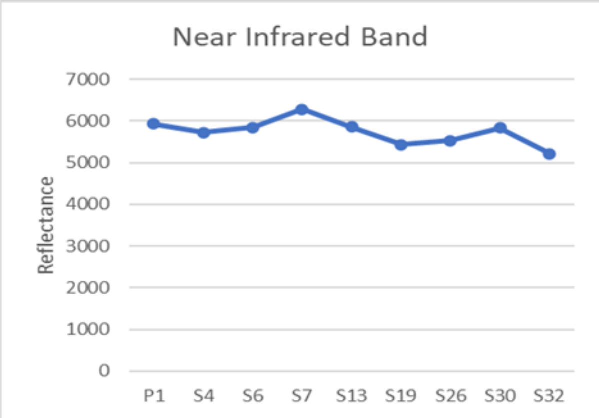


**Figure 14. Spectral reflectivity of the near-red band reflected from palm trees**

**Table 6. Spectral reflectance values of the near-red, red, and green bands reflected from palm trees**

| Spectral reflectivity from palm trees | | | |
|---|---|---|---|
| **NO.** | **Band3** | **Band4** | **Band8** |
| **P1** | **4420** | **4084** | **5928** |
| **S4** | **3774** | **3032** | **5728** |
| **S6** | **2634** | **2300** | **5840** |
| **S7** | **5252** | **4440** | **6280** |
| **S13** | **3590** | **2932** | **5864** |
| **S19** | **3208** | **2652** | **5428** |
| **S26** | **2376** | **2080** | **5532** |
| **S30** | **3064** | **2736** | **5832** |
| **S32** | **2504** | **2144** | **5216** |

As for the reflectance of the blue band from water, the highest reflectance was recorded in Water Basin 5, reaching 1349, while the lowest reflectance was in Water Basin 2, with a reflectance value of 1029.The highest reflectance of the green band from water was 1534, reflected from Water Basin 3, whereas the lowest reflectance was 518, reflected from Water Basin 1.The highest reflectance of the red band was 1532, reflected from Water Basin 3, while the lowest was 528, reflected from Water Basin 2 .As for the near-infrared (NIR) band, the highest reflectance was 1830, reflected from Water Basin 4, and the lowest reflectance was 1032, also reflected from Water Basin 2.The reason for the high reflectance values in the green and near-infrared bands compared to the blue band reflected from water is due to the presence of a large amount of algae in the water, which relatively increases the reflectance values-especially in Water Basin 3, and Water Basin 4. As for the high reflectance values in the red band, the reason is attributed to the presence of impurities and suspended sediments in the water basins, which lead to increased reflectance values-particularly in Water Basin 3 (16).As shown in Table (7) and Figures 15, 16, 17, and 18, the spectral reflectance values of the Blue, Green, Red, and Near Infrared bands reflected from water are illustrated.

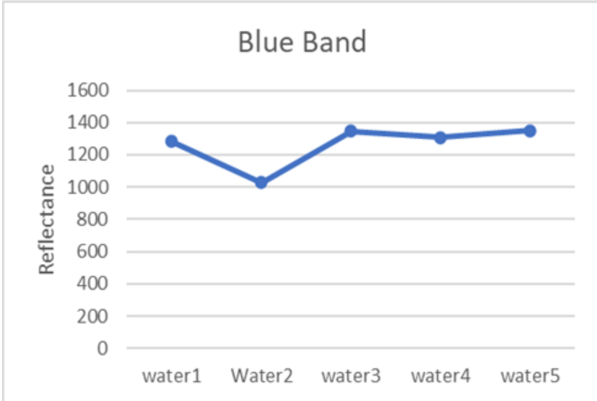


**Figure 15. Spectral reflectivity of water for the Blue band reflected from water basins**

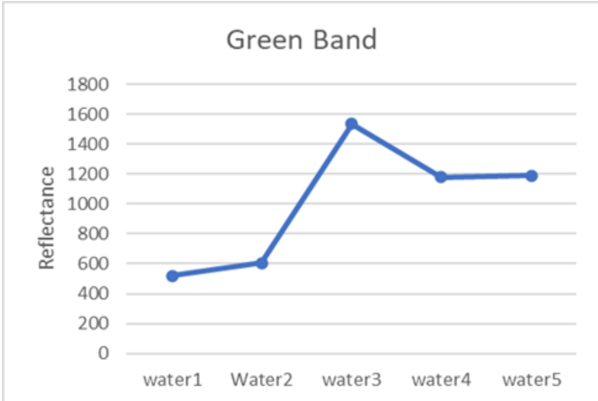


**Figure 16. Spectral reflectivity of water for the green band reflected from water basins**

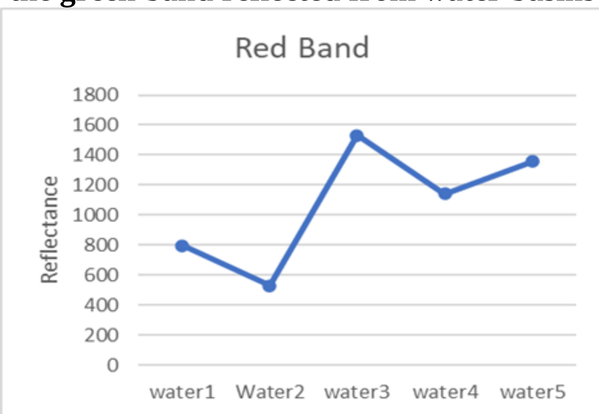


**Figure 17. Spectral reflectivity of water for the red band reflected from water basins**

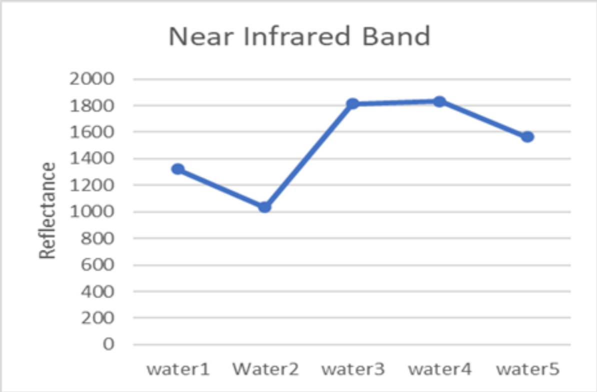


**Figure 18. Spectral reflectivity of water for the near-infrared band reflected from water basins**

**Table 7. Spectral reflectivity values of the Bule, Red, Green, Red, and Near Infrared bands reflected from water basin**

| Spectral reflectivity from water basins | | | | |
|---|---|---|---|---|
| NO. | B2 | B3 | B4 | B8 |
| water1 | 1282 | 518 | 797 | 1320 |
| Water2 | 1029 | 604 | 528 | 1032 |
| water3 | 1346 | 1534 | 1532 | 1812 |
| water4 | 1307 | 1180 | 1140 | 1830 |
| water5 | 1349 | 1190 | 1358 | 1562 |

Table (8) and Figures (19), (20), and (21) indicate the spectral reflectance values for the green, red, and near-infrared bands of the buildings. The highest reflectance for the green band was 8504, reflected from Building1, while the lowest reflectance was 4728 in Building2.As for the red band, the highest reflectance was 7468 from Building1, and the lowest was 6040, reflected from Building2. In the near-infrared band, the highest spectral reflectance value was 6904, recorded from Building1, while the lowest was 6060, reflected from Building3.The reason for the high reflectance values of the buildings in the farm is due to their light color, which increases their reflectance across all spectral bands. The elevated reflectance values in the green band for Building1 and Building3 are due to the presence of abundant natural vegetation next to these buildings. This causes a mix in reflectance between the buildings and the vegetation, as they are located within the same pixel, thus resulting in high reflectance values in Band 3 (Green).

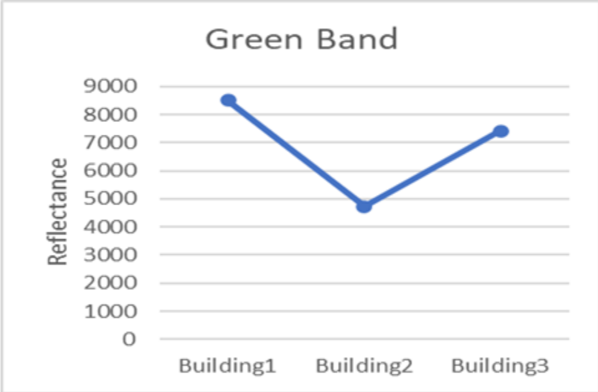


**Figure 19. Spectral reflectivity of buildings for green band reflected from buildings**

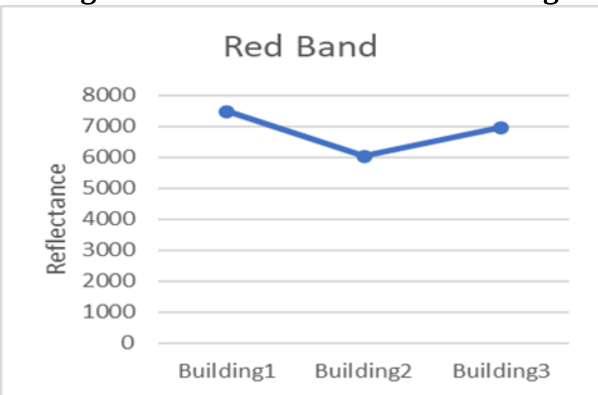


**Figure 20. Spectral reflectivity of buildings for red band reflected from buildings**

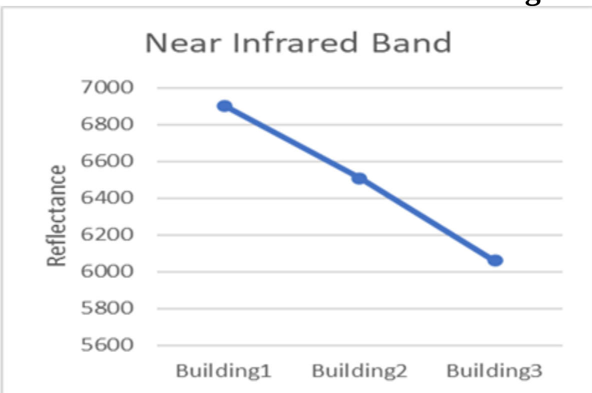


**Figure 21. Spectral reflectivity of buildings for the near-infrared band reflected from building**

**Table 8. Spectral reflectivity values of buildings**

| Spectral reflectivity from buildings | | | |
|---|---|---|---|
| No. | B3 | B4 | B8 |
| Building1 | 8504 | 7468 | 6904 |
| Building2 | 4728 | 6040 | 6508 |
| Building3 | 7420 | 6952 | 6060 |

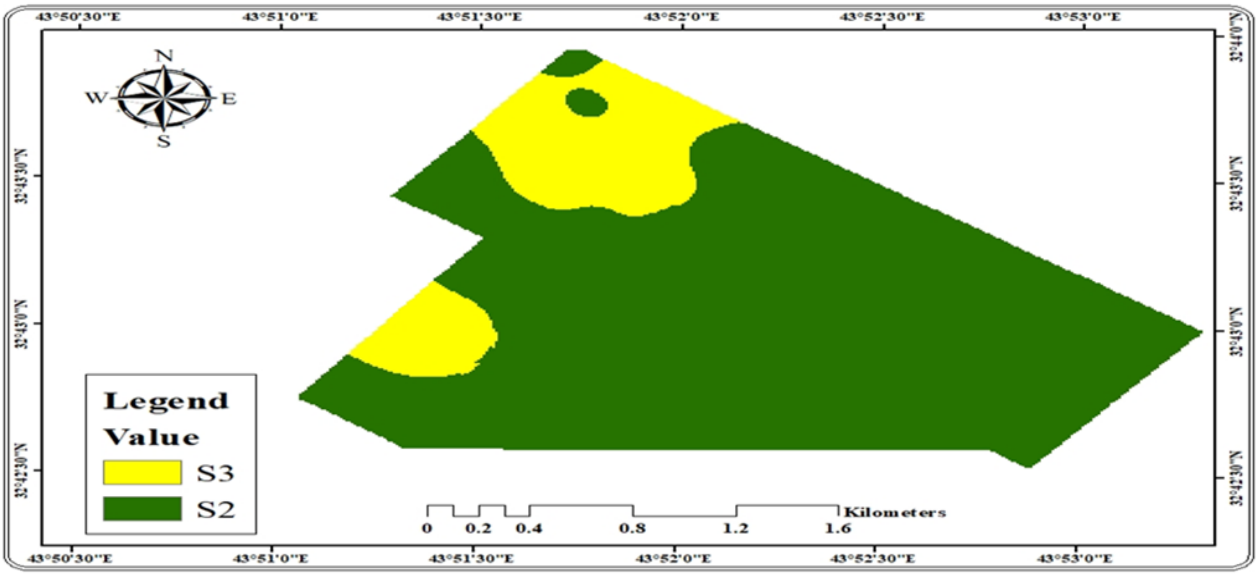


**Figure 22. Spatial distribution of soil suitability varieties for palm cultivation in Fadak Farm, according to the method of Sys et al., 1993**

Figure (22) shows the presence of two land suitability classes for date palm cultivation. The S3 (Marginally suitable) class covers an area of 82.82397 hectares, representing 15.64911% of the total area of the study region. Meanwhile, the remaining area of the study region falls under the S2 (Moderately suitable) class for date palm cultivation, occupying 446.4329 hectares, which accounts for 84.35089% of the total area of the study region. The most significant limiting factors for date palm cultivation were the high levels of calcium carbonate and gypsum, as well as the low organic matter content.

**Conclusions**

The study demonstrates that the northern part of the study area is marginally suitable for palm cultivation, while the southwestern part is moderately suitable; overall, the area is generally suitable. The main limiting factors, including calcium sulfate, calcium carbonate, and locally high sand content, should be considered in agricultural planning. Land cover analysis revealed the presence of palm trees, barren lands, buildings, water bodies, and other vegetation such as pomegranate and olive trees. The highest near-infrared reflectance observed across all covers in Fadak farm indicates the effectiveness of remote sensing for monitoring soil and vegetation conditions, supporting sustainable land management and planning decisions.

**CONFLICT OF INTEREST**

The authors declare that they have no conflicts of interest.

**DECLARATION OF FUND**

The authors declare that they have not received a fund.

**JOURNAL DECLARATION**

The Second author (**A. I. Hamad**) serves as an editor for Iraqi Journal of Agricultural Sciences but was not involved in the peer review process of this manuscript beyond their role as an author. The authors declare no other conflict of interest.

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