Plant Archives Volume 20 No. 1, 2020 pp. 1359-1365 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EFFECT OF SOIL SALINITY ON SPECTRAL REFLECTANCE OF RED AND NIR WAVELENGTHS IN AL-SALAMIYAT PROJECT

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Abstract

This study was carried out to seek the effect of soil salinity in different biophysical characteristics of vegetative covers and the effect of salinity on the behavior of red and near infrared wavelengths in the spectral reflectance curve to figure out the relationship between the density and type of vegetation in saline soils according to some vegetation indices, Salamiyat project was selected to conduct this study in. It's located within geographical coordinates (E44 296120 N 33 361311, N33 418853 E 44 153791) with 34 m high above sea level, in a total area about 14265 Acres. Samples were taken selectively from surface and sub surface soil from the studied area and according to the previously identified salinity units map that was update under this study. Two pedons were exposed in each salinity unit class and it has been morphologically described. Soil samples had been taken from each horizon, some chemical and physical properties were estimated and the spectral reflectance of each the surface layer (0-5 cm) and the natural plant of each site was measured. The study showed that there was a close correlation between the reflectance and type of common salts in soil, and it gave the highest reflectance for the soil of white salt crust while it gave a low reflectance for the dark soil surfaces. Location six (pedon 6) has given the highest reflectance value for soil in the red wavelength where it was 0.3504 and it also has given the highest reflectance value in the NIR wavelength at 0.4057 of the same pedon. The first location (pedon 1) showed less reflectance in the red wavelength curve where it was 0.0807, and it gave the least reflectance in the NIR wavelength where it was 0.1124 of the same pedon. The correlation graph of soil salinity and reflectance showed that reflectance is increasing up to some limits then starts to decrease with salts accumulation. Salinity effects the reflectance of plants through effecting its physiological characteristics particularly plant leaves therefor the reflectance decreases in the Red and NIR wavelengths in the plant that have no salts stress, water stress or disease stress. while there was a clear difference between the reflectance of the Red and NIR wavelength that can be used in distinguishing plant cover that suffers from salinity stress even if it was a perfectly growing in that soil.

Keyword: spectral signature, reflectance curve, NDVI, Soil Salinity, RED and NIR.

Introduction

The salinity contributes in lands deterioration and reduction its production in the meanwhile of the world witnessing an increase in population that needed to provide food to fill their needs. Therefore, the process of soil salinization is one of the main problems that causes the deterioration of lands and reduction the agricultural production and leads to a reduction not only in quantity but in quality of agricultural crops mainly in the arid and semi-arid areas which depends on the irrigation in farming. The salt stress is one of the most important non-vital stresses widespread, which limits plant growth, cell dissection and productivity because it effects on the ion balance and plants relationship with soil and water, so by this the salt stress affects the bio-photosynthesis and Nitrogen metabolism in the plant (Ashraf 2007). It affects the characteristics of vegetative growth of the plant, the first apparent appearance in the leaves of the plant (Munns 2002), (Parida and Das 2005). And that affects the physiological characteristics of the plant which later is reflected in the calculation of some indices depending on red and near infrared wavelengths (Wang *et al.*, 2002). Remote sensing data has the portability to diagnose lands which are affected by the salinity and distinguish the types of salts and how they spread out spatially in the soil through special spectral indices such as (Salinity index SI, normalized difference of salinity index NDSI, and brightness index BI) (Douaik *et al.*, 2004).The increase in concentration of salts in soil necessarily will affect the nature of developing vegetation covers, where the latest reflect rays of the Red and NIR wavelengths, which they are essential in calculating some of the spectral index, some of them (normalized difference vegetation index NDVI, soil adjusted vegetation index SAVI, and difference vegetation index DVI) that they are measured by remote sensing technologies.

Farifteh *et al.,* 2007 found the relationship between the salinity of soil and the spectral reflectance of salt affected soils follow a linear relationship, where they were able to predict values of soil salinity from values of spectral reflectivity for each of the linear and non-linear relationship.

The Red wavelength and its edge is the sharpest change in the reflectance of the rays from the leaves of plant in the wavelength 680-750 nm which can be measured in field or laboratory using reflectivity measuring devices (Dunagan 2007, Horler 1983, Carter 1993).

The leaf area and the internal construction of it may be considered as the main factor that formulates the spectral reflectance survey of green covers (Sims and Gamon 2002).

Therefore the objectives of the study are:

1. To seek the effect of soil salinity in some of biophysical characteristic for green covers.
2. To evaluate the potential of using the Red and NIR wavelengths to predict the spectral indices for plants grown in different salinity levels.

Materials and Methods

AL-Salamiyat project was selected to study the effect of soil salinization processes on reflection of the Red and NIR wavelengths (700-1400)nm in the leaves of plant and which is reflected from the green cover and depended on in calculating some spectral indices.

Soils of this project are affected by the salinization because the farmers of this area have small share of water to irrigate their plants in addition to the high temperature in the long dry season which contributes in salinization widely in the lands of this project. The area of study located on a 34m elevation above sea level and within geographical coordinates ($E^0$44.153791 $N^0$33.418853 and $N^0$33.361311 $E^0$44.296120) as shown in figure(1) and with total area about 14265 Acres (Sigar 1987).

The pedons were selected according to the salinity map that published by (Sigar 1987) and according to salinity units categories that suggested by SOSLAR (Soil Survey and land classification and hydrological investigation in the engineering designs department of ministry of Iraqi Water Resources), as the flow:

After determining the number of pedons according to soil salinity categories which they were 12 pedons that

EC dS.m^{-1}	**Class**
0-4	None saline
4-8	Slightly saline
8-16	Moderately saline
16-50	Saline
50-100	Strongly saline
>100	Extremely saline

have been morphologically described and samples have been taken from each horizons, after getting the samples and laboratory analyzed the map of the salinity units was updated according to the same categories used in the previous study and getting anew categories with different salinity units classes.

An image of the satellite Landsat8 OLI sensor, was obtained for calculating the spectral indices that have the relationship with biophysical characteristics of plant and soil which depends on the Red and NIR wavelengths in calculation as following:

NDVI = NIR - RED / NIR + RED

………………...…(Rouse *et al.,* 1973)

Spectral reflectance: during collecting the samples of soil for the laboratory analysis purposes, extra samples were collected from each salinity class of three replicates to measure the spectral reflectance purpose in the laboratory using spectroradiometer. Soil samples were collected in special cylindrical dishes made for this purpose to keep it undisturbed till it reaches the lab to measure the reflectance.

Spectral reflectance was measured for the dominant natural plant in the project after collecting the plant samples and keep it in sealed bags preserved in a cool box.

Electrical conductivity (EC_e) : EC_e was measured in extract 1:1 and turned into saturated soil paste extract by using Electrical conductivity bridge according to method was mentioned (Richards 1954).

Cations and Anions: cations (K^+,Na^+,Mg^{++},Ca^{++}) and the anions (CO_3^{-2},HCO_3^-,SO_4^{-2},Cl^-) were estimated in an extract 1:1 and turned into saturated soil paste extract for the surface layer of the soil (0-5)cm according to (Richard 1954).

Cations exchange capacity (CEC): Ammonium acetate method was used in (PH 7.0) according to (Black

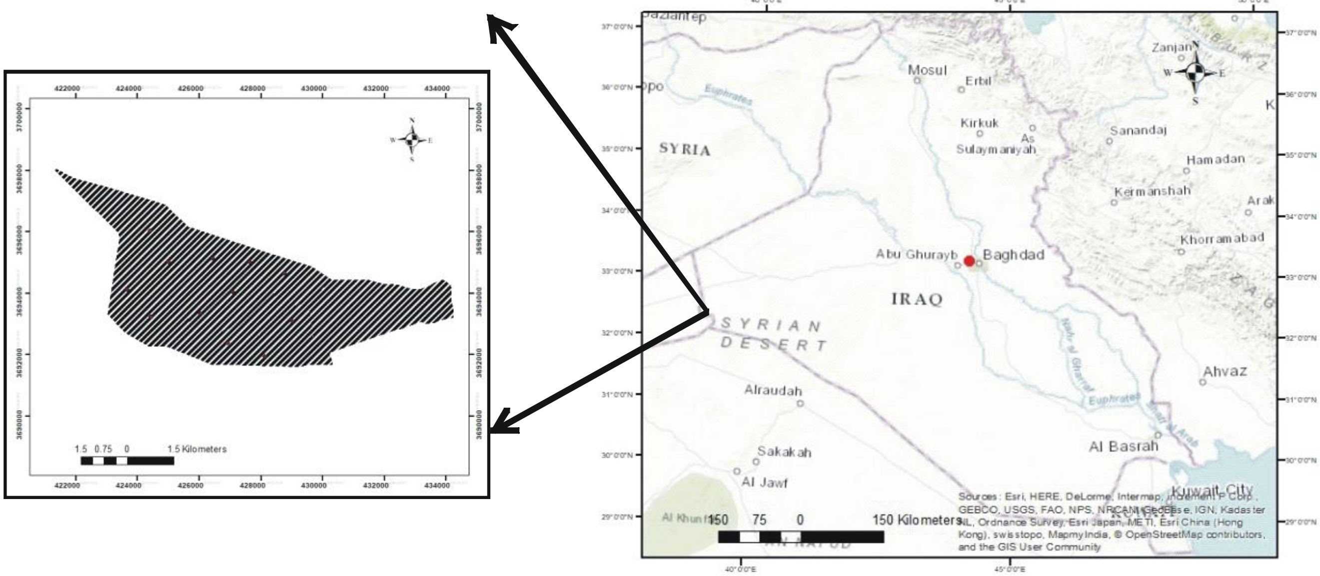

Fig. 1: Al-Salamiyat project map located in Iraq and pedons locations.

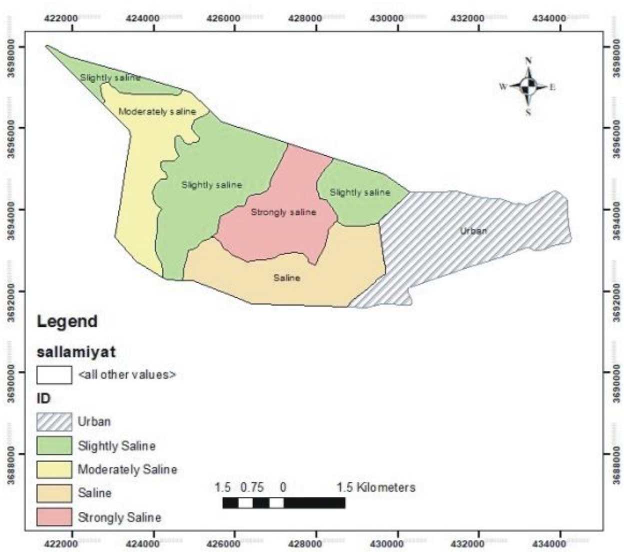

Fig. 2: Map of soil salinity for the current study.

1965).

Carbonate minerals content of Soil: it was estimated using the calcimeter method according to (Hesse 1972).

Results and Discussion

Soil Salinity values of studied pedons were ranging from 1.1 dsm^{-1} in the horizon C_2 for the pedon number 12 to 41.6 dsm^{-1} in the surface horizon Ap for the ninth pedon. The soil salinity map was classified depending on the effective horizon that carries the highest ECe, in that case they were A_1, Ap. Besides they are affected by erosion and water logging etc.

And to achieve one of this study objectives, soil salinity samples were taken from the surface 0-5 cm depth regardless to horizons to measure the spectral reflectance of soil surface as it is dependent for such purpose. This layer salinity was measured besides estimating cations and anions in soil extract as shown in (Table 1).

Table 1 shows that the soil salinity of the 0-5 cm in pedons of study, they were ranging between (2.8 dsm^{-1}) in the surface layer of pedon four to (168.5 dsm^{-1}) in surface layer for pedon seven and this is related to natural land use in each pedon, so pedon four was typically used in farming while soil of pedon seven was abandoned for a long time which caused a high accumulation of salts on the surface, resulting layers of salts in different levels spread from Shura to sabakh soils, the cations and anions were calculated in that area to know the hypothetical distribution of salts, as shown in the same (Table 1). The accumulation of these salts firmly affects reflectance of electromagnetic ray while they incident on soil surface. The sabakh soils that have dark color, will have a low reflectance because it absorbs most of the incident light. Whereas the shura soils which have a white salts crust reflect most of the incident electromagnetic ray and appears in a bright white colors that is easy to recognize during the visual interpretation of the satellite images (Stoner and Baumgardner 1981, Metternticht and Zinck 2003, Howari *et al.*, 2002, Wheib 2013)

The spectral reflectance of soil: The spectral reflectance was calculated for that samples and it was extracted for the Red and NIR ray as shown in (Table 3).

A significant relationship between the reflectance and the dominant salts type that existed in the soils can be noticed from this table. The highest reflectance of the

Table 1: Soil salinity, cations, and anions of 0-5 cm of soil samples.

No.	EC_dS.m-1	Salinity phase	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	SO4—	HCO3-	CO3—
			$Meq.l^{-1}$							
1	106.9	sabakh	808.6	520.5	355.5	14.5	1286.0	393.0	16.6	3.5
2	139.4	sabakh	655.5	510.3	344.3	30.1	1100.6	419.0	17.8	2.8
3	4.1	-	12.8	9.5	18.4	1.9	16.5	24.3	1.8	0.0
4	2.8	-	13.0	6.0	10.0	1.5	14.5	13.8	2.2	0.0
5	37.6	white spots	188.9	129.2	101.9	6.7	238.8	175.5	11.9	0.5
6	15.3	white spots	66.8	38.5	104.5	4.8	88.8	117.0	8.8	0.0
7	168.5	sabakh	490.5	850.2	305.7	12.3	1268.4	360.0	28.8	1.5
8	137.4	shura	506.5	330.4	754.8	25.8	1068.6	533.4	10.8	4.7
9	140.0	shurasabakh	935.5	706.5	870.6	19.8	1156.5	1351.4	21.2	3.3
10	7.5	-	31.4	24.6	19.7	3.2	38.6	36.7	3.6	0.0
11	8.0	-	39.3	23.8	20.5	2.2	22.9	58.1	4.8	0.0
12	9.2	-	33.8	26.8	40.1	5.6	72.8	29.8	3.7	0.0

Table 2: The saline composition in the surface layer (0-5)cm of the study soil.

S.N.	$CaCO_3$	$Ca(HCO_3)_2$	$CaSO_4$	$CaCl_2$	$MgCO_3$	$Mg(HCO_3)_2$	$MgSO_4$	$MgCl_2$	$NaCO_3$	$NaHCO_3$	Na_2SO_4	NaCl	K2CO3	$KHCO_3$	K_2SO_4	KCl	Salinization Phase
1	3.5	16.6	393	395.5	0	0	0	520.5	0	0	0	355.5	0	0	0	14.5	sabakh
2	2.8	17.8	419	215.9	0	0	0	510.3	0	0	0	344.3	0	0	0	30.1	sabakh
3	0	1.8	11	0	0	0	9.5	0	0	0	3.8	14.6	0	0	0	1.9	-
4	0	2.2	10.8	0	0	0	3	3	0	0	0	10	0	0	0	1.5	-
5	0.5	11.9	175	1	0	0	0	129.2	0	0	0	101.9	0	0	0	6.7	white spots
6	0	8.8	58	0	0	0	38.5	0	0	0	20.5	84	0	0	0	4.8	white spots
7	1.5	28.8	360	100.2	0	0	0	850.2	0	0	0	305.7	0	0	0	12.3	sabakh
8	4.7	10.8	491.1	0	0	0	47.3	288.1	0	0	0	754	0	0	0	25.8	shura
9	3.3	21.2	911	0	0	0	440.4	266.1	0	0	0	870.6	0	0	0	19.8	Shura/sabakh
10	0	3.6	27.8	0	0	0	8.9	15.7	0	0	0	19.7	0	0	0	3.2	-
11	0	4.8	34.5	0	0	0	23.6	0.2	0	0	0	20.5	0	0	0	2.2	-
12	0	3.7	29.8	0.3	0	0	0	26.8	0	0	0	40.1	0	0	0	5.6	-

Table 3: Spectral reflectance for Red and NIR wavelengths as related to soil salinity.

S.N.	Ref_Red_Soil	Ref_NIR_Soil	EC dS.m-1	Salinization phase
1	0.0807	0.1124	106.9	sabakh
2	0.1884	0.2404	139.4	sabakh
3	0.1813	0.197	4.1	-
4	0.1331	0.191	2.8	-
5	0.2526	0.31	37.6	white spots
6	0.3504	0.4057	15.3	white spots
7	0.2047	0.2532	168.5	sabakh
8	0.3333	0.3918	137.4	shura
9	0.2949	0.3549	140	shurasabakh
10	0.1127	0.1329	7.5	-
11	0.1423	0.1743	8	-
12	0.2982	0.33	9.2	-

Red and NIR wavelengths was found in the soils that contain white salt crust. Whereas the lowest values of reflectance was recorded in the soils that contain dark hydrated salts.

From the table above we have observed that the sabakh soils showed a lower reflectance for the electromagnetism rays for the Red and NIR wavelengths because the type of the dominant salts in these soils is a hydrated salts which it works to absorb water molecules from the atmosphere to the chemical composition of the salt, therefore it seems darker, in addition to this, salts have the ability to make complexes with organic compounds that existed in the soil and leads to increase the darkness of the soil which affects the reflectance, and for these reasons the most of the incident light on the soil is absorbed by the soil surface. The shura soils are marked with white salt crust and the dominant salts in the NaCL, $MgCL_2$, Na_2SO_4 as in table 2.The crust with pale color works to reflects the incident light, so its reflectance is increasing as compared to the absorbed light. Table 3 shows that the shura soils have the highest reflectance of both Red and NIR wavelengths as it was confirmed by studies of Baumgardner *et al.*, 1988, Rao *et al.*, 1995, Zinck 2002, Howari and Goodell 2002, Metternicht and Zinck 2008. Figure 3 shows the relationship between the spectral reflectance of the Red NIR wavelengths and soil salinity (dsm^{-1}). The figure confirms that the average of reflectance of both wavelength are increasing to some stage (in the beginning the salts developing of shura soils), then it starts to decrease after the salt developing towards the sabakh soils (Csillag *et al.*, 1993, Sidike *et al.*, 2014).

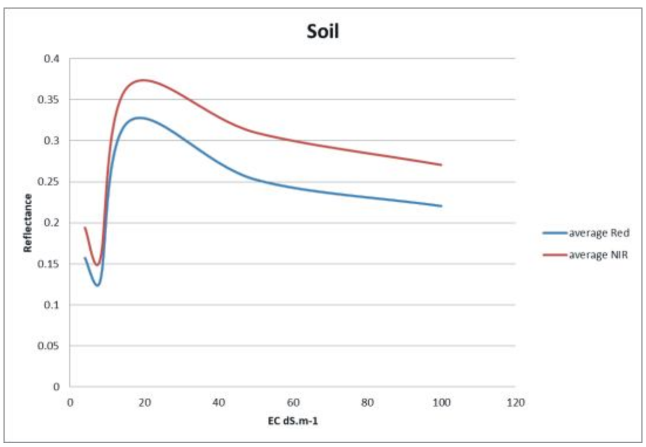

Fig. 3: Relationship between Red and NIR wavelengths and soil salinity.

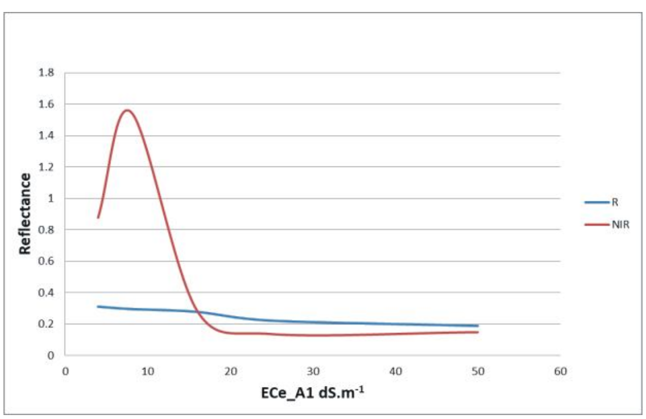

Fig. 4: Reflectance for Red and NIR wavelengths of leaves in deferent soil salinity levels of (0-30) cm.

The Fig. (4) shows the relationship between the reflectance of the Red and NIR wavelengths of plant leaves with soil salinity of the surface horizon (0-30) cm which represents the rhizosphere of plant so it's affected by salts that existed in this soil depth, and that's why it was selected for the comparison and it shows that the salts in the soil have an effect on the values of the reflectance generally in the vegetative part of plant (leaves), so the reflectance from plant is affected by soil salinity, where in another term it affected the physiological characteristics of the plant especially leaves which leads to decrease the reflectance of Red and NIR wavelengths.

To explain this phenomena, firstly we should have known that the use Red and NIR wavelengths in distinguishing the green vegetative covers from the other covers, where the reason is related to the influence of the plant that affect both wavelengths. Reflectance curve of plant shows that the highest reflectance appears in the NIR wavelength while the lowes appears in the RED one. Therefore the difference between these two wavelengths gives a clear picture about the density and health of vegetative cover in a certain place Fig. 5 (Gausman 1974, Horler *et al.*, 1983, Steven *et al.*, 1983, Datt 1989, Elvidge and Chen 1994, Penuelas and Fellela 1998). The natural plant that lives in perfect conditions without any kind of stresses such as saline, water or disease stress, in this case most of the NIR wavelength is reflected from the leaves of plant where while a bit of the Red wavelength is reflected from it.

In case the plant suffering from stresses whether they were salts or water, etc., the reflectance of the NIR wavelength almost decreases to a level that is the same of Red wavelength, therefore this can be used to distinguish between the vegetation cover that suffers from salinity stress even it is grown typically in these soils and the reason returns to the increase of salts concentration in the plant cell that leads to a great physiological changes that certainly reflected on the morphological characteristics of the leaf in special and on the plant in general. (Macleod 1972, Thomas *et al.*, 1971, Sellers 1985, Jackson 1986, Grant 1987, Carter 1993, Carter and Knapp 2001 Lee and Carrow 2004, Jones 2013).

Cstar center for spatial technologies and remote sensing, department of land and water resources, university of California, Davis, published a scheme explains briefly what it has been mentioned above. (Fig. 6)

It is worth mentioning that the value of soil salinity clearly influenced the NDVI (Normalized difference vegetation index), where in spite of there was a high

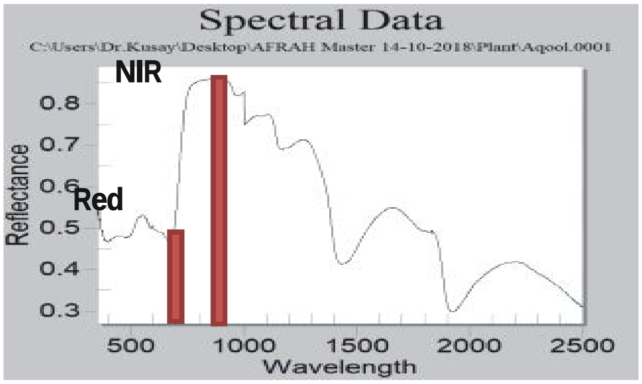

Fig. 5: Sample of the Red and NIR reflectance of Agool vegetative part.

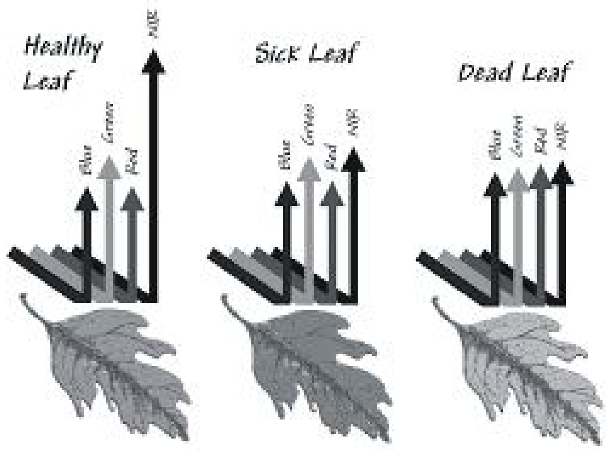

Fig. 6: Reflectance of Red and NIR rays from leaves in different cases (after CStar2019).

growth for the natural halophytes in salt affected soils, but their reflectance was in non-standard case, where the leaves of plants in the salt affected soils were high in biomass while the plant was in unhealthy physiological condition which led to decrease the spectral reflectance of Red and NIR wavelengths in a hand, and the NDVI on the other hand which depends on these two wavelengths in calculation. That what was observed in the field where the most of Tertae (*Schanginia aegyptiaca*) leaves were tend to be more purple and red in color with the increase of salts in soil, whiles Tarfa (*Tamarix* L.) plants were pale in color and has a cumulated white powder on the vegetative part with high salts concentrations. Agool (*Alhagi maurorum*) plants had a dark color which differ from those grown in a no and slightly saline soils, so that certainly will affect the calculating of NDVI negatively which is calculated using the Red and NIR wavelengths.

Conclusions

1. Wide area of soils appeared to be affected by salts, some of them were sabakh and others were shura,which showed different reflectance curve, so the shura soils marked with high reflectance for both bands the Red and NIR, whereas the Sabakh soils marked with low reflectance, since the absorbency of these wavelengths increase against reflectance.
2. The reflectance curve of surface soil showed a clear effect of salts that accumulated on the surface for both Red and NIR bands.
3. The reflectance curve of plant leaves showed a clear effect of salts content in soil. Each plant had a particular spectral print which characterizes it from other plants, and the reason returns to the different action of salt on each plant species.
4. The NIR wavelength was more affected by the increase of salts content in soil as compared to the Red rays.
5. NDVI showed a negative relationship with salts content in soil, but it was weak, because the saline soils were characterized with vegetation cover which prefers salts (halophytes).

Recommendations

1. Putting some consideration in calculating of the vegetative indices, where the low values of these indices might not represents a low vegetation cover in some of salt affected soils because some halophytes typically grow in these soils.
2. Focusing on the spectral behavior of halophytes and agronomic plants because each species reflects different condition of soil.
3. Study the spectral of halophytes spectral signature in more detailed and compare them to agronomic plants for the purpose of calculating vegetative indices and its relation to biomass.

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