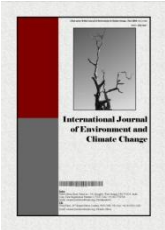

International Journal of Environment and Climate Change

12(11): 1792-1804, 2022; Article no.IJECC.90275
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Identification of Suitable Spectral Bands Related to Soil Properties of Major Soils of Telangana, India

R. Ajaya Kumar [a*], G. Jayasree [a], Tarik Mitran [b] and T. L. Neelima [c]

[a] Department of Soil Science and Agricultural Chemistry PJTSAU, CoA, Rajendranagar, Hyderabad, Telangana, India.
[b] Soil and Land Resource Assesment Division, NRSC, ISRO, Balanagar ,Hyderabad, Telangana, India.
[c] Water Technology center, PJTSAU, CoA, Rajendranagar, Hyderabad, Telangana, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1131164

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/90275

Original Research Article

Received 12 June 2022
Accepted 16 August 2022
Published 25 August 2022

ABSTRACT

A study was conducted to identify suitable spectral bands related to soil properties of major soils of Telangana using hyperspectral data. A total of 200 surface soil samples were collected from district of Sangareddy (20 soil samples), Yadadri Bhuvangiri (20 soil samples), Nizamabad (20 soil samples), Adilabad (20 soil samples), Jayashankar Bhupalpally (60 soil samples), Nagar Kurnool (20 soil samples) and Nalgonda (40 soil samples) analyzed for soil properties viz., pH, electric conductivity (EC), organic carbon, total nitrogen, total phosphorus, total potassium, soil texture (percent clay). Soil spectral data (350-2500 nm) was measured using ASD spectroradiometer and correlated with soil properties using Pearson correlation test. Result shows that the soil properties like pH, OC, total N, total K , total Mn, % Clay showed significant negative correlation at 1210-1280 nm (r= -0.345**) for Ph, 610-630 nm (r= -0.415**) for OC, 390-410 nm (r= -0.180*, 0.183*, 0.175*, 0.170*) for total N, 360-390 nm (r= -0.174**,-0.158**,-0.163**,0.160**) for total K , 590-610 nm (r= -0.527** and -0.526**) for clay %.However significant positive correlation was observed with ECand 1110-1130 nm (r= 0.150* and 0.149*). These sensitive bands for soil parameters can be further used for prediction of soil properties.

**Corresponding author: E-mail: akr18000@gmail.com;*

Keywords: Hyperspectral data; spectroradiometer; pearson correlation; soil reflectance.

1. INTRODUCTION

Infrared and visible soil reflectance (VNIR) interactions in the area (350–2500 nm) between the bonds in and the electromagnetic energy components of soil molecules. The soil reflectance spectra is significantly impacted by its characteristics such as clay minerals, and iron (Fe) soil texture, soluble salts, oxide content, and soil's moisture content [1]. Consequently, it offers a chance to gather information about different soil characteristics using the relationship between soil analysis data with reflectance at various wavelength ranges. Several soil attributes can be predicted from a single soil spectrum using the spectral reflectance measurement (also known as spectroscopy) of a soil in a laboratory environment. The benefits of soil reflectance spectroscopy include speed, economy, and precision in addition to its non-destructive nature, ease of sample preparation (soils are simply sieved), lack of chemical reagent use, and simplicity. Organic matter in soil greatly influences reflectance in the 500–1100 nm wavelength range [2,3]. According to Henderson et al. [4], the visible regions are crucial for determining the amount of organic matter. The amount of soil organic carbon (SOC) has a significant impact on soil fertility, classification and mapping, and the suitability of the soil for different purposes. SOC has a significant impact on soil reflectance, and generally, as organic matter concentration increases, soil reflectance decreases from 400 to 2500 nm. Chen et al. [5]; Henderson et al. [4]. Many have shown more predictability when using hyperspectral reflectance to forecast SOC [6,7,8,9].

In order to relate the soil spectra to the desired soil attributes (as measured by a laboratory procedure), the study of soil spectra mostly uses multivariate calibration techniques (Martens and Naes 1989). The calibration equation can be used to predict the property of fresh samples from their reflectance spectra once it has been calibrated.

Saline soils showed noticeably greater reflectance values across the whole range of wavelengths from 325 to 2500 nm [10]. In contrast to moderately salinized soils, significantly salinized soils may have lower reflectance due to increased water absorption characteristics between 1400 and 1900 nm of the spectrum. The most vulnerable spectral ranges in the soils of south Spain have been identified as being 390-400, 615-625, 685-695, 800-810, 950-960, 1410-1420, 1935-1945, and 2350-2360 nm [11].

Many people utilise spectral reflectance to measure the chemical fertility of soil in the visible and near infrared (VIS/NIR, 400–2500 nm) as well as mid infrared (MIR, 2500–25000 nm) spectrum ranges. The most frequently examined fertility parameters with varying degrees of prediction accuracy were soil organic carbon (SOC), inorganic carbon (SIC), total nitrogen (TN), cation exchange capacity (CEC), pH, potassium (K), magnesium (Mg), calcium (Ca), zinc (Zn), iron (Fe), and manganese (Mn) [12,1].

2. MATERIALS AND METHOD

2.1 Collection of Soil Samples and Preperation

The 200 surface samples were collected from 100 sites representing 10 major soils of Telangana using stratified random sampling. At each place surface soil (0-30 cm) has been collected in duplicate. Sample were collected from district Sangareddy (20 soil samples), Yadadri Bhuvangiri (20 soil samples), Nizamabad (20 soil samples),Adilabad (20 soil samples), Jayashankar Bhupalpally (60 soil samples), Nagar Kurnool (20 soil samples) and Nalgonda (40 soil samples).Soil samples were collected and Dried in shade.The air dried samples were pounded using wooded pestel and mortar and passed through 2 mm sieve and stored for determination of various soil properties.

2.2 Collection of Spectral Data

ASD Field Spec TM 3 ground-based spectroradiometer with a 25° Field of View (FOV) was used to evaluate the spectral reflectance of soils in field conditions. A general-purpose spectrometer that can be used for applications that call for the measurement of reflectance, transmittance, radiance, or irradiance is the Field Spec 4 spectroradiometer. It is especially made to collect visible near-infrared (VNIR) and short-wave infrared (SWIR) spectra from outdoor environments. The spectral range between 350 and 2500 nm is covered by the Analytical Spectral Device (ASD). The sampling rate is 0.2

seconds per spectrum. With a spectral resolution varying from 3nm in the very short and 10nm in the farer wavelengths, the device records spectra based on the information of 2151 bands. RS^3 was the software used. View spec pro was the software used for post processing of specctral data.

2.3 Physico-Chemical Properties

pH of the soil samples was determined in 1:2.5 soil water suspension by using pH meter (DI-707) with glass electrode [13]. The electrical conductivity was determined in 1:2.5 soil water extract with help of a digital conductivity meter (DI-909) and results were expressed in dS m^{-1} [13]. The organic carbon content was of the soils was determined by Walkley and Black (1934) rapid titration method and OC contents were expressed in percentage. The total nitrogen was estimated by Kjeldahl method as described by Page et al., (1982) as total N content is expressed as percentage [14]. The total phosphorous was estimated by Perchloric acid ($HClO_4$) digestion method as described by Jackson [13]. Total potassium in soil was estimated by Perchloric acid ($HClO_4$) digestion method as described by Jackson [13]. Total potassium in soil was estimated by Perchloric acid ($HClO_4$) digestion method as described by Jackson [13]. The soil texture texture analysis was carried out by the Boucous hydrometer method.

2.4 Staistical Analysis

Using XLSTAT(by addinsoft) and microsoft office, the Pearson product moment correlation coefficient was used to measure the degree of linear relationship between the measured soil variables with reflectance values as well as absorption feature parameter at obtained wavelength intervals characteristics of a specific soil parameter.

3 RESULTS AND DISCUSSION

3.1 Soil Properties of Major Soils of Telangana

The Ph of T1-Deep calcareous soil ranged from 7.42-7.89, T2-Red gravelly loam soil ranged from 7.11-7.28, T3-Red shallow gravelly loam soil from 7.11-7.36, T4-Shallow black soil from 7.56-7.88, T5-Red shallow loam soil from 6.91-7.91, T6-Red loam soil from 7.41-7.94, T7-Deep black soil from 5.55-7.77,T8-Red clayey soil from 6.63-7.75,T9-Alluvio colluvium clay from 7.44-7.96 and Red gravelly clay soil from 7.44-7.77.The highest pH of 7.97 was recorded in T5-Red shallow loam soil.

The EC (dS m^{-1}) of T1-Deep calcareous soil ranged from 0.232-0.332, T2-Red gravelly loam soil ranged from 0.321-0.33, T3-Red shallow gravelly loam soil from 0.152-0.345, T4-Shallow black soil from 0.166-0.341, T5-Red shallow loam soil from 0.176-0.348, T6-Red loam soil from 0.282-0.388, T7-Deep black soil from 0.142-0.397, T8-Red clayey soil from 0.283-0.468, T9-Alluvio colluvium clay soil from 0.344-0.499 and Red gravelly clay soil from 0.211-0.298.The highest EC of 0.499 dS m^{-1} was recorded in T9-Alluvio colluvium clay soil.

The OC (per cent) of T1-Deep calcareous soil ranged from 0.13-0.68, T2-Red gravelly loam soil ranged from 0.1-0.75, T3-Red shallow gravelly loam soil from 0.31-0.84, T4-Shallow black soil from 0.43-1.11, T5-Red shallow loam soil from 0.08-0.53, T6-Red loam soil from 0.25-0.89, T7-Deep black soil from 0.17-0.75, T8-Red clayey soil from 0.09-0.97, T9-Alluvio colluvium clay soil from 0.344-0.499 and T10 Red gravelly clay soil from 0.14-0.82 .The highest O.C of 1.11 was recorded in T4-Shallow black soil.

The total nitrogen content (per cent) of T1-Deep calcareous soil ranged from 0.02-0.037, T2-Red gravelly loam soil ranged from 0.031-0.12, T3-Red shallow gravelly loam soil from 0.01-0.031, T4-Shallow black soil from 0.01-0.06, T5-Red shallow loam soil from 0.014-0.312, T6-Red loam soil from 0.053-0.211, T7-Deep black soil from 0.045-0.141, T8-Red clayey soil from 0.08-0.23, T9-Alluvio colluvium clay soil from 0.01-1.456 and T10 Red gravelly clay soil from 0.04-0.12. The highest total N of 1.11 was recorded in T9-Alluvio colluvium clay soil.

The total phosphorus content (per cent) of T1-Deep calcareous soil ranged from 0.008-0.021, T2-Red gravelly loam soil ranged from 0.024-0.04, T3-Red shallow gravelly loam soil from 0.024-0.05, T4-Shallow black soil from 0.016-0.067, T5-Red shallow loam soil 0.024-0.059, T6-Red loam soil from 0.022-0.047, T7-Deep black soil from 0.029-0.055, T8-Red clayey soil from 0.026-0.042, T9-Alluvio colluvium clay soil from 0.017-0.076 and T10 Red gravelly clay soil from 0.026-0.047.The highest phosphorous of 0.067 was recorded in T4-Shallow black soil.

The total potassium content (per cent) of of T1-Deep calcareous soil ranged from 0.04-0.19, T2-Red gravelly loam soil ranged from 0.04-0.19, T3-Red shallow gravelly loam soil from 0.08-0.26, T4-Shallow black soil from 0.08-0.18, T5-Red shallow loam soil from 0.09-0.96, T6-Red loam soil from 0.07-0.25, T7-Deep black soil from 0.06-0.2, T8-Red clayey soil from 0.06-0.27, T9-Alluvio colluvium clay soil from 0.06-0.18 and T10 Red gravelly clay soil from 0.07-0.15.The highest potassium of 0.96 (per cent) was recorded in , T5-Red shallow loam soil.

The per cent clay content of T1-Deep calcareous black soil ranged from 0.43-0.57, T2-Red gravelly loam soil ranged from 0.1-0.19, T3-Red shallow gravelly loam soil from 0.12-0.16, T4-Shallow black soil from 0.34-0.44, T5-Red shallow loam soil from 0.18-0.32, T6-Red loam soil from 0.21-0.28, T7-Deep black soil from 0.22-0.36, T8-Red clayey soil from 0.18-0.27, T9-Alluvio colluvium clay soil from 0.11-0.26 and T10 Red gravelly clay soil from 0.1-0.16.The highest per cent clay content 0.57 was recorded in T1-Deep calcareous black.

3.2 Spectral Reflectance of Soils under Laboratory Condition

A high intensity source equipment called the FieldSpec 4 and a Spectralon panel for white reference were used to scan soil samples with a spectral range of 350-2500 nm. 8° FOV is employed. It was positioned in the nadir position on a tripod. A lamp fixed 45 cm from the soil sample was placed at a distance of 20 cm from the optical head. The RS3 programme was used to obtain all spectral data.

It is non-imaging hyperspectral data that can forecast the characteristics of the soil. Each spectral signature was pre-treated with View Spec Pro software, which also converted each one into ASCII format.The analysis was conducted for 200 soil samples from soil collected from 100 major locations.

Pearson correaltion studies were carried out with sampled reflectance values at 10 nm interval for entire wavelength range. The soil properties like Ph, OC, total N, total K, total Mn, total Zn, % Clay showed significant negative correlation at 1210-1280 nm (r= -0.345**) for Ph , 610-630 nm (r= -0.415**) for OC, 390-410 nm (r= -0.180*, 0.183*, 0.175*, 0.170*) for total N,360-390 nm (r= -0.174**,-0.158**, -0.163**,0.160**) for total K, 590-610 nm (r= -0.527** and -0.526**) for % clay. Positive significant correlation was seen in case of EC and and in case of total Fe correlation was non significant with spectral reflectance data.For EC significant spectral bands were 1110-1130 (r= 0.150* and 0.149*).

From pearson correaltion between OC and spectral reflectance (350-2500) shows that correlated significant bands were 610 nm-630 nm Similar findings were also reported by Spectral correlation study showed that the visible region, or the range of 620 to 810 nm, had the strongest correlation (-0.55). In contrast to Beck et al. [15], who claimed that the 900-1220 nm range was ideal for mapping organic carbon in soils, Mathews et al. [16] discovered that organic matter associated most strongly with reflectance in the 500–1200 nm range.The the spectral bands findings were similar to that of Stoner [10] demonstrated that organic matter is the single most significant variable to explain reflectance variances in the spectral range between 500 and 1750 nm.

From pearson correaltion between total and spectral reflectance (350-2500 nm) shows that correlated significant bands were 390-410 nm. According to Vibute et al. [17] T480 nm, 511 nm, 653 nm, 997 nm, 1472 nm, 1795 nm, 2210 nm, and 2296 nm wavelength bands were found to be sensitive to nitrogen levels.

From pearson correaltion between % clay and spectral reflectance (350-2500 nm) shows that correlated significant bands were 580-640 nm. The reflectances of varying mixtures of clay and sand were measured by Gerberman and Neher [18] at different wavelengths ranging from 400 to 900 nm and they found that the reflectance increases with the sand content.

From pearson correaltion between EC and spectral reflectance shows that correlated significant bands were 1110 nm-1130 nm, according to Al-Mahawili [19] the spectral range from 500 to 2380 nm for EC. Further, he found that leaching the saline soils, and thus significantly reducing the electrical conductivity, increased the reflectance. The most sensitive bands soil properties are mentioned in the table below (Table 1).

Table 1. Soil parameters and its significant bands

Sr. No	Soil parameter	Most sensitive spectral region (nm)	Other sensitive spectral region (nm)	Found in literature
1.	**P^H**	1210-1280	1200,1190,1290	720, 1700,1860
2.	**E.C**	1080,1110-1120		390-400, 615-625, 685-695, 800-810, 950-960
3.	**O.C**	610-630	600, 630-660,700-710, 760	500-1200, 900-1200, 1700-2050, 1530
4.	**Total N**	400,390,410	420, 510	
5.	**Total P**	700-730	690, 740, 660	
6.	**Total K**	360-390		
7.	**Clay%**	580-640,	650, 660, 690, 780	1500-1730

Table 2. Ranges of soil properties of major soil of Telangana

	PH	E.C(ds/m)	O.C (percent)	Total N (percent)	Total P (percent)	Total K (percent)	%Clay
T1-Deep Calcareous Black soil							
Mean	7.662	0.295	0.522	0.026	0.015	0.103	52.700
Range	7.42-7.89	0.232-0.332	0.13-0.68	0.02-0.037	0.008-0.021	0.04-0.19	43-57
SD	0.143	0.032	0.191	0.006	0.004	0.045	4.200
CV	0.019	0.107	0.366	0.218	0.263	0.443	0.151
T2-Red gravelly loam soil							
Mean	7.473	0.288	0.785	0.050	0.241	0.399	13.500
Range	7.11-7.28	0.321-0.33	0.1-0.75	0.031-0.12	0.0248-0.043	0.04-0.19	10.00-19
SD	0.176	0.058	0.075	0.176	0.043	0.226	2.300
CV	0.024	0.003	0.001	0.024	0.178	0.566	0.170
T3-Red shallow gravelly loam soil							
Mean	7.28	0.285	0.66	0.026	0.035	0.13	12
Range	7.11-7.36	0.152-0.345	0.31-0.84	0.01-0.031	0.0244-0.0508	0.08-0.26	12.00-16.00
SD	0.064	0.057	0.159	0.007	0.008	0.049	1.100
CV	0.009	0.229	0.299	0.327	0.215	0.380	0.090
T4-Shallow black soil							
Mean	7.710	0.258	0.678	0.031	0.037	0.137	40.700
Range	7.56-7.88	0.166-0.341	0.43-1.11	0.01-0.06	0.0162-0.0676	0.08-0.18	34-44
SD	0.101	0.051	0.195	0.019	0.019	0.033	3.200
CV	0.013	0.199	0.288	0.607	0.512	0.244	0.070
T5-Red shallow loamy soil							
Mean	7.392	0.270	0.308	0.071	0.034	0.273	24.500
Range	6.91-7.97	0.176-0.348	0.08-0.53	0.014-0.312	0.0248-0.0592	0.09-0.96	18-32
SD	0.331	0.057	0.144	0.086	0.008	0.314	3.700
CV	0.045	0.212	0.468	1.219	0.221	1.151	15.200
T6-Red loamy soil							
Mean	7.625	0.337	0.493	0.220	0.034	0.132	24.100
Range	7.41-7.94	0.282-0.388	0.25-0.89	0.053-0.211	0.0224-0.0476	0.07-	21-28

	PH	E.C(ds/m)	O.C (percent)	Total N (percent)	Total P (percent)	Total K (percent)	%Clay
						0.25	
SD	0.140	0.032	0.192	0.360	0.009	0.069	2.200
CV	0.018	0.094	0.389	1.638	0.278	0.520	0.090
T7-Deep black soil							
Mean	7.113	0.293	0.395	0.085	0.044	0.099	30.700
Range	5.55-7.77	0.142-0.397	0.17-0.75	0.045-0.141	0.0296-0.0556	0.06-0.2	22-36
SD	0.644	0.094	0.159	0.030	0.009	0.046	4.500
CV	0.091	0.320	0.402	0.357	0.210	0.462	0.146
T8-Red clayey							
Mean	7.017	0.391	0.362	0.147	0.034	0.130	22.800
Range	6.63-7.75	0.283-0.468	0.09-0.97	0.08-0.23	0.0268-0.0426	0.06-0.27	18-37
SD	0.370	0.060	0.278	0.047	0.005	0.057	2.300
CV	0.053	0.153	0.767	0.323	0.137	0.441	0.100
T9-Alluvio-colluviom clay							
Mean	7.697	0.457	0.199	0.768	0.044	0.096	19.900
Range	7.44-7.96	0.344-0.499	0.008-0.47	0.01-1.456	0.0174-0.076	0.06-0.18	11-26.5
SD	0.209	0.045	0.142	0.381	0.017	0.035	4.900
CV	0.027	0.098	0.712	0.495	0.391	0.368	0.240
T10-Red gravelly clay soil							
Mean	7.622	0.258	0.489	0.056	0.034	0.104	13.900
Range	7.44-7.77	0.211-0.298	0.14-0.82	0.04-0.12	0.0268-0.047	0.07-0.15	10.00-19.00
SD	0.088	0.027	0.195	0.024	0.007	0.026	1.800
CV	0.011	0.103	0.400	0.427	0.198	0.246	0.129

Table 3. Pearson correlation

Variable	pH	EC	OC	Total N	Total P	Total K	% Clay
pH							
EC	0.182						
OC	0.087	-0.363					
Total N	0.153	0.562	-0.333				
Total P	-0.252	0.168	-0.175	0.145			
Total K	0.022	-0.143	-0.079	-0.087	-0.032		
Total Fe	0.074	-0.180	-0.058	-0.163	-0.177	0.056	
Total Cu	0.283	-0.216	0.316	-0.160	0.041	0.151	
Total Mn	0.290	0.173	0.070	0.142	0.091	-0.066	
Total Zn	0.307	-0.218	0.292	-0.275	-0.048	0.070	
% Clay	0.149	-0.039	0.234	-0.141	-0.351	-0.051	
350	-0.170	-0.010	-0.318	0.117	0.145	-0.126	-0.373
360	-0.016	-0.082	-0.174	0.106	0.118	-0.174	-0.255
370	0.075	-0.090	-0.136	0.140	0.069	-0.158	-0.222
380	0.157	-0.071	-0.096	0.165	0.021	-0.163	-0.161
390	0.193	-0.070	-0.082	0.180	-0.011	-0.160	-0.155
400	0.234	-0.068	-0.062	0.183	-0.047	-0.140	-0.121
410	0.255	-0.076	-0.046	0.175	-0.071	-0.138	-0.096
420	0.252	-0.075	-0.054	0.170	-0.086	-0.132	-0.099
430	0.250	-0.083	-0.068	0.164	-0.098	-0.119	-0.111
440	0.223	-0.095	-0.101	0.155	-0.107	-0.108	-0.134
450	0.200	-0.099	-0.119	0.151	-0.104	-0.106	-0.149
460	0.209	-0.094	-0.110	0.152	-0.091	-0.111	-0.158
470	0.210	-0.092	-0.100	0.151	-0.081	-0.117	-0.160
480	0.207	-0.091	-0.100	0.146	-0.074	-0.118	-0.164
490	0.194	-0.096	-0.108	0.138	-0.070	-0.110	-0.179
500	0.169	-0.098	-0.131	0.132	-0.057	-0.101	-0.210
510	0.016	0.012	-0.300	0.173	-0.044	-0.088	-0.393
520	-0.036	0.032	-0.331	0.171	-0.029	-0.074	-0.431
530	-0.041	0.019	-0.330	0.160	-0.019	-0.072	-0.439
540	-0.063	0.015	-0.339	0.148	0.007	-0.067	-0.455
550	-0.101	0.017	-0.356	0.138	0.040	-0.067	-0.478
560	-0.147	0.027	-0.376	0.131	0.076	-0.068	-0.500
570	-0.197	0.035	-0.391	0.122	0.112	-0.071	-0.517
580	-0.238	0.046	-0.403	0.116	0.144	-0.077	-0.525
590	-0.272	0.054	-0.411	0.111	0.167	-0.081	-0.527
600	-0.295	0.061	-0.414	0.108	0.184	-0.085	-0.527
610	-0.310	0.066	-0.415	0.107	0.196	-0.088	-0.526
620	-0.319	0.070	-0.416	0.105	0.203	-0.089	-0.526
630	-0.327	0.073	-0.415	0.105	0.208	-0.090	-0.525
640	-0.331	0.076	-0.414	0.105	0.210	-0.090	-0.524
650	-0.336	0.078	-0.414	0.105	0.212	-0.090	-0.522
660	-0.339	0.081	-0.414	0.106	0.215	-0.089	-0.521
670	-0.290	0.036	-0.359	0.078	0.167	-0.089	-0.474
680	-0.273	0.050	-0.327	0.080	0.169	-0.082	-0.487
690	-0.347	0.086	-0.412	0.106	0.217	-0.090	-0.518
700	-0.349	0.088	-0.411	0.107	0.218	-0.090	-0.517
710	-0.350	0.090	-0.411	0.108	0.218	-0.089	-0.517
720	-0.353	0.089	-0.409	0.105	0.215	-0.089	-0.514
730	-0.354	0.092	-0.410	0.108	0.217	-0.088	-0.514
740	-0.354	0.093	-0.409	0.109	0.216	-0.086	-0.514
750	-0.353	0.094	-0.409	0.110	0.214	-0.085	-0.515
760	-0.351	0.097	-0.410	0.112	0.211	-0.084	-0.515
770	-0.348	0.098	-0.409	0.114	0.207	-0.083	-0.516

Variable	pH	EC	OC	Total N	Total P	Total K	% Clay
780	-0.343	0.099	-0.409	0.117	0.201	-0.083	-0.516
790	-0.338	0.100	-0.408	0.119	0.196	-0.081	-0.518
800	-0.333	0.101	-0.408	0.123	0.191	-0.080	-0.517
810	-0.327	0.103	-0.407	0.126	0.186	-0.080	-0.517
820	-0.321	0.105	-0.407	0.130	0.179	-0.079	-0.515
830	-0.314	0.106	-0.405	0.134	0.173	-0.079	-0.514
840	-0.308	0.108	-0.404	0.137	0.168	-0.079	-0.512
850	-0.302	0.110	-0.402	0.140	0.162	-0.079	-0.509
860	-0.297	0.112	-0.401	0.143	0.158	-0.079	-0.506
870	-0.282	0.106	-0.395	0.143	0.141	-0.077	-0.497
880	-0.290	0.116	-0.398	0.149	0.151	-0.080	-0.500
890	-0.288	0.119	-0.398	0.152	0.148	-0.080	-0.496
900	-0.285	0.122	-0.397	0.154	0.146	-0.081	-0.494
910	-0.284	0.124	-0.396	0.155	0.144	-0.081	-0.491
920	-0.285	0.125	-0.396	0.156	0.143	-0.081	-0.488
930	-0.285	0.128	-0.395	0.157	0.142	-0.082	-0.485
940	-0.286	0.130	-0.395	0.158	0.141	-0.083	-0.482
950	-0.288	0.131	-0.394	0.158	0.141	-0.083	-0.480
960	-0.289	0.133	-0.393	0.158	0.141	-0.084	-0.477
970	-0.292	0.135	-0.392	0.158	0.140	-0.084	-0.475
980	-0.295	0.137	-0.393	0.158	0.142	-0.084	-0.473
990	-0.297	0.137	-0.391	0.156	0.141	-0.085	-0.471
1000	-0.300	0.139	-0.391	0.156	0.143	-0.085	-0.470
1010	-0.306	0.143	-0.392	0.158	0.144	-0.089	-0.470
1020	-0.309	0.147	-0.393	0.159	0.145	-0.088	-0.469
1030	-0.311	0.146	-0.392	0.157	0.144	-0.089	-0.468
1040	-0.314	0.146	-0.391	0.155	0.145	-0.088	-0.467
1050	-0.316	0.147	-0.390	0.153	0.145	-0.088	-0.466
1060	-0.319	0.148	-0.390	0.152	0.145	-0.087	-0.466
1070	-0.321	0.149	-0.390	0.150	0.146	-0.087	-0.466
1080	-0.324	0.150	-0.390	0.149	0.147	-0.086	-0.465
1090	-0.326	0.149	-0.390	0.146	0.147	-0.086	-0.466
1100	-0.325	0.155	-0.385	0.146	0.150	-0.081	-0.453
1110	-0.330	0.150	-0.390	0.142	0.149	-0.085	-0.465
1120	-0.332	0.149	-0.389	0.140	0.149	-0.084	-0.467
1130	-0.335	0.149	-0.390	0.138	0.150	-0.084	-0.467
1140	-0.336	0.148	-0.390	0.135	0.150	-0.083	-0.467
1150	-0.338	0.146	-0.389	0.132	0.150	-0.084	-0.468
1160	-0.340	0.146	-0.388	0.130	0.151	-0.083	-0.468
1170	-0.341	0.145	-0.388	0.128	0.149	-0.083	-0.468
1180	-0.342	0.144	-0.388	0.126	0.150	-0.083	-0.470
1190	-0.343	0.142	-0.387	0.122	0.149	-0.083	-0.471
1200	-0.344	0.141	-0.387	0.121	0.150	-0.082	-0.471
1210	-0.346	0.140	-0.386	0.119	0.149	-0.083	-0.472
1220	-0.345	0.138	-0.386	0.117	0.148	-0.082	-0.473
1230	-0.345	0.137	-0.386	0.115	0.147	-0.082	-0.473
1240	-0.345	0.136	-0.385	0.113	0.146	-0.082	-0.473
1250	-0.345	0.134	-0.384	0.111	0.144	-0.082	-0.474
1260	-0.344	0.133	-0.384	0.109	0.143	-0.082	-0.475
1270	-0.344	0.131	-0.383	0.107	0.142	-0.082	-0.474
1280	-0.344	0.130	-0.383	0.106	0.140	-0.082	-0.474
1290	-0.343	0.128	-0.382	0.104	0.138	-0.082	-0.475
1300	-0.341	0.126	-0.381	0.102	0.136	-0.082	-0.475
1310	-0.339	0.126	-0.380	0.102	0.133	-0.083	-0.474
1320	-0.338	0.124	-0.380	0.101	0.132	-0.082	-0.474
1330	-0.337	0.123	-0.379	0.099	0.130	-0.082	-0.474

Variable	pH	EC	OC	Total N	Total P	Total K	% Clay
1340	-0.335	0.121	-0.378	0.098	0.128	-0.082	-0.474
1350	-0.332	0.120	-0.377	0.098	0.126	-0.082	-0.474
1360	-0.328	0.121	-0.377	0.098	0.124	-0.081	-0.472
1370	-0.320	0.120	-0.376	0.100	0.118	-0.081	-0.470
1380	-0.299	0.124	-0.376	0.108	0.108	-0.079	-0.461
1390	-0.286	0.123	-0.369	0.110	0.098	-0.079	-0.448
1400	-0.288	0.108	-0.357	0.094	0.094	-0.081	-0.435
1410	-0.274	0.103	-0.351	0.090	0.088	-0.081	-0.418
1420	-0.290	0.098	-0.352	0.081	0.100	-0.084	-0.427
1430	-0.312	0.096	-0.358	0.074	0.113	-0.085	-0.443
1440	-0.319	0.100	-0.361	0.077	0.118	-0.084	-0.450
1450	-0.320	0.101	-0.363	0.078	0.117	-0.084	-0.452
1460	-0.321	0.099	-0.363	0.077	0.115	-0.084	-0.454
1470	-0.322	0.099	-0.363	0.077	0.115	-0.085	-0.457
1480	-0.322	0.099	-0.364	0.077	0.114	-0.084	-0.460
1490	-0.322	0.099	-0.365	0.077	0.112	-0.084	-0.463
1500	-0.323	0.098	-0.366	0.077	0.111	-0.084	-0.466
1510	-0.325	0.098	-0.364	0.077	0.108	-0.088	-0.465
1520	-0.325	0.097	-0.364	0.076	0.107	-0.087	-0.467
1530	-0.324	0.096	-0.365	0.075	0.105	-0.087	-0.468
1540	-0.324	0.096	-0.365	0.075	0.103	-0.086	-0.469
1550	-0.323	0.096	-0.365	0.074	0.099	-0.085	-0.470
1560	-0.323	0.097	-0.366	0.075	0.097	-0.084	-0.471
1570	-0.323	0.098	-0.366	0.076	0.094	-0.082	-0.472
1580	-0.323	0.097	-0.365	0.075	0.093	-0.083	-0.473
1590	-0.322	0.095	-0.365	0.074	0.093	-0.083	-0.474
1600	-0.321	0.094	-0.364	0.072	0.092	-0.084	-0.473
1610	-0.320	0.091	-0.362	0.070	0.091	-0.084	-0.473
1620	-0.320	0.091	-0.362	0.069	0.091	-0.084	-0.473
1630	-0.320	0.090	-0.361	0.068	0.090	-0.085	-0.473
1640	-0.319	0.088	-0.360	0.067	0.089	-0.085	-0.473
1650	-0.318	0.088	-0.360	0.067	0.089	-0.085	-0.474
1660	-0.318	0.087	-0.359	0.066	0.088	-0.085	-0.474
1670	-0.318	0.086	-0.359	0.066	0.088	-0.086	-0.474
1680	-0.317	0.084	-0.358	0.064	0.087	-0.086	-0.475
1690	-0.316	0.083	-0.358	0.063	0.087	-0.086	-0.474
1700	-0.316	0.082	-0.357	0.062	0.086	-0.086	-0.473
1710	-0.316	0.081	-0.356	0.062	0.086	-0.086	-0.473
1720	-0.315	0.080	-0.356	0.061	0.084	-0.086	-0.473
1730	-0.315	0.080	-0.356	0.060	0.084	-0.085	-0.472
1740	-0.313	0.079	-0.355	0.059	0.084	-0.085	-0.472
1750	-0.313	0.079	-0.354	0.059	0.082	-0.085	-0.470
1760	-0.312	0.078	-0.354	0.058	0.081	-0.085	-0.469
1770	-0.312	0.076	-0.353	0.056	0.080	-0.085	-0.468
1780	-0.310	0.076	-0.352	0.056	0.078	-0.085	-0.467
1790	-0.308	0.075	-0.351	0.056	0.077	-0.086	-0.467
1800	-0.308	0.075	-0.350	0.055	0.076	-0.086	-0.466
1810	-0.303	0.079	-0.357	0.059	0.085	-0.072	-0.473
1820	-0.308	0.077	-0.353	0.062	0.082	-0.089	-0.470
1830	-0.308	0.079	-0.353	0.063	0.083	-0.087	-0.469
1840	-0.307	0.077	-0.353	0.061	0.082	-0.086	-0.469
1850	-0.306	0.077	-0.352	0.060	0.082	-0.086	-0.468
1860	-0.304	0.076	-0.352	0.058	0.082	-0.084	-0.465
1870	-0.297	0.075	-0.352	0.055	0.083	-0.077	-0.461
1880	-0.282	0.072	-0.349	0.049	0.083	-0.066	-0.444
1890	-0.271	0.054	-0.340	0.030	0.089	-0.049	-0.429

Variable	pH	EC	OC	Total N	Total P	Total K	% Clay
1900	-0.260	0.043	-0.318	0.009	0.111	-0.028	-0.385
1910	-0.264	0.031	-0.301	0.003	0.117	-0.052	-0.358
1920	-0.278	0.041	-0.297	0.024	0.117	-0.097	-0.354
1930	-0.284	0.054	-0.306	0.039	0.117	-0.104	-0.364
1940	-0.286	0.062	-0.314	0.046	0.117	-0.099	-0.377
1950	-0.289	0.066	-0.319	0.050	0.117	-0.097	-0.385
1960	-0.290	0.067	-0.323	0.052	0.114	-0.096	-0.392
1970	-0.294	0.069	-0.326	0.054	0.109	-0.095	-0.399
1980	-0.295	0.070	-0.329	0.056	0.106	-0.095	-0.405
1990	-0.296	0.071	-0.332	0.057	0.102	-0.095	-0.411
2000	-0.297	0.073	-0.335	0.059	0.098	-0.096	-0.418
2010	-0.296	0.075	-0.339	0.061	0.094	-0.094	-0.424
2020	-0.297	0.077	-0.341	0.063	0.091	-0.092	-0.430
2030	-0.300	0.082	-0.349	0.067	0.090	-0.089	-0.429
2040	-0.296	0.082	-0.349	0.068	0.083	-0.086	-0.438
2050	-0.296	0.086	-0.352	0.072	0.077	-0.082	-0.443
2060	-0.295	0.093	-0.356	0.078	0.070	-0.077	-0.446
2070	-0.293	0.096	-0.357	0.081	0.064	-0.074	-0.446
2080	-0.290	0.095	-0.357	0.080	0.062	-0.073	-0.446
2090	-0.289	0.092	-0.356	0.079	0.060	-0.074	-0.446
2100	-0.286	0.091	-0.355	0.079	0.058	-0.074	-0.445
2110	-0.281	0.091	-0.356	0.080	0.056	-0.073	-0.445
2120	-0.279	0.090	-0.354	0.081	0.054	-0.073	-0.444
2130	-0.275	0.092	-0.355	0.084	0.053	-0.072	-0.442
2140	-0.265	0.094	-0.356	0.088	0.050	-0.068	-0.441
2150	-0.243	0.104	-0.358	0.100	0.043	-0.062	-0.430
2160	-0.218	0.108	-0.354	0.111	0.033	-0.054	-0.419
2170	-0.202	0.106	-0.347	0.116	0.025	-0.053	-0.408
2180	-0.190	0.102	-0.342	0.115	0.019	-0.052	-0.398
2190	-0.180	0.099	-0.337	0.109	0.011	-0.051	-0.383
2200	-0.161	0.102	-0.333	0.114	0.002	-0.047	-0.365
2210	-0.157	0.108	-0.324	0.126	-0.001	-0.065	-0.351
2220	-0.210	0.080	-0.332	0.082	0.020	-0.075	-0.386
2230	-0.233	0.071	-0.333	0.069	0.031	-0.078	-0.399
2240	-0.240	0.072	-0.334	0.068	0.038	-0.077	-0.402
2250	-0.245	0.072	-0.336	0.068	0.041	-0.074	-0.406
2260	-0.245	0.077	-0.340	0.075	0.046	-0.073	-0.410
2270	-0.244	0.080	-0.340	0.079	0.047	-0.072	-0.410
2280	-0.240	0.083	-0.340	0.083	0.049	-0.070	-0.408
2290	-0.237	0.084	-0.339	0.084	0.051	-0.067	-0.405
2300	-0.230	0.087	-0.339	0.089	0.048	-0.067	-0.400
2310	-0.222	0.087	-0.337	0.090	0.038	-0.065	-0.384
2320	-0.220	0.090	-0.336	0.090	0.034	-0.065	-0.373
2330	-0.216	0.085	-0.332	0.083	0.023	-0.063	-0.358
2340	-0.218	0.087	-0.332	0.081	0.024	-0.064	-0.351
2350	-0.210	0.088	-0.329	0.085	0.020	-0.064	-0.344
2360	-0.208	0.089	-0.328	0.089	0.025	-0.064	-0.351
2370	-0.204	0.083	-0.324	0.087	0.026	-0.066	-0.355
2380	-0.195	0.088	-0.324	0.097	0.031	-0.068	-0.352
2390	-0.196	0.085	-0.317	0.098	0.039	-0.069	-0.339
2400	-0.210	0.084	-0.301	0.094	0.033	-0.061	-0.341
2410	-0.204	0.077	-0.319	0.081	0.041	-0.073	-0.350
2420	-0.201	0.075	-0.315	0.079	0.037	-0.070	-0.334
2430	-0.193	0.070	-0.311	0.077	0.037	-0.074	-0.332
2440	-0.194	0.073	-0.308	0.077	0.041	-0.072	-0.320
2450	-0.195	0.077	-0.308	0.079	0.046	-0.070	-0.318

Variable	pH	EC	OC	Total N	Total P	Total K	% Clay
2460	-0.191	0.070	-0.304	0.078	0.042	-0.075	-0.310
2470	-0.193	0.070	-0.311	0.073	0.057	-0.075	-0.310
2480	-0.179	0.071	-0.306	0.080	0.049	-0.066	-0.309
2490	-0.178	0.075	-0.305	0.083	0.054	-0.066	-0.303
2500	-0.185	0.054	-0.295	0.064	0.054	-0.064	-0.310

4. CONCLUSION

The spectral reflectance curves were generated using ASD Field Spec 4 standard res. (FS4). Hyperspectral data covering range of wavelengths between 350 and 2500 nm (2150 bands) under lab condition. Pearson correaltion studies were carried out with sampled relctance valyes at 10 nm interval for entire wavelength range. The soil properties like Ph, OC, total N, total K, total Mn, total Zn, % Clay showed significant negative correlation at 1210-1280 nm for Ph, 610-630 nm for OC, 390-410 nm for total N, 360-390 nm for total K .Positive significant correlation was seen in case of EC and and in case of total Fe correlation was non significant with spectral reflectance data. For EC significant spectral bands were 1110-1130.These sensitive bands for soil parameters can be further used for prediction of soil properties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ben-Dor E, Banin A. Near-Infrared Analysis as a Rapid Method to Simultaneously Evaluate Several Soil Properties. Soil Science Socirety. American. Journey. 1995a;59:364- 372.
2. Swain PH, Davis SM. Remote Sensing: The Quantitative Approach, McGraw-Hill, New York. 1978;396.
3. Latz K, Weismiller RA, Van Scoyoc GE, Baumgardner MF. Characteristic variations in spectral reflectance of selected eroded Alfisols. Soil Science Soc. Amer J. 1984;48:1130-1134.
4. Henderson TL, Henderson A, Szilagyi MF, Baumgardner CCT, Chen, Landgrebe DA. Spectral band selection for classification of soil organic matter content. Soil Sci. Soc. Am. J. 1989;53:1778-1784.
5. Chen F, Kissel DE, West LT, Adkins W. Field scale mapping of surface organic carbon using remotely sensed imagery, Soil Sci. Soc. Am. J. 2000;64(2):746–753.
6. Ingleby HR, Crowe TG. Reflectance models for predicting organic carbon in Saskatchewan soils. Can. Agri. Eng. 2000; 42(2):57-63.
7. Thomasson JA, Sui R, Cox MS, Al-Rajehy A. Soil Reflectance Sensing for Determining Soil Properties in Precision Agriculture. Trans. ASAE. 2001;44(6): 1445-1453.
8. Martin PD, Malley DF, Manning G, Fuller L. Determination of soil organic carbon and nitrogen at the field level using near-infrared spectroscopy. Canandian Journal of Soil Science. 2002;82:413-422.
9. Brown DJ, Bricklemyer RS, Miller PR. Validation requirements for diffuse reflectance soil characterization models with a case study of VNIR soil C prediction in Montana. Geoderma. 2005;129: 251–267.
10. Stoner FR. Physicochemical, Site, and Bidirectional Reflectance Factor Characteristics of Uniformly Moist Soils. Ph.D. dissertation, Purdue Univ., West Lafayette, Indiana; 1979.
11. Margate DE, Shrestha DP. The use of hyperspectral data in identifying desert-like soil surface features in Tabernas Area, Southeast Spain, The 22nd Asian Conference on Remote Sensing 5-9 November 2001, Singapore, CRISP, SISV, AARS. 2001;736-741.
12. Baumgardner MF, Silva LF, Biehl LF, LL, Stoner ER. Reflectance properties of soils. Adv. Agron. 1985;38:l-44.
13. Jackson ML. Soil Chemical Analysis. Prentice Hall of India. New Delhi. 1973;498.
14. Kjeldahl J. A new method for the estimation of nitrogen in organic compounds, Z. Analatical. Chemistry. 1883; 22:366.
15. Beck RH, Robinson BF, McFee WH, Peterson JB. Spectral Characteristics of Soils Related to the Interaction of Soil Moisture, Organic Carbon and Clay Content; LARS Information Note 081176; Laboratory Application of Remote Sensing, Purdue University: West Lafayette, IN, USA; 1976.

16. Mathews HL, Cunningham RL, Peterson GW. Spectral reflectance of selected Pennsylvania soils. Soil Science Society America Journey. 1973;37:421–424.
17. Vibhute AD, Kale KV, Gaikwad SV, Dhumal RK. Estimation of soil nitrogen in agricultural regions by VNIR reflectance spectroscopy. SN Applied Science. 2020; 2:1523.
18. Gerberman AH, Neher DD. Reflectance of varying mixtures of a clay soil and sand. Photogrmm. Eng. Remote Sensing. 1979; 45:1145-1151.
19. Al-Mahawili SMH. Satellite image interpretation and laboratory spectral reflectance measurement of saline and gypsiferous soils of west Baghdad, Iraq. M.Sc. thesis, Purdue University; 1983.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/90275