Spectral Reflectance Study for Assessing Soil Properties of Spatially Associated Red and Black Soils of Saptdhara Watershed, Nagpur, India

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Abstract

Soil reflectance behavior can be used to understand soil quality and further soil mapping. An attempt has been made in the Nagpur district, India to measure the spectral reflectance of spatially associated red and black soils using ISCO (Model S.R.) Spectroradiometer for assessing soil quality. Spectral reflectance from red and black soils increases with increase in wavelength and red soils reflects more compared to black. Soil color (hue), Fe_20_3, sand and clay have significant correlation with spectral reflectance while organic carbon, value and chroma have non-significant correlation. Highest negative correlation of hue on soil reflectance was observed at 900 and 1200 nm wavelength. The clay has negative correlation while sand has positive and the significant effect of both has been observed at 900 and 1200 nm wavelength. Fe_20_3 have significant positive correlation between 625 to 900 and 1050 to 1200 nm wavelength regions. The above wavelength bands can be the indicators for differentiating kinds of soil based on their properties.

1. Introduction

The effective utilisation of remotely sensed data requires thorough knowledge and understanding of spectral characteristics of various earth surface features and the factors that influence these spectral characteristics. The major problem in deriving soil information from remotely sensed data is the complex nature of relationship between soil parameters and reflectance. Soil color, particle size, organic matter, iron content and soil moisture influence the spectral reflectance behaviour of the soils (Baumgardner et al., 1970, Bowers and Hanks, 1965, Hoffer and Johannsen, 1969, Mathews et al., 1973 and Montgomery, 1976). The major soil components are inorganic solids consisting primarily of crystalline minerals and non-crystalline substances, organic matter, air and water or a solution containing a variety of dissolved compounds (Irons et al., 1989). The effect of soil constituents on soil reflectance can also be quantitatively measured by laboratory or field spectroradiometer. A detailed study of reflected radiation and reflectance, the geometry of the beam of incident flux, and composition and physical properties have shown strong relationship and these parameters must be considered while undertaking studies. Concepts of spectral reflectance libraries are gaining momentum (Shepherd and Walsh, 2002) and further have been used for characterization of soil properties. In the present paper, an attempt has been made to characterize the salient properties of spatially associated red and black soils *vis a vis* to measure its spectral reflectance for assessing soil quality for their mapping.

2. Study Area

The study area Saptdhara watershed is located between 21°10' to 21°20' N latitude and 78°40' to 79°0' E longitude partially covering the SOI Toposheets 55 K/12, 55K/15, and 55K/16 which is situated in the Northern part of Nagpur district, Central India with an area of about 23627.1 ha (Figure 1). The climate of the study area is mainly sub tropical dry and sub humid type with mean annual precipitation of about 1127 mm of which nearly 90 per cent is received during southwest monsoon period (June to October). The mean annual air temperature is 27°C and May is the hottest month with an average maximum temperature of about 42.7 °C. The month of January is coldest with an average minimum temperature of about 12.3°C. The soil moisture regime of Sapthdara watershed is Ustic where as temperature regime is Hyperthermic. The geological formations in the study area consist of extrusive igneous formation, "the Deccan Trap", and the sedimentary formation, "the Kamthi Sandstone". Physiographically, the area is having

ISSN 1686-6576 / © Geoinformatics International

hills and ridges, uplands and valley areas. The sedimentary formations are represented by red soils whereas black soils are formed from basalt, both at similar topographical conditions. The dominant cultivated field crops in the study area are Cotton (*Gossypium species*), Jowar (*Sorghum bicolour*), Pigeonpea (*Cajanus cajan*), Wheat (*Triticum aestivum*), Gram (*Cicer arientinum)* and Soybean (*Glycin max*) both under irrigated and rainfed conditions. The fruit crops like Mandarin (*Citrus reticulata*), Sweet orange (*Citrus sinensis*) and kagzi lime (*Citrus aurantifolia*) are growing under irrigated conditions. The dominant natural vegetation of the area comprises of dry deciduous tree species of Palas (*Butea monosparma*), Teak (*Tectona grandis*), Tendu (*Diospyrous tomatoso)*, Ber (*Ziziphus jujube*) and Anjan (*Terminalia arjuna*).

3. Methodology

3.1 Soil Study

The soils occurring on different physiographic units having wide variation in their morphological, physical and chemical properties were studied in the field representing the soil order Entisol, Inceptisols and Vertisols of Soil Taxonomy (Soil Survey Staff, 1998). The locations of 14 representative sites are given in the figure 1. The detail profile study was carried out at these representative sites in the field for their morphological and site characteristics. Horizon wise soil samples were collected from these representative sites, air dried, grinded and passed through 2 mm sieve for further laboratory analysis. The physical and chemical properties of soils were determined using standard procedure.

3.2 Soil Reflectance Measurement

The surface samples of representative soils having less than 2 mm size from red and black soils were used for spectral reflectance study and further correlation with soil properties. These samples were kept in iron rings for measurement of the spectral reflectance behavior. The iron rings were black coated to avoid the reflection of light from metal. The measurements were taken outdoors on cloud less days using ISCO (Model S.R.) spectroradiometer operating in visible (450-725 nm) with 25 nm spectral band width and infrared wavelengths (750-1350 nm) with 50 nm interval in bright and clear sunlight during 9.30 to 10.30 A.M. The average of three spectra was recorded for each sample to minimize the error. Before reading each sample reflectance of Barium Sulphate plate was recorded as calibration standard to account for possible changes in the intensity of solar radiation. The simple radiance of soils was converted to Bidirectional Reflectance Factor (B.R.F. %) dividing by the radiance acquired over the Barium Sulphate panel (Franklin et al., 1993). Curves for Bidirectional Reflectance Factors were drawn against the spectral data with respect to different soil properties to represent the effect of soil properties on spectral reflectance of soils.

4. Results and Discussion

4.1 Soil Characterization

The color of soil varies from 2.5YR 3/3 (Dark reddish brown) to 10YR 3/4 (Dark yellowish brown) (Table 1). The total clay content varies from 19.1 to 72.3 percent where as sand varies from 5.9 to 68.8 percent. The available water content at 33 kPa of sols varies from16.3 to 49.3 kPa. The Fe_2O_3 content of soils vary from 2.1 percent in P7 to 9.4 percent in P3 and the organic carbon content varies from 0.20 to 0.58 percent. Soils developed on hills/ridges and pediments are shallow, well drained, reddish brown and fine to fine-loamy in texture.

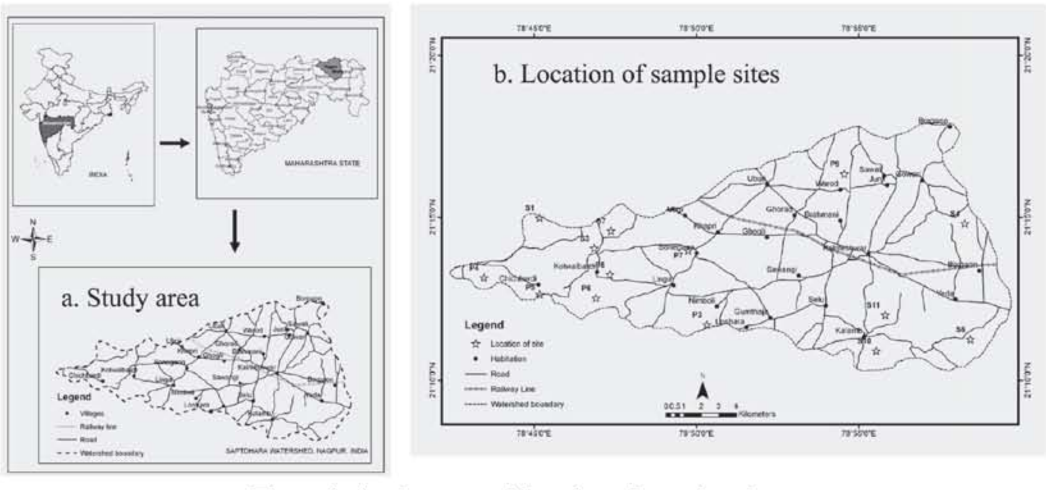

Figure 1: Study area and location of samples sites

Table 1: Dominant soil characteristics

Soils	Colour (m)	Water Retention		Particle Size Distribution			Fe_2O_3 (%)	Organic Carbon (%)	pH (1:2 Soil: Water)
		33 kPa	1500 kPa	Sand (%)	Silt (%)	Clay (%)			
P3	2.5YR4/4	20.1	10.7	48.1	15.3	36.6	9.4	0.41	6.3
P4	5YR 3/2	22.5	11.3	65.3	13.5	21.2	2.7	0.51	6.8
P5	2.5YR3/4	16.3	9.9	48.2	20.7	31.1	4.7	0.2	6.6
P6	5YR 4/4	18.2	7.7	65.9	11.2	22.9	5.8	0.36	6.2
P7	10YR 4/3	41.3	19.7	37.1	20	42.9	2.1	0.48	7.8
P8	10YR 3/3	42.2	20.3	37.9	19.9	42.2	2.1	0.48	7.8
P9	10YR 3/2	49.3	22.9	5.9	21.8	72.3	3.57	0.52	7.7
S1	2.5YR3/3	19.2	10.7	46.1	19.9	34.0	6.8	0.30	6.6
S3	10R3/3.5	22.2	15.0	49.0	18.4	32.6	5.7	0.40	6.8
S4	2.5YR3/4	21.3	12.8	50.9	20.1	29.0	5.0	0.40	6.3
S6	5YR 4/4	17.7	10.0	68.8	12.1	19.1	6.4	0.48	6.9
S7	7.5YR5/4	25.0	12.1	48.9	20.5	30.6	7.2	0.44	6.4
S10	10YR 3/3	36.7	19.0	15.9	28.4	55.7	3.01	0.39	7.9
S11	10YR 3/3	35.0	16.8	14.8	27.9	57.3	2.23	0.58	8.0

These soils are slightly acidic to neutral, mixed in mineralogy and qualify *Typic Haplustepts* subgroup. Red soils on uplands have deep, well drained, fine-loamy texture, mixed mineralogy and qualify for *Typic Haplustepts* subgroup while the black soils are moderately shallow, moderately well drained, fine-textured and have smectitic mineralogy and qualify for Vertic Haplustepts. Soils developed in the valleys are moderately shallow to deep, moderately well drained, calcareous brown to dark brown in color and have fine to very fine texture, smectitic mineralogy and qualify for *Vertic Haplustepts* and *Typic Haplusterts* subgroups.

4.2 Soil reflectance

To compare and understand the reflectance behaviour of both red and black soils, mean of the reflectance values in each wavelength band was calculated. The bidirectional reflectance has been plotted and the same has been depicted in Figure 2. Spectral reflectance from all the red and black soils increases with the increase in wavelength from visible to infrared region except at 1200 nm, where the reflectance decreased in all soils due to weaker water absorption band. Similar observations have been made by Lindberg and Snyder (1972). Reflectance curves for soils developed from sedimentary and basaltic parent material exhibited contrast in characteristics shapes and was separated at all the wavelengths from 450 to 1350 nm. The spectral reflectance from soils developed on sedimentary parent material was higher as compared to soils developed on basaltic patent material. Soil parent material seemed to affect the overall spectral reflectance of soils. The soils developed on sedimentary parent material are red in color and having lighter hues which might have reflected more the incoming radiation. In the contrary soils developed on basaltic parent material are dark in color might have absorbed more radiation as compared to earlier this may be due to more retained moisture. In order to understand the relationship between soil properties and reflectance of soil the correlation between soil properties and spectral reflectance at different wavelengths have been shown in figure 2. The values of correlation coefficient (r) indicate that soil color (Hue), iron oxides and soil texture (sand and clay) have significant correlation with spectral reflectance at specific wavelength while organic carbon showed non-significant correlation throughout the spectrum. Since, the organic carbon content in all soils is low; it appears that effect of organic carbon has been masked by soil color. The soil color, iron oxides and soil texture showed significant correlation with soil reflectance has been investigated separately.

4.2.1 Soil color

Soil color is one of the important morphological characteristics of soil which indicates the fertility status and drainage condition of the soils. Soil color parameters such as hue, intensity and saturation, which are comparable with Munsell color parameters (hue, value and chroma) can be observed in the field, that can be quantified and relate to soil spectral reflectance in the visible domain.

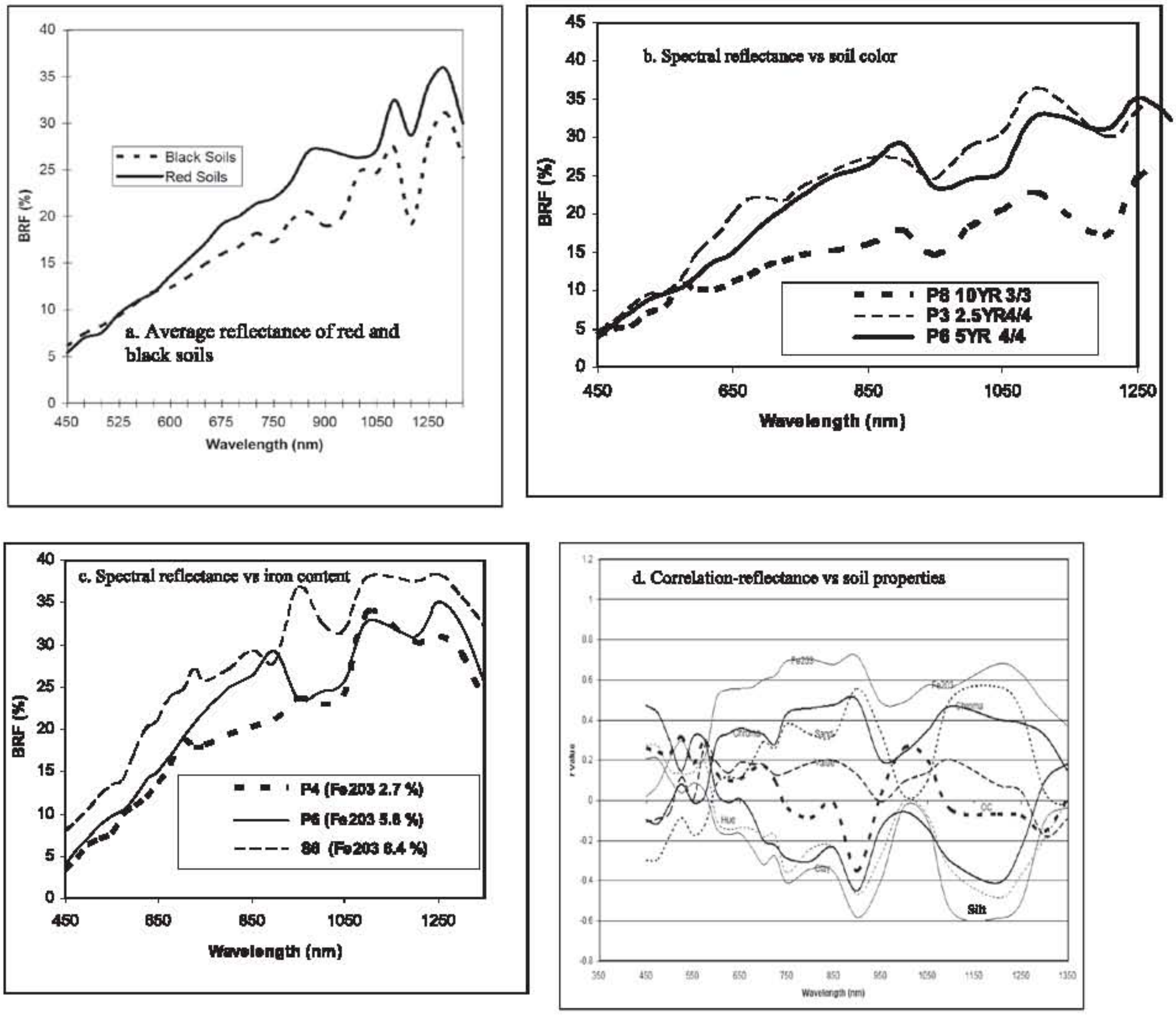

Figure 2: Relationship of sepectal reflectance and soil properties

The spectral curves drawn for 2.5 YR 4/4, 5 YR 4/4 and 10 YR 3/3 colors indicate that soils having reddish brown color (2.5 YR 4/4) showed highest reflectance followed by soil having yellowish red (5 YR 4/4) and then by dark brown (10 YR 3/3) (Figure 2). This indicates that as hue is increasing from 2.5 YR to 10 YR the soils becoming dark in color due to absorbed moisture and absorbs more radiation. Further it is evident from figure 2 where hue has negative correlation with soil reflectance while value and chroma have positive correlation. The highest negative significant correlation of hue on soil reflectance was observed at 900 and 1200 nm wavelength while the effect of value and chroma were nonsignificant throughout the spectrum. Negative correlation of Hue with soil reflectance indicates that as the hue changes from reddish brown (2.5 YR) to brown (10 YR), soil reflectance decreases. On the contrary, increase in value and chroma shows increase in spectral reflectance.

It is observed that soils become lighter in color with increase in value and chroma and thus they reflect more of the incoming radiation while the darker ones absorb more radiation (Subrahmanyam et al., 1996).

4.2.2 Iron oxides

The spectral curves for three kinds of soils (P4, P6 and S6) with varying amount of Fe_20_3 content have been depicted in figure 2. It is evident from the figure that soils with high Fe_20_3 content showed higher reflectance at almost all the wavelength as compared to soils with low Fe_20_3 content. The values of correlation coefficient indicate that Fe_20_3 has significant positive correlation with spectral reflectance between 625 to 900 nm, and 1050 to 1200 nm wavelength regions. It indicates that iron oxides influence the intensity of energy reflected by soil in this region and these wavelength regions can be a better indicator for differentiating soils based on iron content. These wavelength bands can be used for mapping the soil and assessment of soil quality based on their iron content.

4.2.3 Soil texture

Soil structure in conjunction with texture and composition are the primary soil properties controlling soil water movement, heat transfer, porosity, aeration, bulk density and reflectance. Soil texture is the proportion of sand, silt and clay in soil. Here the variation in the silt content in all the soils is almost less. So the effect of silt on spectral reflectance of soils was almost same for all the soils under study. The correlation of clay content and spectral reflectance indicate that clay has, in general, negative correlation with soil reflectance while sand has positive correlation. The significant effect of clay and sand on soil reflectance has been observed at 900 and 1200 nm wavelength. The content of sand and clay are the mirror for each other and play important role in mapping and management of soil resource. The above wavelength bands can be helpful for identification and mapping of soils based on their sand, silt and clay content.

5. Conclusions

Spectral reflectance of the red and black soils developed on sedimentary and basaltic parent material respectively is influenced by soil properties. Soil parent material seemed to affect the overall spectral reflectance of soils. The spectral reflectance curves are helpful in understanding the spectral sepratability and mixing of various red and black soil types and can be delineated on the basis of spectral signature. Soil color, iron oxides and texture having significant influence on soil reflectance and hence these parameters can be useful for soil mapping and assessment of soil quality.

Acknowledgement

Authers are indebted to Dr. D. K. Pal, Principal Scientist and Head, SRS, Sh. K. S. Verma, Principal Scientist, RSA, Dr. Rajeev Srivastava, Principal Scientist, RSA and Sh. A K. Barthwal, Technical Officer, NBSS&LUP, Nagpur for providing necessary guidance and facilities for carrying out the work.

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