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Spectral reflectance properties of some dominant soils occurring on different altitudinal zones in Uttaranchal Himalayas

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Abstract : The paper discusses the physical and chemical characteristics of some dominant soils of the Uttaranchal State *vis-à-vis* their spectral reflectance characteristics. The soil textures vary from loamy sand to silty clay loam. The soil colour varies from very dark greyish brown (10 YR) to olive yellow in 2.5 Y hue and reddish yellow (7.5YR). Soil pH varies from 5.2 to 6.5 and organic carbon from 9.2 to 83.2 g kg^{-1} soil. Soil reflectance varies with the variation in soil physical and chemical characteristics. Statistical correlation between soil reflectance and soil properties indicate that soil spectral reflectance decreases with increase in soil organic carbon and soil moisture contents.

Additional key words: Soil characteristics, spectral library, soil albedo, hill and mountain soils

Introduction

The information on soil spectral reflectance properties in narrow wavelength bands is necessary to derive information related to soil properties/ qualities from hyperspectral satellite images. The shapes of soil spectra respond to mineral composition, organic matter, water (hydration, hygroscopic and its free pore water), iron form and its amount, salinity and particle-size distribution (Mathews *et al.* 1973; Baumgardner *et al.* 1985; Ben-Dor 2002; Shepherd and Walsh 2002). These attributes of soil, basically determine their capacity to perform production and environmental functions. Condit (1972) measured spectral reflectance of 160 soil samples and classified all spectra into three general types with respect to their curve shape. The present paper highlights the salient morphological, physical and chemical characteristics of the soils of the Uttaranchal State and their spectral behaviour in spectral range of 350 to 1800 nm for developing spectral reflectance library.

Materials and methods

Study area: The Uttaranchal state lies between 29° to 31°27'N latitude and 77°40' to 81°E longitude and is bounded by Nepal in the east, China in the north, Himachal Pradesh in the west and Uttar Pradesh in the south. Ninety per cent area of the state is hilly and the altitude ranges from 200 to 7800 m above msl. Physiographically, the area is divided into 4 divisions, *viz.* i) Indo-Gangetic plain including Tarai in the south ii) Siwaliks/Outer Himalayas iii) Lesser Himalayas and iv) Greater Himalayas. Vast variation in altitude has direct bearing on climatic conditions including rainfall, temperature regime and snowfall. The soil moisture regimes are *Ustic, Udic and Cryic*. The soil temperature regime ranges from *Hyperthermic* in Lesser Himalayas to *Thermic/Mesic* in Greater Himalayas. High reaches are covered with snow and have *Frigid* soil temperature regime.

Methodology

Forty soil pedons occurring on different altitudinal zones in the Uttaranchal Himalayas representing Entisols, Inceptisols, Mollisols and Alfisols orders were studied (Soil Survey Division Staff 1995) and surface soil samples were collected. Soil samples were air-dried and passed through 2 mm sieve. Soils were analyzed for their physical and chemical characteristics following standard procedures. Physical and chemical properties of 10 selected sites (surface horizon) representing three altitudinal zones have been given in table 1.

Soil reflectance measurement

Soil diffuse reflectance spectra were recorded for each soil (2-mm air-dried soil sample) using a FieldSpecPro NIR-I Spectroradiometer (Analytical Spectral Devices Inc., Boulder, Colorado) at a wavelength from 0.35 to 1.8 μm with a spectral sampling interval of 1 nm. Measurements were taken outdoors on cloudless days. The average of ten spectra (the manufacturer's default value) was recorded for each sample to minimize instrument noise. Before taking the readings of each sample, ten white reference spectra were recorded using calibrated spectralon (Labsphere, Sutton, NH) placed at the same distance from the foreoptic as the soil sample.

Results and discussion

Soil characterization

The salient morphological, physical and chemical characteristics of soils have been given in table 1. The colour of the dry soil varies from very dark greyish brown (10YR3/2) at Shelang to light yellowish brown (2.5Y6/4) at Pithoragarh. The soils are moderately well to well-drained. The soil textures vary from sandy loam to silt loam. The clay content ranges between 5.8 and 23.5 per cent whereas the silt varies between 20.0 and 68.9 per cent. The soils

Table 1. Salient characteristics of soils

Site	Colour (Dry)	Elevation	Soil Tex	Particle-size distribution (%) Sand (2.0-0.05 mm)	Silt (0.05-0.002 mm)	Clay (<0.002 mm)	pH (1:2.5)	Org carbon g kg^{-1}	CEC cmol (p+) kg^{-1}
Karan Prayag	Greyish brown	832	l	51.2	39.1	9.7	5.7	20.7	7.3
Baijnath	Brown	1144	sl	72.5	21.7	5.8	5.7	10.4	3.8
Mahergaon	Light yellowish brown	1485	l	34.4	44.5	21.1	5.8	30.0	13.2
Pithoragarh	Olive yellow	1498	sil	7.6	68.9	23.5	5.9	14.7	9.3
Pandukeshwar	Dark greyish brown	1958	sl	63.3	24.0	12.7	6.5	57.6	22.5
Chaukori	Brown	1980	l	39.6	37.2	23.3	5.4	39.8	12.7
Auli	Light olive brown	2684	sl	66.9	21.5	11.6	6.0	40.6	15.3
Malari	Reddish yellow	3185	sl	56.6	32.0	11.4	6.3	9.2	9.4
Badrinath	Brown	3105	sl	70.8	20.0	9.2	6.1	36.9	14.0
Shelang	Very dark greyish brown	2684	l	36.9	39.6	23.6	5.2	83.2	n.d.

are strongly acid to slightly acid (pH 5.2 to 6.5). The soils have low CEC but are rich in organic carbon.

Soil characteristics vis-à-vis *soil reflectance*

The soil reflectance spectra are grouped altitude-wise, *viz.* low altitude (<1500 m), mid altitude (1500-2500 m) and high altitude (>2500 m) and has been discussed with respect to their shape and absorption bands wherever noticed. The spectral reflectance data between 1350-1450 nm have been removed as it gives noise due to presence of atmospheric water.

Soils of low altitudes

Karan Prayag site: Soils are moderately deep, greyish brown (2.5Y5/2 D) and dark greyish brown (2.5Y4/2 M), well drained, sandy loam in texture, moderately acid (pH 5.7) and occur on hill slopes. These soils are grouped under Coarse-loamy, mixed, hyperthermic family of Typic Ustorthents.

The reflectance of Karan Prayag soils (Fig. 1) increased from 5 per cent at 350 nm to 18 per cent at 600 nm, 32 per cent at 900 nm and almost 42 per cent at 1200 nm. The maximum reflectance (52%) was noticed around 1700 nm. The shape of the spectral curve is linear between 350 to 900 nm and slightly convex between 900-1200 and 1500-1800 nm. The soils have four

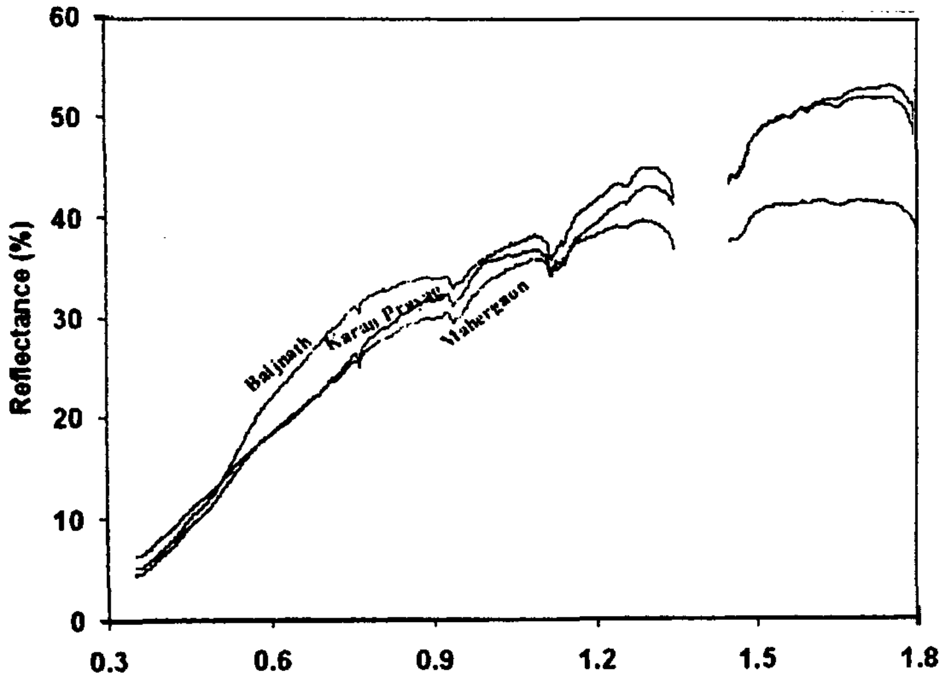

Fig. 1 Spectral curves of low altitude soils

conspicuous absorption bands located at 750 nm, 950 nm, 1100 nm and 1300 nm.

Baijnath site: Soils are deep to very deep, brown (10YR 5/3 D&M), sandy loam in texture, moderately well drained, moderately acid (pH 5.7) and occur on cultivated broad river terraces. These soils are classified as Coarse-loamy, mixed, hyperthermic family of Typic Haplustepts.

The reflectance of Baijnath soil (Fig 1) increased from 5 per cent at 350 nm to 22 per cent at 600 nm, 34 per cent at 900 nm and 38 per cent at 1200 nm. Maximum spectral reflectance was recorded at 1700 nm where it reached to almost 41 per cent. The shape of the curve is slightly concave between 350-600 nm and convex between 600 and 900 nm and almost flat between 900-1800 nm with conspicuous absorption bands at 950 and 1100 nm.

Mahergaon site: Soils are deep, light yellowish brown (2.5Y6/4 D) and very dark greyish brown (10YR4/3 M), loam in texture, well drained, moderately acid (pH 5.8) and occur on cultivated hill terraces. These soils are classified as Fine-loamy, mixed, hyperthermic family of Typic Haplustepts.

The reflectance of Mahergaon soil (Fig. 1) increased from about 4 per cent at 350 nm to 18 per cent at 600 nm, 30 per cent at 900 nm and about 40 per cent at 1200 nm. Maximum spectral reflectance was recorded at 1700 nm where it reached to almost 54 per cent. The shape of the curve was linear between 350 to 1200 nm and convex between 1500 to 1800 nm with conspicuous absorption at 950 and 1100 nm.

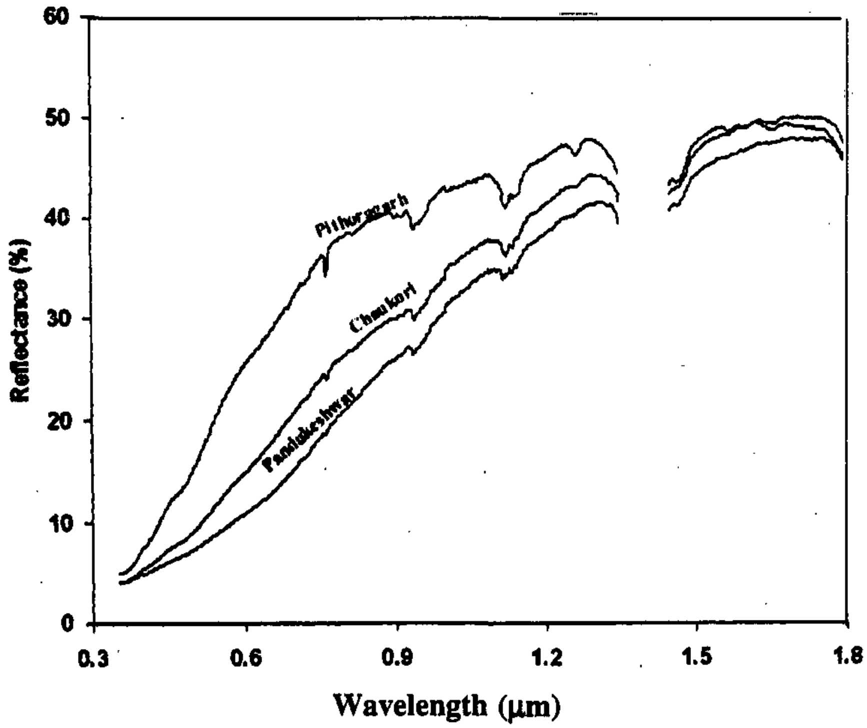

Fig. 2. Spectral curves of mid altitude soils

Soils of mid-altitudes

Pithoragarh site: Soils are deep to very deep, olive yellow (2.5Y6/6 D), silt loam in texture, moderately well drained, moderately acid (pH 5.9) and occur on broad terraces of the Pithoragarh valley. These soils are grouped under Fine-silty, mixed, thermic family of Ultic Hapludalfs.

The reflectance of Pithoragarh soil (Fig. 2) increased from 5 per cent at 350 nm to 25 per cent at 600 nm, 40 per cent at 900 nm and 45 per cent at 1200 nm. The maximum reflectance was recorded at 1650 nm where it reached to almost 49 per cent. The shape of the curve is slightly concave between 350 to 600 nm and slightly convex from 600 to 1200 and almost flat between 1500 to 1800 nm. The prominent absorption bands are noticed at 750, 900, 1100 and 1275 nm.

Pandukeshwar site: Soils are deep, dark greyish brown (10YR4/2 D) and very dark greyish brown (10YR3/2 M) sandy loam in texture, slightly acid (pH 6.5) and occur on hill terraces under potato cultivation. These soils are grouped under Coarse-loamy, mixed, thermic family of Typic Hapludolls.

The reflectance of Pandukeshwar soil (Fig. 2) increased from 4 per cent at 350 nm to 11 per cent at 600 nm, 26 per cent at 900 nm and 38 per cent at 1200 nm. The maximum reflectance was recorded at 1700 nm where it reached to almost 48 per cent. The shape of the curve is concave between 350 to 900 nm and linear between 900 and 1200 nm and slightly convex between 1500 and 1800 nm. The reflectance curve of the

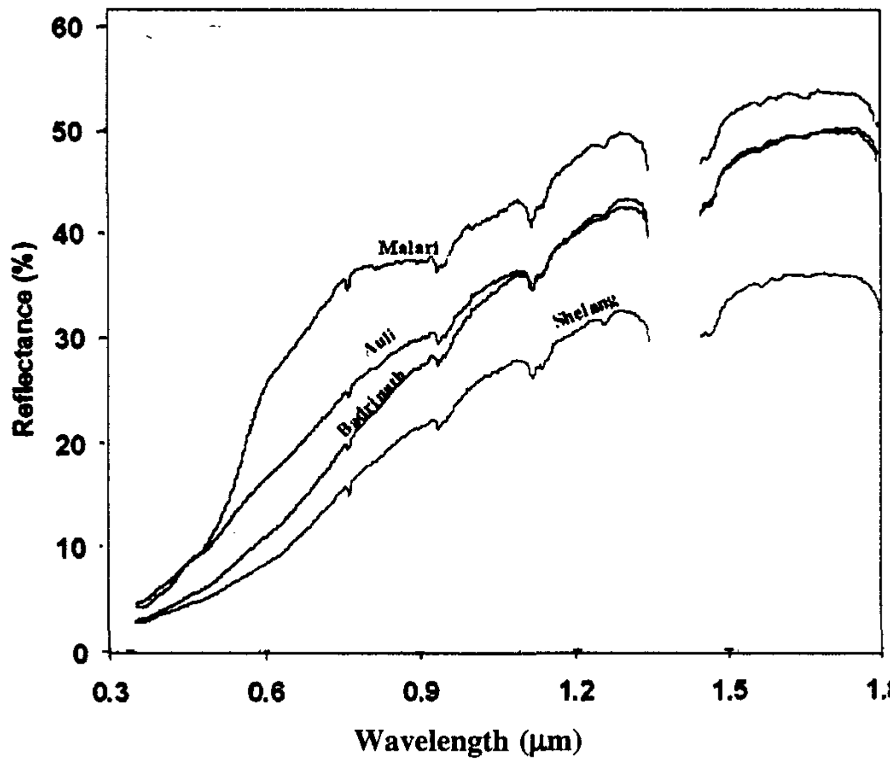

Fig. 3. Spectral curves of high altitude soils

soils showed two absorption bands located at 950 and 1100 nm.

Chaukori site: Soils are deep to very deep, brown (10YR4/3 D) and dark brown (10YR3/3 M) loam in texture, well drained, strongly acid (pH 5.4) and occur on break of hill slopes under *Banj* forest. These soils are classified as Fine-loamy, mixed, thermic family of Typic Argiudolls.

The reflectance from Chaukori soil (Fig. 2) increased from 4 per cent at 350 nm to 15 per cent at 600 nm, 30 per cent at 900 nm and 41 per cent at 1200 nm. The maximum reflectance of 50 per cent was noticed at 1700 nm. The spectral curve of soil showed two prominent absorption bands at 950 and 1100 nm and a weak absorption band at 750 nm wavelengths.

Soils of high altitudes

Auli site: Soils are deep to very deep, very dark greyish brown (10YR3/2 D) loam in texture, strongly acid (pH 5.2) and occur on high hill slopes under pasture. These soils are classified as Coarse-loamy, mixed, mesic family of Humic Pachic Dystrudepts.

The reflectance from Auli soil (Fig. 3) increased from about 4 per cent at 350 nm to 17 per cent at 600 nm, 30 per cent at 900 nm and 40 per cent at 1200 nm. The maximum soil reflectance was noticed at 1700 nm where it reached to 50 per cent. The shape of the curve was slightly concave between 350 to 600 nm and almost linear between 600 and 1200 nm and slightly convex between 1500 to 1800 nm. Three prominent absorption bands at 750,

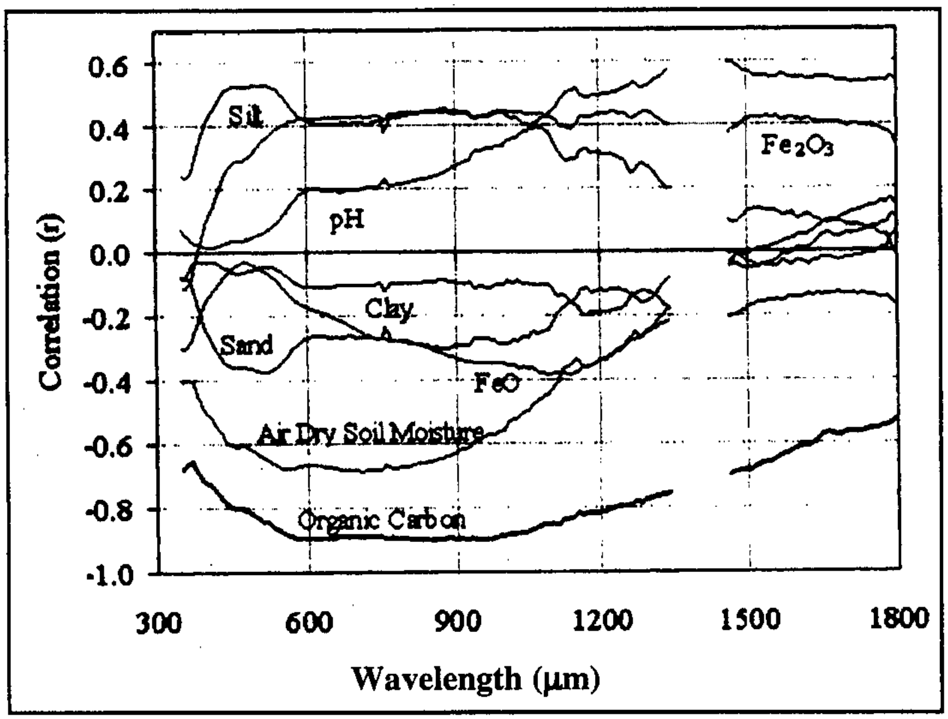

Fig. 4. Curves showing correlations between various soil parameters and spectral reflectance data

950 and 1100 nm were noticed.

Malari site: Soils are deep to very deep with increasing gravel content with depth, well drained, reddish yellow (7.5YR 6/6 D) sandy loam in texture, slightly acid (pH 6.3) and occur on terraces of high hill slopes. These soils qualify for Loamy-skeletal, mixed, mesic, Typic Eutrudepts soil family.

The reflectance from Malari soil (Fig. 3) increased from 4 per cent at 350 nm to 25 per cent at 600 nm, 38 per cent at 900 nm and 47 per cent at 1200 nm. The maximum reflectance of 54 per cent was recorded at 1700 nm. The shape of the curve was concave between 350 to 600 nm, convex between 600 to 900 nm, almost linear from 900 and 1500 nm and again convex between 1500 to 1800 nm. Four prominent absorption bands at 750, 950, 1100 and 1275 nm were noticed on the spectral curve.

Badrinath site: Soils are moderately deep (AISLUS 1971) with stones in subsurface horizons, well drained, brown (10YR4/3 D&M) sandy loam in texture, slightly acid (pH 6.1) and occur on terraces of high hill slopes. These soils are classified as Loamy-skeletal, mixed, mesic family of Lithic Udorthents.

The reflectance from Badrinath soil (Fig. 3) increased from 2 per cent at 350 nm to 11 per cent at 600 nm, 28 per cent at 900 nm and 40 per cent at 1200 nm. The maximum reflectance was recorded at 1700 nm where it reached to about 50 per cent. The shape of the curve is slightly concave between 350 to 600 nm, linearly straight between 600 to 900 nm, slightly convex between 900 to 1200 nm region and convex between 1500 and 1800 nm. Four promi-

Table 2. Albedo of the soil

Site	Soil albedo (%)			Org. C.
	λ (0.35 -1.8 μm)	λ (<0.7 μm)	λ (0.7 – 1.8 μm)	(g kg^{-1})
Karan Prayag	33.8	14.4	40.3	20.7
Baijnath	31.6	15.7	37.0	14.7
Mahergaon	32.9	13.6	39.4	10.4
Pithoragarh	37.4	18.3	43.8	39.8
Pandukeshwar	29.2	8.7	36.1	30.0
Chaukori	32.1	11.3	39.1	57.6
Auli	32.0	12.3	38.6	40.6
Malari	37.7	16.2	45.0	83.2
Badrinath	30.2	8.2	37.6	36.9
Shelang	22.7	6.6	28.1	9.2

λ - *Wavelength*

nent absorption bands at 750, 950, 1100 and 1275 nm wavelength were noticed.

Shelang site: Soils are deep, moderately well drained, very dark greyish brown (10YR 3/2 D&M) loam in texture, strongly acid (pH 5.2) and occur on northern aspect of high hill slopes under *Moru* forest. These soils are classified as Fine-loamy, mixed, mesic family of Typic Hapludolls.

The reflectance from Shelang soil (Fig. 3) increased from 2 per cent at 350 nm to 8 per cent at 600 nm, 22 per cent at 900 nm and 30 per cent at 1200 nm. The maximum reflectance was recorded at 1700 nm where it reached to about 35 per cent. The shape of the curve is concave between 350-600 nm, almost linear between 600-900 nm and slightly convex between 900-1800 nm.

Soil albedo

Albedo (relative reflectance averaged across the entire spectrum) of all the soils for visible (0.35-0.7μm), near infrared (0.7-1.8 μm) and entire spectrum (0.35-1.8 μm) is given in table 2. It is observed that albedo in the visible portion of the spectrum ranged from 6.6 per cent in Shelang to 18.3 per cent in Pithoragarh soils while in infrared region it varies from 28.1 per cent in Shelang soils to 45 per cent in Malari soils. The soil albedo (0.35-1.8 μm) varies from 22.7 per cent in the Shelang soils to as high as 37.7 per cent in Malari soils. The major factor influencing the soil albedo appears to be due to variation in the organic carbon content. Ben-Dor *et al.* (1999) also observed influence of soil organic matter on soil albedo.

Relationship between soil properties and soil spectral reflectance

Statistical correlations between various soil properties and spectral reflectance (resampled to 10 nm bandwidth) at different wavelengths have been studied using limited data (40 soil samples). The relationship between various soil parameters and soil reflectance between 350 - 1800 nm has been depicted in fig. 4. The results indicate that soil reflectance at all the wavelengths decreases with the increase in organic carbon (r = -0.90) and air-dry soil moisture content (r = -0.68) at the time of spectral measurements. The effects of other soil variables were found non-significant at 5 per cent level. Further studies in these lines, based on larger dataset, are required to establish the relationships between different soil properties and soil spectral reflectance.

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