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A comparative study on soil colour determination through munsell colour chart and hyper spectral remote sensing technique

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Abstract
Soil colour is useful to characterize and differentiate soils. Routine determination of soil colour in the field is usually accomplished by visually comparing a soil sample with the Munsell Soil Colour Charts. The colour of soil can be measured in laboratory using Hyperspectral Remote Sensing Technique. Spectral reflectance measurement of 150 samples were carried out in the laboratory using spectroradiometer (model: GER1500; range: 350 to 1050nm). Colours were also visually estimated using Munsell soil colour charts. The Hyperspectral data were analysed for different indices and correlated with Munsell Soil colour measurement using correlation techniques and they showed good agreements. The overall correlation was 0.776. Thus the colour aspect of soil sample can be predicted from its spectral reflectance and this has numerous applications in remote sensing.

Keywords: hyperspectral technique, munsell colour chart, Soil Colour

1. Introduction

Soil colour is an important soil property that is reported in all soil profile descriptions because it constitutes a useful first approximation of soil conditions and properties. Soil colour is used for both soil classification and evaluation. From colour, inferences regarding such things as reduction status (whether or not a soil remains waterlogged for long periods of time), organic matter content, iron oxide content and mineralogy are possible. The practice of describing soil colour first began in Russia, where attempts were made to form a cohesive system of soil colour identification. In America, soil colours were occasionally mentioned in reports of the early 1900's, but no formal system was agreed upon until the 1940's, when the work of Dorothy Nickerson and Albert H. Munsell led to the use of the colour chip system now employed. The system has led to a uniform and systematic description of soil colour employed in all current scientific literature.

The colour of soil is also measured by instruments such as photoelectric tristimulus colorimeters and Spectrophotometer and Spectroradiometers. The photoelectric colorimeters have source–filter-photodetector combinations that simulate the CIE Standard Observer functions. Spectrophotometers have wavelength isolation systems, such as gratings, prisms, or system of filters that provide the true reflectance spectrum of the sample; however, the wavelength band pass and wavelength accuracy varies widely the simpler to sophisticated models. On the other hand Spectroradiometers measures the reflected light energy as a function of wavelength. And the amount of energy reflected either in the natural light or artificial light is depends on the properties of the soil. Fernandez and Schulze (1987) calculated soil colours from their reflectance spectra. Escadafal *et al.* (1989) [4] measured spectral reflectance of soils and computed chromaticity co-ordinates expressed in RGB (Red, Green & Blue) notation, which were strongly correlated with the soil reflectance measured in the corresponding spectral bands of Landsat sensors. The spectral reflectance data obtained with Spectrophotometers are converted to C.I.E tristimulus values manually or with the help of appropriate software in external or built in computers.

Although the soil colour is commonly described using Munsell soil colour system, it has disadvantages *viz.*, absence of direct mathematical conversions and require large look up tables to make continuous transformations. Hence, the Munsell system is mostly used for categorial qualifications of colour, which makes it less useful for numerical and statistical analysis

(Melville and Atkinson, 1985) [13]. Such calculations have already been done for a light of the c-illuminant type and are available under the form of tables, which allow to go from one system to the other (Wiszecki and Stiles, 1982) [20].
With these background knowledge the present study was carried out to determine the soil colour through instrumentation technique (Spectroradiometer) with following objectives:

i. Determination of soil colour through Munsell Soil Colour chart as well as Spectroradiometer.
ii. Establishing relationship between Munsell Soil Colour and Spectroradiometer data.

2. Materials and Methods

2.1 Details of laboratory analysis conducted

2.1.1 Sample selection

Sample selected from the collections of soil samples available in the department of Remote Sensing and Geographical Information System. The samples represent different agroclimatic zones as well as different blocks of Tamil Nadu with varying soil types. The samples were selected based on visual colour variations.

2.1.2 Processing and storage

a. The collected soil samples were assigned sample number and entered in the laboratory soil sample register.
b. The samples collected were dried in shade by spreading on a clean sheet of paper after breaking the large lumps, if present.
c. The dried samples were sieved through 2 mm sieve, this process was repeated until we collect 250 to 300 g of sample.
d. The samples were stored in polythene bag with proper labelling for further analysis.

2.1.3 Soil colour determination

The present study involved determination of colour of soils collected from different regions of the state with varying properties at laboratory using Munsell Soil Colour chart (2009). Totally 150 soil samples (both surface and sub-surface) were collected and compared with Munsell Soil colour chart to determine the colour. The colour of air dried samples was matched by holding the sample directly behind the colour sheets separating the closest matching colour chips. The resultant colour notations *viz.*, Hue, Value and Chroma were noted in the register against the sample code.

2.1.4 Spectral reflectance measurement

The reflectance properties of a soil were described by spectral reflectance curve. This spectral reflectance curve for a given object or material is called spectral signature, which is a characteristics feature of that object or material. The reflectance measurement were done using the instrument called "spectroradiometer", and the spectroradiometer which measures the reflected light energy from the object at narrow wavelength interval (5 to 10nm) is called Hyperspectral Radiometer.
For the present study the Hyperspectral radiometer available in the Department of Remote Sensing and GIS (model: GER1500; range: 350 nm to 1050 nm) was utilized. The instrument is capable of measuring the reflectance at 2 nm interval and record in 512 channels. The air dried samples were packed uniformly in a circular glass disc of diameter 10 cm and depth 2 cm, by tapping the tray on table to ensure a smooth surface. The circular glass disc filled with soil was kept above the dark background on a table and the light reflectance was measured (Plate 1). Reflectance measurements were taken under bright sunshine conditions between 1100 and 1200 hours and the colour estimates were made in the wave length region (350-1050 nm) of the spectrum.

2.2 Data / observations recorded

a. Soil colour notations from Munsell soil colour chart.
b. Spectral reflectance curve for all the soil samples.
c. Conversion of Munsell soil colour values into RGB by referring ready reckanor table.
d. Deriving RGB values (band combinations) from spectral reflectance date to predict the soil colour components.

2.3 List of statistical methodology adopted

The Hyperspectral data were analysed to determine RGB and correlated with Munsell Soil colour measurement using correlation techniques.

3. Results and Discussions

Soil colour is generally determined in the field as well as in the laboratory by visually matching the samples with colour chips in standard Munsell Soil Colour charts (soil survey staff, 1951). The Munsell colour system utilizes a descriptive system of hue, value and chroma which limits the establishment of any quantitative relationship between soil colour and soil constituents. Further, its accuracy and precision are determined by many factors including the light, the moisture contant in the sample and condition of colour chart surfaces and the skill of the person making the colour match.
Colour determined using instruments like Spectrophotometers or Spectroradiometers would give values which are amenable for any numerical or statistical analysis and to establish quantitative relationships with soil constituents. Measurement of Spectral reflectance from soil using Spectroradiometers is a nondestructive single measurement in which colour is one of the properties that can be estimated. This is generally performed in visible and near infrared wavelength region of the electromagnetic Spectrum and the resultant Spectral reflectance cure as a function of wavelength is called Spectral signature.
Spectral signature the amount of energy reflected at specific wavelength and this is unique for each and every property as this is wavelength and material dependent on many studies have been conducted to measure the soil colour through instruments and correlated with Munsell colour values by bringing them to common conversion system viz., red, green and blue (RGB) coordinates.
In the present investigation Spectral signature of 150 soil samples were derived and compared with Munsell soil colour values. The soil colour determined by conventional method using Munsell soil colour chart is presented in Table1. Hue varies from 10YR, 7.5YR, 5YR and 2.5YR and the values ranges from 3 to 8 and chroma values of 1 to 6 indicating a varied representation of soil samples collected for the study.
The Hue value and chroma (HVC) obtained from Munsell charts were converted to Red, Green and Blue (RGB) coordinates using the conversion table and are presented in Table 2.
The trend of RGB indicates increasing order of values from Blue to Red and this trend is similar to the Spectral signature curve obtained by Spectral measurement technique. The RGB values shows good variation among different samples.

It is clear from all the figures that the darker the colour low in the quantity of energy or light reflected and vice versa. Thus, the Spectral measurement techniques is able to differentiate soil colours as that of Munsell soil colour chart. The high reflection is also due to light coloured soil as well as fine soil texture and coarse soil texture would absorb more light. The advantage of Spectral measurements is observation in near infrared wavelength in addition to visible region. Thus, enables easy differentiation of different coloured soils.

The graph showed in Fig. 1 contains Munsell colour notations 10 YR7/1, 10 YR7/2, 7.5 YR4/3, 5 YR3/4. Among these notations 5YR3/4 is darker than others and it has recorded low reflection. The light coloured one is 10YR7/1 and has recorded high to very high reflection.

Fig. 2 contains Munsell colour notations like 2.5Y8/1, 10YR6/2, 5YR4/1, 10 YR5/2. Among these notations 10YR5/2 is more darker than others and it has recorded low reflection. The light coloured one is 2.5Y8/1and has recorded high to very high reflection.

For comparing the Munsell colour values with corresponding reflectance spectra, the value and chroma were converted to Red, Green and Blue (RGB) values using a ready reckener table (Annon, 2012) (Table 3). Similarly the average reflectance in the region of 400 – 500 nm, 500 – 600 nm and 600 – 700 nm corresponding to Blue, Green and Red wavelength, respectively were calculated.

The low reflection in the blue region and gradual increase towards near infrared through green and red has observed for all the measurement and it is typical for soil. This is due to absorption by minerals particles in some wavelength (Torrent and Barron, 1993). The correlation established between RGB values of hue and Spectral measurements is present in Table 4. The Munsell soil colour values (RGB) are correlated well with RGB values of Spectral data. The correlation of red is 0.6436, green is 0.6506 and blue 0.6997 and the overall correlation obtained was 0.776 and this findings are in accordance with Mattikalli (1997) [12] and Richard Escadafal (1989) [4].

Though, the Munsell colour notations as such may not be useful for any numerical or statistical analysis, still the same can be used by converting into RGB values. In the present study the conversion values are available only for the 7.5 YR and 10 YR thus restrict the establishment of wider correlation between the Munsell soil colour and Reflectance Spectra.

Table 1: The Hue Value, Chroma of soils determined by Munsell soil colour chart for 150 samples

Sample Number	Munsell colour notation (Hue, Value and Chroma)
1	10YR7/2
2	10YR5/2
3	10YR4/2
4	10YR4/2
5	10YR4/1
6	10YR5/2
7	10YR3/2
8	10YR3/2
9	10YR5/1
10	10YR6/2
11	10YR5/4
12	10YR5/2
13	10YR5/4
14	10YR4/2
15	10YR5/2
16	10YR5/1
17	10YR5/1
18	10YR5/2
19	10YR4/1
20	10YR4/3
21	10YR6/2
22	10YR4/3
23	10YR4/2
24	10YR5/2
25	10YR4/2
26	10YR4/2
27	10YR6/2
28	10YR5/2
29	10YR3/1
30	10YR4/2
31	10YR7/4
32	10YR5/2
33	10YR3/2
34	10YR4/3
35	10YR4/2
36	7.5YR4/3
37	7.5YR5/2
38	7.5YR3/4
39	7.5YR3/2
40	7.5YR4/4
41	7.5YR4/2
42	7.5YR5/6

43	7.5YR2.5/1
44	7.5YR4/3
45	7.5YR3/1
46	7.5YR3/4
47	7.5YR3/2
48	7.5YR4/1
49	7.5YR4/4
50	7.5YR4/4
51	7.5YR3/2
52	7.5YR4/4
53	7.5YR4/3
54	7.5YR4/1
55	7.5YR4/3
56	7.5YR3/3
57	7.5YR4/6
58	7.5YR4/2
59	7.5YR4/4
60	7.5YR4/1
61	7.5YR4/2
62	7.5YR4/4
63	7.5YR4/1
64	7.5YR4/3
65	7.5YR5/4
66	7.5YR4/2
67	7.5YR4/6
68	7.5YR5/6
69	7.5YR4/6
70	7.5YR4/6
71	10YR5/4
72	10YR4/2
73	10YR3/1
74	10YR4/3
75	1OYR4/2
76	10YR4/1
77	10YR4/2
78	10YR5/4
79	10YR4/3
80	10YR4/1
81	10YR5/1
82	10YR5/4
83	10YR3/1
84	10YR4/3
85	10YR3/2
86	10YR3/1
87	10YR4/3
88	7.5YR2.5/1
89	7.5YR4/3
90	7.5YR3/3
91	7.5YR4/3
92	7.5YR3/4
93	7.5YR4/6
94	7.5YR3/2
95	7.5YR3/4
96	7.5YR4/3
97	7.5YR4/3
98	7.5YR4/4
99	7.5YR4/1
100	7.5YR4/2
101	10YR77/1
102	7.5YR6/4
103	7.5YR5/2
104	10YR7/2
105	5YR2.5/2
106	7.5YR6/4
107	5YR4/4
108	5YR4/4
109	5YR4/4
110	5YR3/3
111	5YR3/4

112	5YR3/3
113	5YR3/3
114	5YR3/4
115	5YR4/1
116	5YR3/4
117	5YR3/3
118	5YR3/4
119	5YR5/6
120	5YR3/4
121	5YR4/6
122	5YR5/6
123	5YR3/4
124	5YR4/1
125	5YR3/4
126	2.5YR4/1
127	2.5Y5/3
128	2.5YR4/1
129	2.5Y6/2
130	2.5Y3/1
131	2.5YR3/6
132	2.5Y4/1
133	2.5Y8/1
134	2.5Y4/1
135	2.5Y7/1
136	2.5YR4/4
137	2.5Y6/2
138	2.5Y3/2
139	2.5Y4/2
140	2.5YR2.5/4
141	2.5YR3/4
142	2.5YR3/4
143	2.5YR6/3
144	2.5YR6/3
145	2.5Y6/3
146	2.5YR4/4
147	2.5YR4/6
148	2.5Y5/3
149	2.5YR4/4
150	2.5YR3/6

Table 2. HVC to RGB converted value

Sample Number	Munsell colour notation			
	HVC	**R**	**G**	**B**
2	10YR7/2	187	171	150
14	10YR5/2	134	119	101
15	10YR4/2	110	94	76
22	10YR4/2	110	94	76
23	10YR4/1	104	96	87
24	10YR5/2	134	119	101
25	10YR3/2	85	71	56
27	10YR3/2	85	71	56
30	10YR5/1	129	120	111
31	10YR6/2	161	145	125
35	10YR5/4	145	117	80
36	10YR5/2	134	119	101
37	10YR5/4	145	117	80
44	10YR4/2	110	94	76
45	10YR5/2	134	119	101
48	10YR5/1	129	120	111
49	10YR5/1	129	120	111
52	10YR5/2	134	119	101
53	10YR4/1	104	96	87
61	10YR4/3	115	93	67
62	10YR6/2	161	145	125
66	10YR4/3	115	96	101
67	10YR4/2	110	94	76
68	10YR5/2	134	119	101
71	10YR4/2	110	94	76

74	10YR4/2	110	94	76
75	10YR6/2	161	145	125
75	10YR6/2	161	145	125
76	10YR5/2	134	119	101
77	10YR3/1	80	72	65
78	10YR4/2	110	94	76
79	10YR7/4	198	169	127
80	10YR5/2	134	119	101
81	10YR3/2	85	71	56
83	10YR4/3	115	93	67
84	10YR4/2	110	94	76
3	7.5YR4/3	118	92	70
4	7.5YR5/2	136	118	104
10	7.5YR3/4	96	67	42
11	7.5YR3/2	87	70	58
16	7.5YR4/4	123	90	61
17	7.5YR4/2	112	93	79
20	7.5YR5/6	159	112	65
28	7.5YR2.5/1	70	61	55
29	7.5YR4/3	118	92	70
33	7.5YR3/1	81	72	66
34	7.5YR3/4	96	67	42
38	7.5YR3/2	87	70	58
40	7.5YR4/1	105	95	88
41	7.5YR4/4	123	90	61
43	7.5YR4/4	123	90	61
50	7.5YR3/2	87	70	58
51	7.5YR4/4	123	90	61
59	7.5YR4/3	118	92	70
70	7.5YR4/1	105	95	88
72	7.5YR4/3	118	92	70
86	7.5YR3/3	92	69	50
90	7.5YR4/6	131	88	44
92	7.5YR4/2	112	93	79
94	7.5YR4/4	123	90	61
95	7.5YR4/1	105	95	88
97	7.5YR4/2	112	93	79
103	7.5YR4/4	123	90	61
104	7.5YR4/1	105	95	88
110	7.5YR4/3	118	92	70
113	7.5YR5/4	149	115	85
301	7.5YR4/2	112	93	79
279	7.5YR4/6	131	88	44
311	7.5YR5/6	159	112	65
343	7.5YR4/6	131	88	44
350	7.5YR4/6	131	88	44
85	10YR5/4	145	117	80
87	10YR4/2	110	94	76
88	10YR3/1	80	72	65
89	10YR4/3	115	93	67
93	1OYR4/2	110	94	76
96	10YR4/1	104	96	87
98	10YR4/2	110	94	76
99	10YR5/4	145	117	80
100	10YR4/3	115	93	67
101	10YR4/1	104	96	87
107	10YR5/1	129	120	111
111	10YR5/4	145	117	80
116	10YR3/1	80	72	65
117	10YR4/3	115	93	67
118	10YR3/2	85	71	56
119	10YR3/1	80	72	65
123	10 YR4/3	115	93	67
114	7.5YR2.5/1	70	1	55
122	7.5YR4/3	118	92	70
125	7.5YR3/3	92	69	50
127	7.5YR4/3	118	92	70
128	7.5YR3/4	96	67	42
131	7.5YR4/6	131	88	44

133	7.5YR3/2	87	70	58
134	7.5YR3/4	96	67	42
136	7.5YR4/3	118	92	70
137	7.5YR4/3	118	92	70
139	7.5YR4/4	123	90	61
140	7.5YR4/1	105	95	88
141	7.5YR4/2	112	93	79

Table 3: Comparison of Red, Green and Blue (RGB) values of Munsell colour notation with Reflectance Spectra.

Sample Number	Munsell Colour Notation				Spectral Curve		
	HVC	R	G	B	R	G	B
2	10YR7/2	187	171	150	24	18	14
14	10YR5/2	134	119	101	15	11	7
15	10YR4/2	110	94	76	16	11	8
22	10YR4/2	110	94	76	12	8	5
23	10YR4/1	104	96	87	13	10	7
24	10YR5/2	134	119	101	20	14	9
25	10YR3/2	85	71	56	11	8	6
27	10YR3/2	85	71	56	11	8	5
30	10YR5/1	129	120	111	15	13	11
31	10YR6/2	161	145	125	20	14	9
35	10YR5/4	145	117	80	22	14	8
36	10YR5/2	134	119	101	18	15	12
37	10YR5/4	145	117	80	18	12	8
44	10YR4/2	110	94	76	16	12	7
45	10YR5/2	134	119	101	19	13	8
48	10YR5/1	129	120	111	15	12	9
49	10YR5/1	129	120	111	15	13	10
52	10YR5/2	134	119	101	17	13	9
53	10YR4/1	104	96	87	14	12	9
61	10YR4/3	115	93	67	15	11	6
62	10YR6/2	161	145	125	28	20	12
66	10YR4/3	115	96	101	16	11	6
67	10YR4/2	110	94	76	12	9	6
68	10YR5/2	134	119	101	19	16	12
71	10YR4/2	110	94	76	12	9	6
74	10YR4/2	110	94	76	14	10	7
75	10YR6/2	161	145	125	24	16	10
76	10YR5/2	134	119	101	24	16	9
77	10YR3/1	80	72	65	10	8	6
78	10YR4/2	110	94	76	41	25	15
79	10YR7/4	198	169	127	12	9	6
80	10YR5/2	134	119	101	24	18	11
81	10YR3/2	85	71	56	11	8	5
83	10YR4/3	115	93	67	12	9	7
84	10YR4/2	110	94	76	11	8	6
3	7.5YR4/3	118	92	70	15	9	6
4	7.5YR5/2	136	118	104	17	10	6
10	7.5YR3/4	96	67	42	14	7	4
11	7.5YR3/2	87	70	58	13	8	5
16	7.5YR4/4	123	90	61	15	9	5
17	7.5YR4/2	112	93	79	14	10	8
20	7.5YR5/6	159	112	65	27	13	7
28	7.5YR2.5/1	70	61	55	10	8	6
29	7.5YR4/3	118	92	70	16	11	6
33	7.5YR3/1	81	72	66	11	9	7
34	7.5YR3/4	96	67	42	14	7	4
38	7.5YR3/2	87	70	58	11	8	6
40	7.5YR4/1	105	95	88	11	9	6
41	7.5YR4/4	123	90	61	15	7	4
43	7.5YR4/4	123	90	61	17	9	5
50	7.5YR3/2	87	70	58	11	7	4
51	7.5YR4/4	123	90	61	18	10	5
59	7.5YR4/3	118	92	70	11	7	5
70	7.5YR4/1	105	95	88	12	10	8
72	7.5YR4/3	118	92	70	13	7	4
86	7.5YR3/3	92	69	50	10	6	3
90	7.5YR4/6	131	88	44	21	10	5

92	7.5YR4/2	112	93	79	16	11	7
94	7.5YR4/4	123	90	61	14	8	4
95	7.5YR4/1	105	95	88	13	10	8
97	7.5YR4/2	112	93	79	14	10	7
103	7.5YR4/4	123	90	61	18	11	7
104	7.5YR4/1	105	95	88	13	10	8
110	7.5YR4/3	118	92	70	17	10	6
113	7.5YR5/4	149	115	85	26	15	8
301	7.5YR4/2	112	93	79	21	16	12
279	7.5YR4/6	131	88	44	21	11	6
311	7.5YR5/6	159	112	65	31	17	9
343	7.5YR4/6	131	88	44	18	9	5
350	7.5YR4/6	131	88	44	17	9	5
85	10YR5/4	145	117	80	22	15	9
87	10YR4/2	110	94	76	14	10	7
88	10YR3/1	80	72	65	10	7	5
89	10YR4/3	115	93	67	15	10	6
93	1OYR4/2	110	94	76	16	12	9
96	10YR4/1	104	96	87	12	9	7
98	10YR4/2	110	94	76	14	10	6
99	10YR5/4	145	117	80	20	13	7
100	10YR4/3	115	93	67	13	9	6
101	10YR4/1	104	96	87	15	12	10
107	10YR5/1	129	120	111	16	14	11
111	10YR5/4	145	117	80	23	16	8
116	10YR3/1	80	72	65	10	9	7
117	10YR4/3	115	93	67	15	10	7
118	10YR3/2	85	71	56	11	8	5
119	10YR3/1	80	72	65	10	8	7
123	1OYR4/3	115	93	67	18	13	8
114	7.5YR2.5/1	70	1	55	9	7	6
122	7.5YR4/3	118	92	70	14	9	6
125	7.5YR3/3	92	69	50	11	6	4
127	7.5YR4/3	118	92	70	13	8	5
128	7.5YR3/4	96	67	42	12	6	4
131	7.5YR4/6	131	88	44	23	12	6
133	7.5YR3/2	87	70	58	15	10	7
134	7.5YR3/4	96	67	42	13	6	4
136	7.5YR4/3	118	92	70	13	7	5
137	7.5YR4/3	118	92	70	11	8	5
139	7.5YR4/4	123	90	61	15	8	5
140	7.5YR4/1	105	95	88	11	8	5
141	7.5YR4/2	112	93	79	12	9	6

Table 4: Correlation of RGB values of HVC and spectral signature

	Munsell Soil Colour value (HVC)			**Spectral signature value**		
Red from Munsell value	R	G	B	R	G	B
Green from Munsell value	1					
Blue from Munsell value	0.889	1				
Red from Spectral value	0.5985	0.8297	1			
Green from Spectral value	0.6436	0.5264	0.2869	1		
Blue from Spectral value	0.5952	0.6506	0.5926	0.8745	1	
	0.4311	0.5961	0.6997	0.6102	0.8916	1
Overall correlation =0.776						

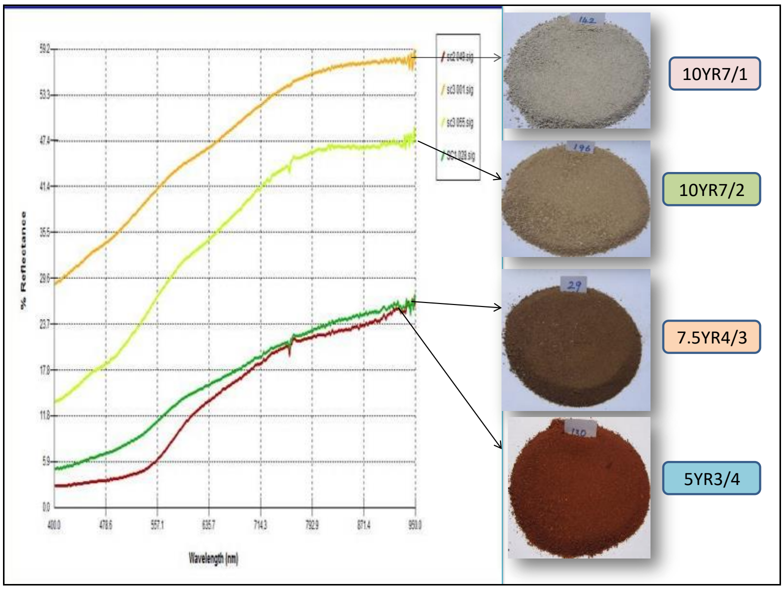

Fig 1: Comparison of Spectral signature of various soils with Munsell colour values.

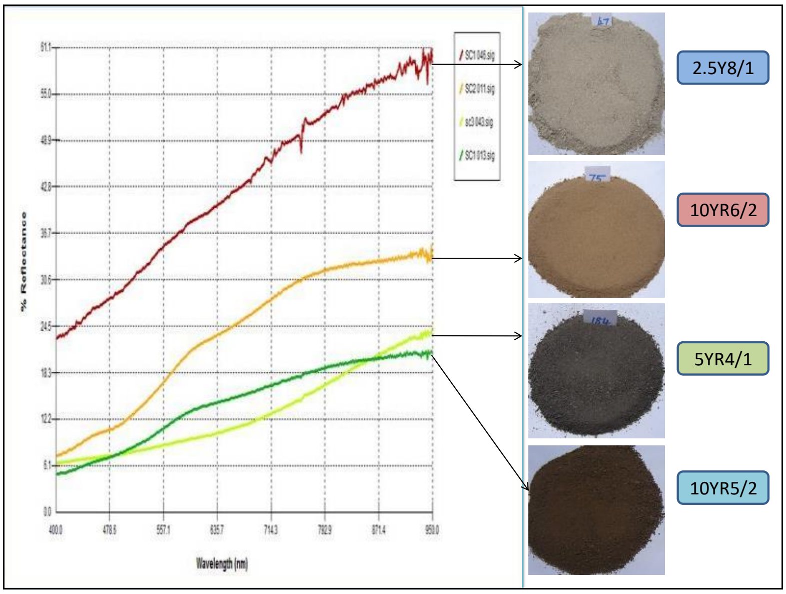

Fig 2: Comparison of Spectral signature of various soils with Munsell colour values.

4. Conclusions

In the present study an attempt was made to determine the soil colour for selected 150 samples by hyperspectral remote sensing technique. The soil shows variability in colour as evident from varying Munsell colour values and Spectral signature. The RGB values obtained by conversion from Munsell colour values as well as Spectral measurement data clearly indicated observable difference among samples. The overall correlation obtained for RGB values of both methods is 0.776 which is significant.

Thus, the instrumentation technique *viz.*, hyperspectral radiometer can very well be used to measure the soil colour for quantitative determination and numerical analysis. However, these results are to be verified by repeated and wide range of soil colours along with soil properties.

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