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Spectral Signatures Obtained from Landsat Digital Data for Forest Vegetation and Land-Use Mapping in India

Spectral signatures of various vegetated and non-vegetated cover types at two different seasons (leaf fall and pre-leaf fall) have been studied.

Introduction

The Multispectral Scanner (MSS) data from Landsat provide information about the reflectance behavior of various objects on the Earth in four different wavelength bands. These objects behave differently with different wavelengths of incident energy and, therefore, have unique spectral signatures. Thus, spectral signature is one of the important tools in the identification of and discrimination between various objects in analysis of Landsat digital data. Unni *et al.* (1980) and Mayer and Fox III (1981) have emphasised the importance of such studies in remote sensing surveys.

While the spectral response patterns form all healthy and green vegetation tend to be generally the same, there are small variations both within and between vegetation types because of their phenology, growth and vigor, crown pattern, association, and various other ecological parameters. These variations can be studied using multidate spectral data, and information thus derived can be extrapolated to unknown areas of similar terrain and vegetation cover.

Abstract: *Spectral signature is one of the important tools in the analysis of Landsat digital data as it forms the basis of identification and discrimination between various features on the Earth. Spectral signatures of various vegetated and non-vegetated cover types at two different seasons (leaf fall and pre-leaf fall) have been studied with the objective to find out their role in analysis of Landsat multispectral digital data using a Multispectral Data Analysis System (M-DAS). Computer compatible tapes (CCTs) having Landsat Multispectral Scanner data in four bands of two different scenes with path-row nos. 156-043 and 155-042 collected on 28 February 1975 and 12 December 1975, respectively, covering part of semi-arid region of Uttar Pradesh have been used for this study. Spectral signatures, obtained after plotting mean grey scale values in the four bands, have helped in the identification of various vegetation and non-vegetation classes and to understand their spectral separability which in turn has given a clue for final grouping of these classes during computer-aided forest classification of the study area.*

Because the chlorophyll content of green leaves is responsible for high absorption in the red portion and cell structure for reflectance in the infrared region of the electromagnetic spectrum (Gates, 1965; Gates, 1970; Knipling, 1967), band 5 and band 7 of the MSS are largely responsible for discrimination between vegetation and non-vegetation classes and within vegetation classes,

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respectively. In the present study, spectral signatures of various vegetated and non-vegetated cover types at two different seasons (leaf fall and pre-leaf fall) have been studied with the objective to determine their role in the analysis of Landsat multispectral digital data. This study was carried out in the course of forest mapping of a semi-arid region in the southern part of Uttar Pradesh.

Materials and Methods

Two computer compatible tapes (CCTs) containing multispectral scanner (MSS) data in band 4 (0.5 μm to 0.6 μm), band 5 (0.6 μm to 0.7 μm), band 6 (0.7 μm to 0.8 μm), and band 7 (0.8 μm to 1.1 μm) of two Landsat scenes with path-row nos. 156-043 and 155-042 collected on 28 February 1975 and 12 December 1975, respectively, were used for the present study. These scenes cover part of semi-arid region of Uttar Pradesh and have almost similar vegetated and non-vegetated cover types.

The supervised classification of forest types and other land covers, based on maximum likelihood decision, was carried out using all the four bands data on an interactive computer known as the Multispectral Data Analysis System (M-DAS). M-DAS is manufactured by the Bendix Corporation. A DEC PDP 11/35 performs M-DAS control and some processing functions (Bendix, 1976). Representative training sample areas of various vegetated and non-vegetated cover-types were located on a color television display unit of the M-DAS. Each training sample was enclosed by a cursor provided with the color TV monitor. A class name and a color code was also assigned to each training sample. Then the parameters of the multivariate normal distribution, comprising the mean vector of grey values and covariance matrix for each training sample, were computed. These mean vectors of grey values in all the four bands of all the training samples have been used for plotting spectral curves.

Twelve training samples for vegetation and 17 training samples for non-vegetation classes have been used to analyze the February scene with path-row No. 156-043. For the analysis of the December scene with path-row No. 155-042, 14 training samples for vegetation and a similar number of training samples for non-vegetation classes have been used.

Results and Discussion

Eleven categories belonging to vegetation and non-vegetation classes viz. *Tectona grandis, Anogeissus pendula, Anogeissus pendula-Acacia catechu,* miscellaneous dry deciduous forest, scrub, standing crop, miscellaneous forest/crops, black soil fallow, barren lands, hill shadow, and water were delineated from CCT data acquired in the month of February (Figures 3 and 4). Similarly, 14 categories such as *Anogeissus pendula, Acacia catechu* mixed, *A. nilotica* mixed, *Boswellia serrata* mixed, other miscellaneous dry deciduous forest, scrub, standing crop, black soil fallow, saline soils, river sand, ravinous areas, barren lands, hill shadow and water were delineated from CCT data obtained in the month of December (Figures 1 and 2).

For calculating percentage accuracy of the classification, ten areas each of about 40 to 80 pixels for each class, were selected on the classified map. For *Tectona grandis* and *Boswellia serrata* only five such areas were selected because the distribution of these species in the study area is very limited. These areas were then verified on the

Table 1. Percentage Classification Accuracy of Various Vegetation and Other Land-Use Classes in the Study Area

Name of the class	No. of areas selected for verification	No. of areas found correctly classified	Percentage accuracy
Tectona grandis	5	4	80
Anogeissus pendula	10	9	90
Anogeissus pendula mixed	10	8	80
Acacia catechu mixed	10	7	70
Acacia nilotica mixed	10	7	70
Boswellia serrata mixed	5	3	60
Misc. dry deciduous Forests	10	9	90
Scrub	10	7	70
Standing crops	10	8	80
Black soil fallow	10	9	90
Red soil fallow/barren land	10	9	90
Saline Soils	10	8	80
Ravinous areas	10	8	80
Water	10	10	100
Average percentage accuracy			80.71

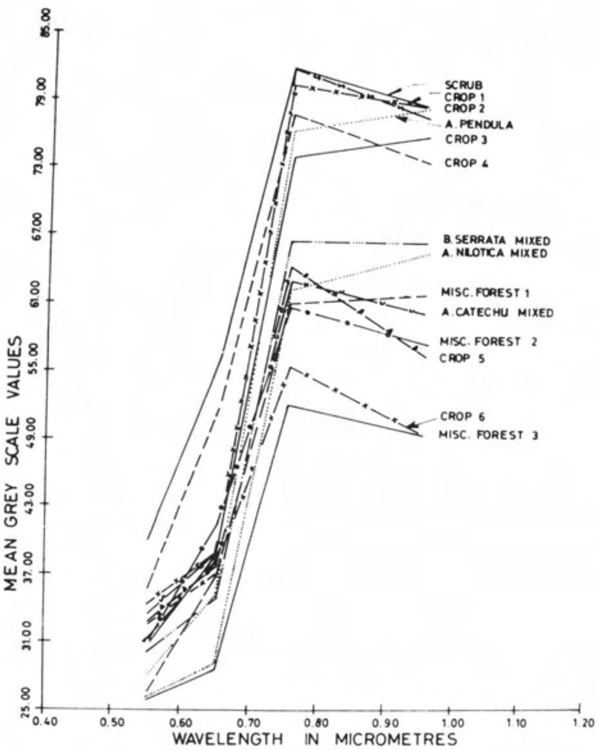

FIG. 1. Spectral signatures for various vegetation cover types in the month of December.

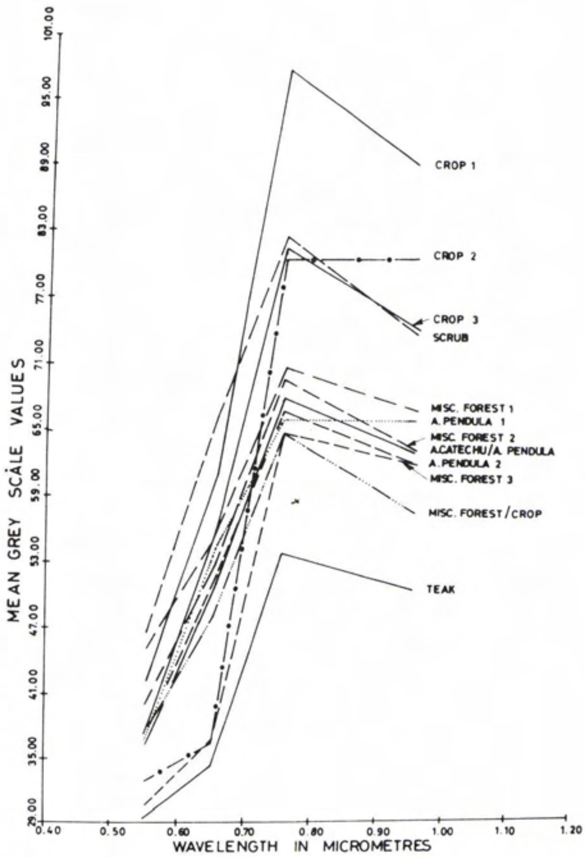

FIG. 2. Spectral signatures for various vegetation cover types in the month of February.

ground in order to determine the accuracy of the classification. The results of the study are shown in Table 1.

VEGETATION CLASSES

Forest vegetation in this area belongs to the Tropical mixed dry deciduous type (Champion and Seth, 1968) and is confined to very small pockets with very sparse growth. Because of the deciduous nature and low density, there is a marked seasonal variation in the spectral response of the forest vegetation in this area. Temporal digital data have been analyzed in order to study these seasonal variations for achieving more accuracy in forest classification. Although the CCTs of two different dates were analyzed, they are not of same path-row and some vegetation classes are not common in both the scenes. Even then, however, comparison between spectral signatures at two different growth stages of other vegetation classes, which are common in both the scenes, could have been possible. The general trend shown by vegetation is low reflectance in bands 4 and 5 and higher reflectance in bands 6 and 7. Similar trends were observed by Unni *et al.* (1980). Figure 1 shows the spectral curves of vegetation classes in the month of December. Normally, for dense, healthy, and green vegetation, reflectance in band 5 is very low; hence, curves tend to dip at this particular band (Gates, 1970), but here no vegetation class has a dip in the spectral curve at band 5. The reason is that the vegetation in this region is very sparse and, therefore, exposed ground is interfering with the spectral signatures of vegetation, resulting in higher reflectance. Mayer & Fox III (1981) have also observed higher reflectance in band 5 as compared to band 4 because of exposed base soils and less exposed surface area of needles in young plantation of ponderosa pine and large trees of fir, respectively. Of course, the curves between bands 4 and 6 are not straight; they tend to bend at spectral band 5. However, in the month of February (dry season) most of the vegetation classes are without leaves and, therefore, less absorption in band 5 and more exposed ground have resulted in much higher reflectance. Thus, curves tend to become straight between bands 4 and 6, as clearly seen in Figure 2.

Figures 1 and 2 show considerable variation in the spectral response of crops even at a single date. This is because of the fact that the training

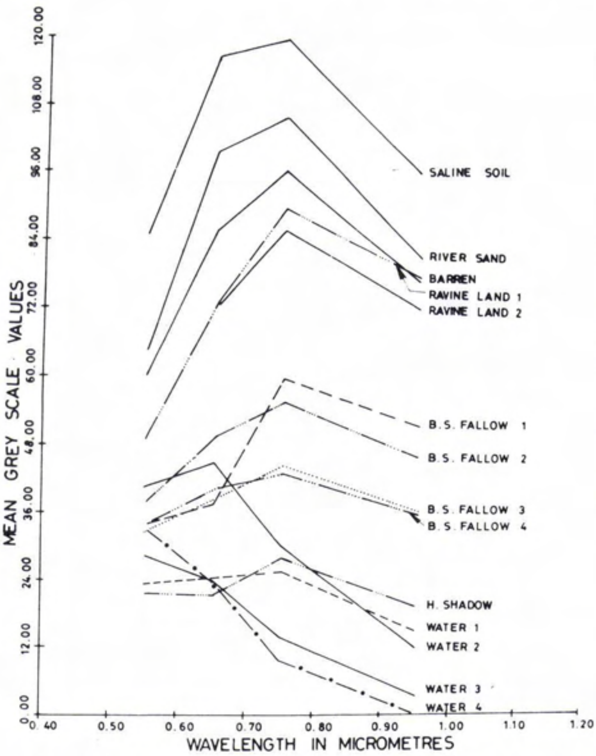

FIG. 3. Spectral signatures for various non-vegetation cover types in the month of December.

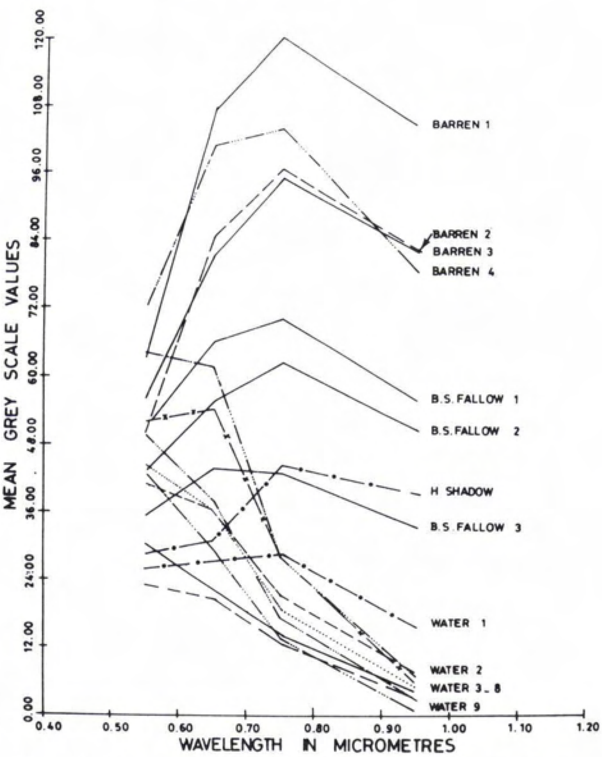

FIG. 4. Spectral signatures for various non-vegetation cover types in the month of February.

samples for the crops 1-3 in the month of February and the crops 1-6 in the month of December belong to different types of agricultural crops of different ages. Because this study on the spectral signatures was carried out in the course of forest mapping of the project area, more emphasis was given to delineate forest classes, and only broad classes of other land use are represented in the final map. Therefore, in order to obtain a color coded map through the computer, only one color code was assigned for all the training samples representing different types of agricultural crops. Similarly, variation in the spectral responses between different miscellaneous forest for just one date is because of the variation in species composition of these forests.

These spectral curves have helped in finding out separability of different vegetation classes and their grouping for final classification. Mayer and Fox III (1981) have also used the spectral curves to make final decisions on identification and grouping of unknown spectral classes of timber species. All the training samples given for various vegetation classes are separable in both the scenes except for two training samples for crop 1 and crop 2 in the December scene (Figure 1) which are very close in all the four bands, but it has not affected the final classification, because, as mentioned earlier, all types of agricultural crops were assigned a single color.

NON-VEGETATION CLASSES

Saline soils, river sand, ravines, and barren lands, having a more or less similar pattern of spectral signature, have higher reflectance in bands 5 and 6 as compared to bands 4 and 7. But, if one examines Figure 3, it is very clear that saline soils show the highest reflectance in all the four bands, next to which is river sand followed by barren land and ravines. Although black soil fallow also shows similar patterns, it has very low reflectance in all the four bands as compared to the categories mentioned above and, therefore, can be very well separated out. Spectral reflectance from water continuously declines from bands 4 to 7, being lowest in band 7. Hill shadow also reflects much less energy in bands 4 and 5, but it does not mix with water as it shows a rising trend towards bands 6 and 7.

Although the cause of variation in spectral response between different training samples of black soil fallow and water for just one date was not studied in detail, but the moisture content of the soil might be the probable cause of this variation in the case of black soil fallow whereas depth variation and turbidity might have resulted in spectral difference between various water classes. Moreover, the water classes belong to water in river, ponds, reservoir etc.

Conclusion

The study of spectral signatures has helped in the identification of various vegetation and non-vegetation classes and in understanding their spectral separability, which in turn has given a clue for final grouping of these classes during computer-aided classification of Landsat digital data. There is considerable variation in the spectral response of vegetation obtained at two different seasons because of differences in growth stages and density. Therefore, with careful temporal study of the spectral signatures, it may be possible to obtain information about the growth stages and density of tropical deciduous forests of unknown areas with similar terrain conditions. Hence, spectral signature can be considered as one of the important tools in the identification of various land covers and their discrimination in remote sensing studies dealing with digital data.

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