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Soil Mapping with IRS-1A Data in Areas of Complex Soil-Scapes

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ABSTRACT: *Remote sensing of soils is based on their spectral variability attributable to their physical characteristics and chemical constituents, although extraneous factors associated with soils under field conditions alter their spectral responses reaching the sensor. Spectral and spatial resolution of the remotely sensed data and the choice of appropriate methodology are crucial to successful mapping. Whereas the former controls the abstraction level, the latter determines the validity of the final map. Outlining these aspects, three approaches of soil mapping, using digital classification of IRS LISS-II data are discussed in this paper and illustrated with the help of case studies. The results show that IRS LISS-II data in conjunction with appropriate methodology, consistent with the pedogenic realm of the area, provide details of soil classes that are often found missing on existing soil maps of reconnaissance and semi-detailed intensities.*

INTRODUCTION

Soil and land uses have become highly competitive, in recent years, as a consequence of population explosion. This has resulted in a particular awareness about scientific data on soil for various programmes like soil conservation, reclamation of problem soils, watershed management, land use planning, and agricultural development. Research and developmental efforts of yesteryears have established application of remote sensing for soil mapping with a high degree of reliability, efficiency and cost-effectiveness. Innumerable studies have been reported on soil mapping with visual interpretation of remotely sensed data. Although a comparatively new approach in India, digital classification in conjunction with IRS-1A data has been successfully employed for soil mapping at small and medium scales[1-5]. Procedures for such mapping in digital format rely primarily on statistical pattern recognition techniques for differentiation of soil classes. Implicit in this approach is the premise that the different soil classes manifest different combinations of DN values, based on the inherent spectral reflectance properties, attributable to their physical make-up and chemical constituents. Notable among these are soil colour, soil texture, moisture content, mineralogy and contents of Org. C, Fe, Mn, $CaCO_3$, and free silica[6].

In practice, soil mapping based on a text-book classification approach is not always satisfactory, since soil reflectance data is subject to the noise caused by several extraneous factors including vegetation. Also, it is not unlikely that two or more soil classes in a project area are seemingly alike in their spectral profile. Careful consideration of the approach, and the procedure to be followed is therefore vital to the reliability of soil mapping, particularly in areas of diverse soil-scapes resulting from complex geology or the intricate nature of other pedogenic factors.

This paper presents soil mapping with IRS LISS-II data in three areas characterised by (i) normal situation, (ii) complex soil-scape resulting from complexity of geologic formation, and (iii) soil-scape with seasonal variability in their spectral profiles.

STUDY AREAS

Three areas were chosen for this study. The choice for these areas was motivated by the already available ground truth data in the form of soil maps produced under NBSS&LUP, Nagpur; AIS & LUS, New Delhi and Soil Survey and Land Use Organisation, Coimbatore. Area I (10° 30' – 10° 45' NL & 77° 05' – 55° 15' EL) is a part of Pollachi and Udumalpet taluks of Coimbatore district, Tamil Nadu. The area II (22° 30'– 22° 50' NL & 77° 50' – 78° 15' EL) is a part of Narmadasagar catchment, Madhya Pradesh, where soils are admirably correlated with geologic formations. Study area III (16° 50' – 17° 00' NL and 74° 25' – 74° 40' EL), located in Sangli district, Maharashtra is excessively irrigated by tubewells for sugarcane crop on heavy black soils that are slowly degrading with salinity and waterlogging.

Data sets

IRS-1A LISS-II data as specified below were used for this study.

- Area I : Path 25, Row 61; March 8, 1990.
- Area II : Path 27, Row 52, L2 A1, B1; Feb. 7, 1989 and May 28, 1989.
- Area III : Path 29, Row 56, L2 B2; Nov. 22, 1990 and May 17, 1990.

Methodology

Digital processing was carried out on DIPIX system at NRSA, Hyderabad, and in VIPS-32 environment on Numelec workstations configured around VAX-11/780 computer system at RRSSC, Nagpur. Maximum likelihood classifier was used for supervised classification in all the three cases. Based on the available soil maps and field observations, two to three training areas were identified for each soil class and the degradation types (erosion, salinity, waterlogging). Training area statistics and confusion matrix were generated to evaluate classification accuracies. Finally, the results were field validated and compared with the available soil maps on the corresponding scales.

Normal soil mapping with standard procedure

The different soils of the area-I have distinct spectral characteristics and clear separability as illustrated by their spectral reflectance curves (Figure 1a). The soil-scape comprises two major formations at subgroup level, namely Typic chromusterts and Typic ustorthents, which are clearly differentiated on the classified output (Figure 2). The Typic ustorthents could be further segregated into their textural types; coarse loamy and fine loamy.

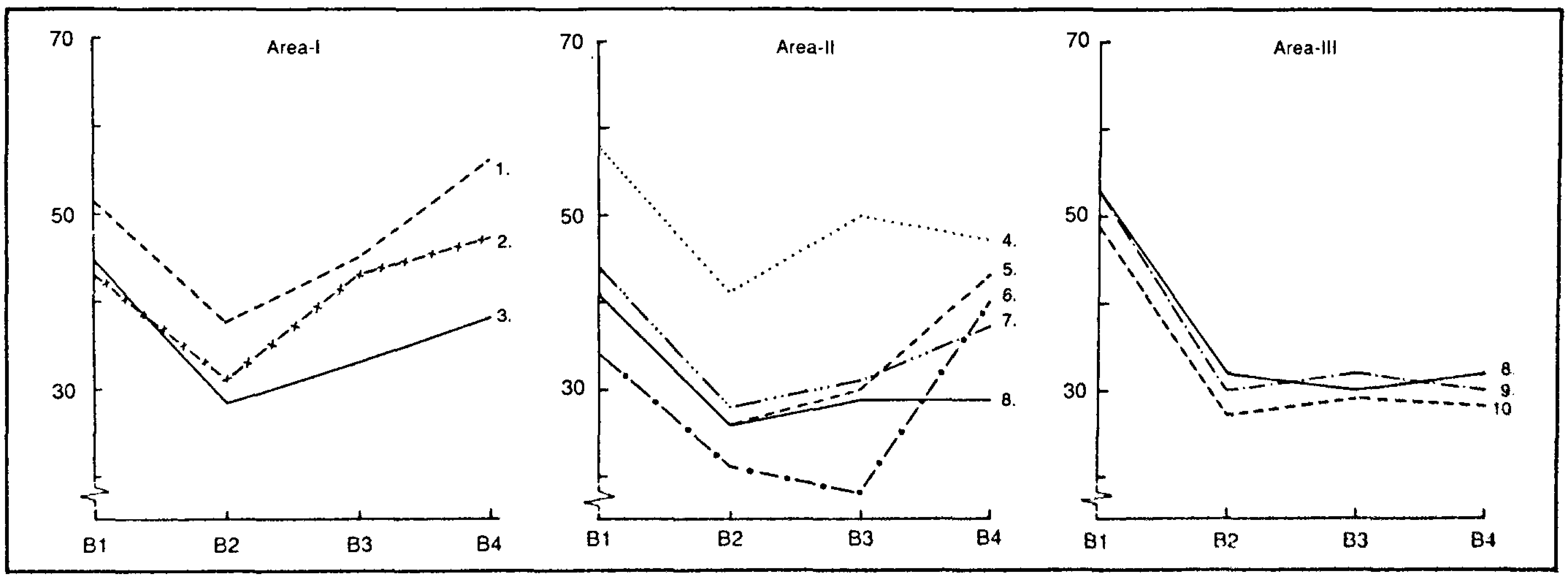

Figure 1a. Spectral reflectance curves of the soils: Area-I – Coimbatore district, Area-II – characterised by complex geological formations in Narmadasagar catchment, and Area-III – Sangli district of Maharashtra affected by soil salinity and waterlogging.

1-T. ustorthents, coarse loamy; 2-T. ustorthents, fine loamy; 3-T. chromusterts
4-T. ustipsamments; 5-L. ustochrepts; 6-U. haplustalfs; 7-T./U. chromusterts, e2-e3
8-T./U. chromusterts; 9-U. chromusterts, saline; 10-L. ustorthents

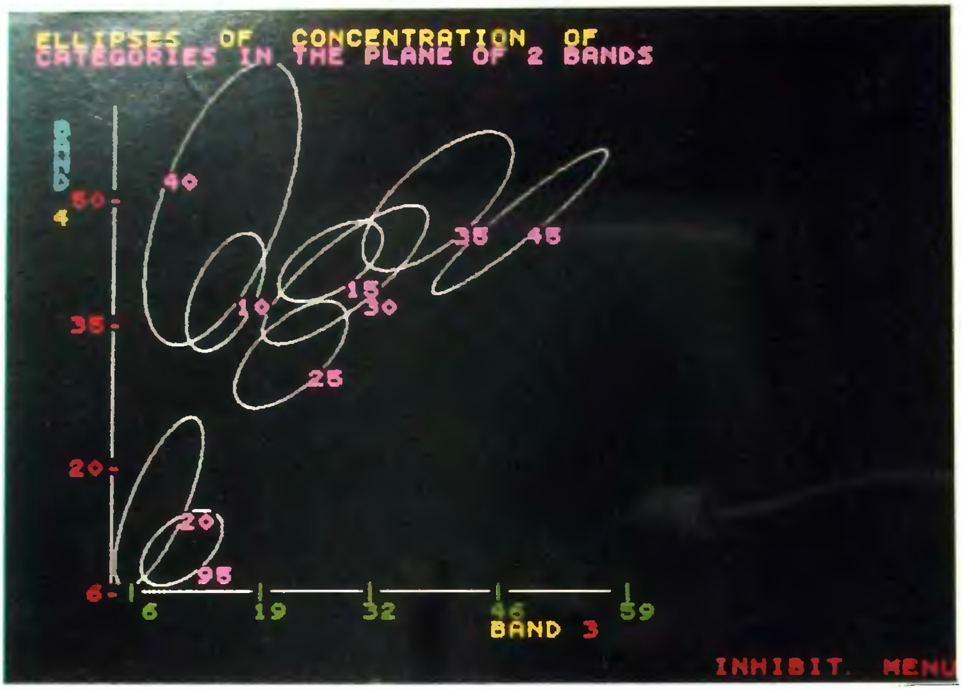

Figure 1b. Overlap of categories within the feature space defined by IRS-1A bands 3 and 4 (10-Udic haplustalfs; 15-Typic/Udic ustorthents; 20-Lithic usthorthents; 25-Udic chromusterts + Vertic ustochrepts; 35-Udic/Typic chromusterts; 40-Lithic/Typic ustorthents; 45-Typic ustorthents; 95-water.

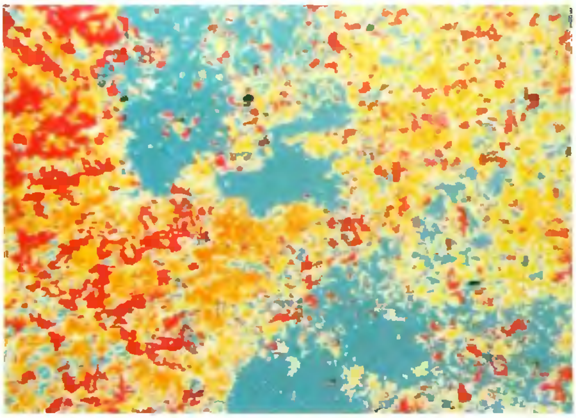

Figure 2. Soil map of a part of Pollachi and Udumalpet taluks of Coimbatore district, Tamil Nadu. (yellow - Typic ustorthents, coarse loamy; orange - Typic ustorthents, fine loamy; cyan - Typic chromusterts; red - coconut plantation)

Soil mapping in complex geologic terrain

Soil map of area-II in Narmada basin generated initially, manifested 8 mapping units (Figure 3). A priori knowledge about the area indicated 6 possible taxonomic classes, aside from the phases of erosion. Of these, three soil classes, viz. Udic haplustalfs, Typic ustipsamments and Lithic ustorthents were discerned as pure units. Udic and Typic chromusterts (U/TC), separable more on conjecture than on directly observable or measurable pedon characters, were not segregated. Even in ground surveys at reconnaissance level separability of these two subgroups is difficult to achieve.

The confusion matrix for the classified output revealed that an association of Typic ustorthents and Vertic ustochrepts (TU+VU) overlapped three other mapping units. This is also evident from the plot of spectral reflectance (Figure 1a) and eclipses of categoric concentrations illustrated in figure 1b. Here, overlap is related to feature space defined by only two bands of visible red and near infrared out of the four IRS bands, but these are the regions that are most favourable for discrimination of soil classes[7]. Substantial encroachment of TU+VU in basaltic region and consequent extinction of U/TC in the initial output were verified from available soil map.

Pedologically, under the mild leaching conditions of the area, parent rock and relief seem to have overriding influence on soil development. The entire basaltic terrain of the study area being plain, barring local relief variations, geologic variability

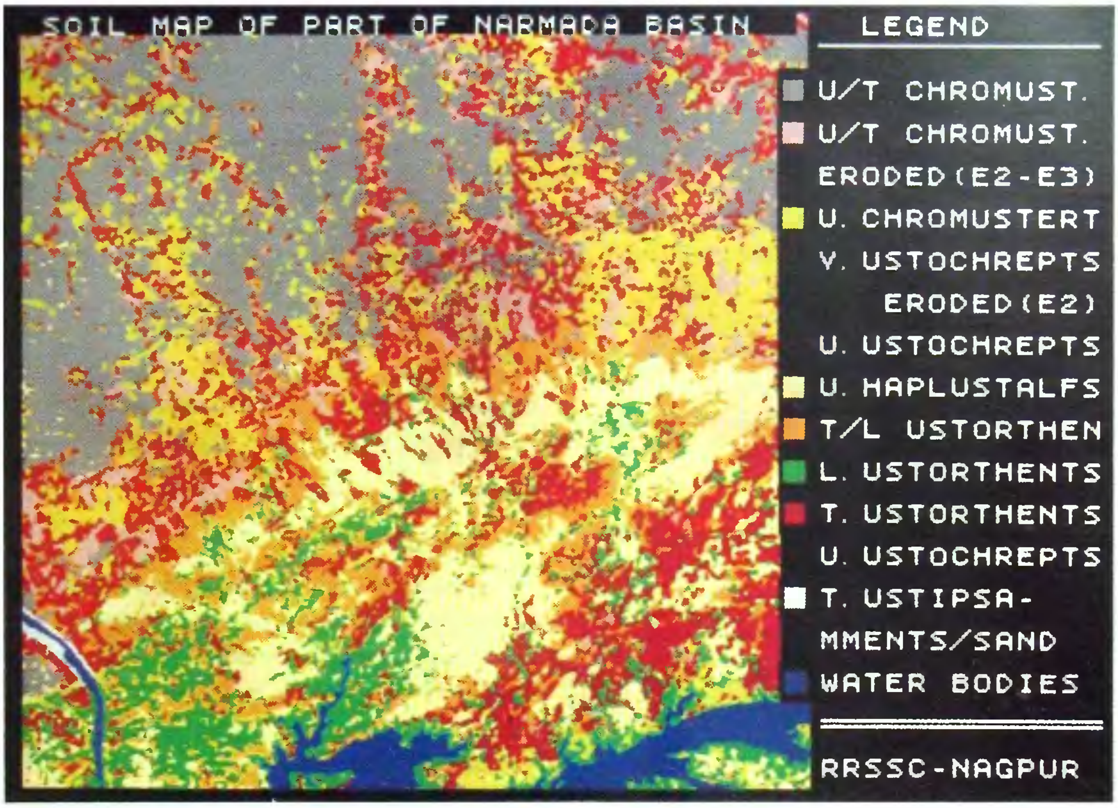

Figure 3. Soil map of a part of Narmadasagar catchment generated by the standard classification approach.

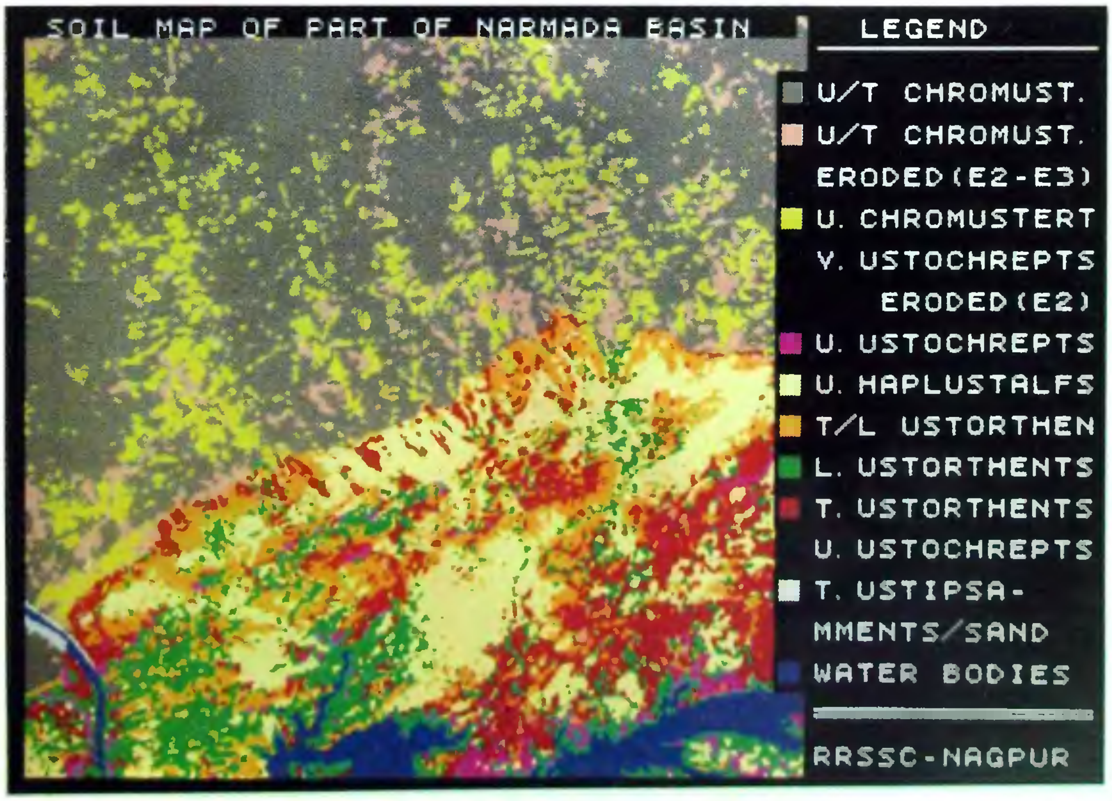

Figure 4. Soil map of the same area as in figure 3, produced by stratified classification.

was logically associated with soil variations. The scene was therefore, stratified on the basis of geological formations and each stratum classified independently. This enabled differentiation of spectrally similar, but taxonomically distinct soil classes developed in the areas from basaltic and Gondwana formations. The results are illustrated in figure 4, which not only show good correspondence with the existing soil map, but also manifest an increased number of polygons and more sharper boundaries compared to the latter. Interestingly, Udic ustochrepts that defied separation with standard procedure are registered as à pure unit on the stratified output.

Data furnished in table 1 brings out the variability between the initial product and the stratified classification output. It thus follows that notwithstanding spatial and spectral qualities of remotely sensed data, point classifiers alone do not seem to give satisfactory results, especially in situations that require awareness of context, and knowledge of pedogenesis. The stratification in the present study provided locational elements of site and association as adjuncts to DN, akin to the layered approach of classification.

Table 1. Comparison of soil classes derived from standard classification approach(1), and stratified iterative procedure(2), for an area of complex geology in Narmada basin

Soil class	Areas (ha)		% of study area	
	1	2	1	2
1. U./T.Chromusterts	8446.9	13964.9	24.87	41.10
2. U./T.Chromusterts (e_2-e_3)	1756.6	1782.8	5.17	5.24
3. U.Ustochrepts	–	620.8	–	1.83
4. U.Haplustalfs	4016.4	3926.1	11.82	11.55
5. T.Ustipsamments	52.5	52.5	0.16	0.16
6. L.Ustorthents	3241.8	3188.8	9.54	9.39
7. T./L.Ustorthents	3886.2	2761.9	11.44	8.13
8. Assoc.U. Chromusterts & V. Ustochrepts(e_2)	3756.7	2801.8	11.06	8.25
9. Assoc. T. Ustorthents & V. Ustochrepts	7674.5	3737.5	22.59	11.00

T.- Typic; U.- Udic; L.-Lithic; V.-Vertic; e_2-moderately eroded; e_3-severely eroded.

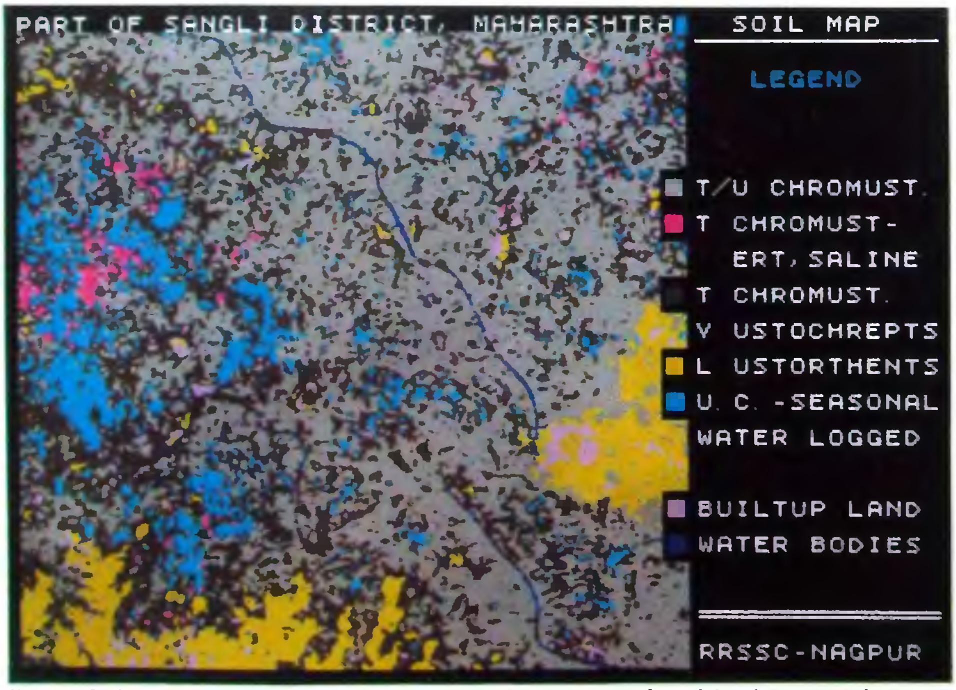

Figure 5. Soil map of a part of Sangli district generated by referential refinement using two seasons data.

AREA AFFECTED BY SALINITY AND WATERLOGGING

In case of area-III in Sangli district, neither the November scene nor the May scene separately allowed extraction of both the salt affected and water logged soils. The November scene provided better mapping of waterlogged areas, whereas the May scene, of the salt affected soils. Aggregation of the two products resulted in more reliable soil map as illustrated in figure 5. Interestingly, many of the waterlogged and salt affected soils captured on this output, which has been ground validated were found missing on the conventional soil map. Similar results have also been recorded in an earlier study in Nagpur district at a reconnaissance level[2].

CONCLUSIONS

The results demonstrate that IRS LISS-II data in conjunction with appropriate methodology, adjusted to the pedogenic realm of the area, provide details and definitions of soil features that are not always recorded even in ground surveys of reconnaissance and semi-detailed intensities.

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