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FOREST TYPE DELINEATION FROM SPACE BORNE DATA USING VISUAL AND COMPUTER AIDED TECHNIQUES A CASE STUDY FROM EASTERN HIMALAYAS, INDIA

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ABSTRACT

Space borne resource data have shown a great utility for forest resource survey in unexplored areas and for monitoring forest land use changes. In unexplored areas the maps become valuable tool showing spatial distribution of resources for formulating management plans. In India, Landsat data are being used for first level/ broad level stratification by using visual and computer aided techniques. The various studies carried out in India, so far, have met with limited success and have posed problems with respect to accuracy and its operationalisation.

The paper deals with a case study carried out in north eastern region of the country which is rich in forest wealth equally being over exploited and degraded due to shifting cultivation. The study area covers lower reaches of Arunachal Pradesh of four Landsat scenes. It is a part of eastern Himalayas having physiographically controlled vegetation. The classification stipulated in the present study shows considerable similarity with the forest types described on the basis of structure, composition and physiography. The problems encountered in the classification have also been highlighted and attempts have been made to overcome them by using visual techniques using raw as well as digitally enhanced data, wherein collateral information has been combined while doing interpretation.

The study demonstrates the usefulness of spaceborne data for forest type delineation in a difficult and unexplored terrain, and also deals with some techniques of extracting such information.

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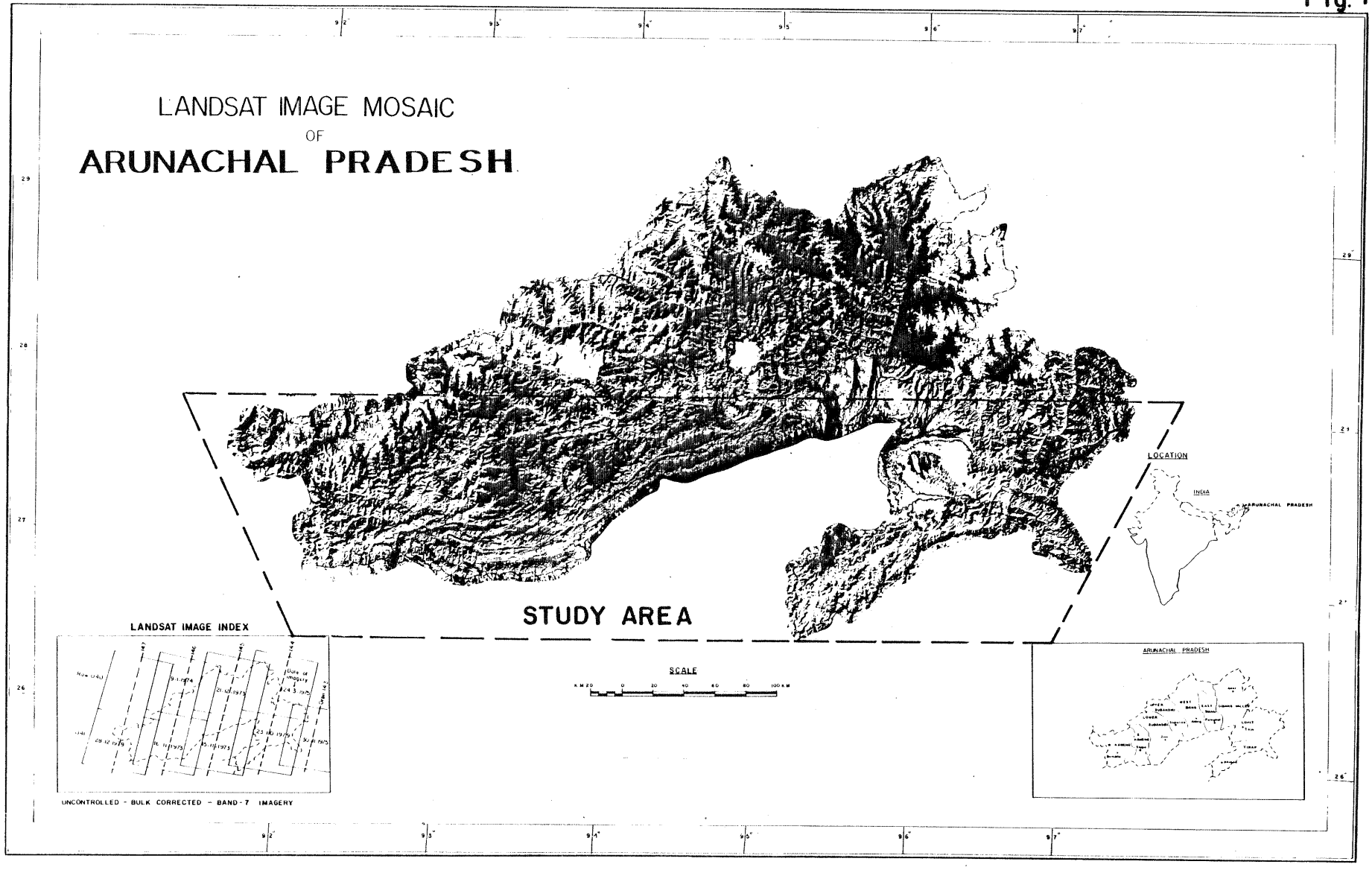
INTRODUCTION

Satellite remote sensing has shown great utility for forest resource survey in unexplored areas and for monitoring forest land use changes. In unexplored areas the maps become valuable baseline information showing areal distribution of resources for formulating management plans. In India, Landsat data are being used for first level/ broad level stratification by using visual and computer aided techniques (Roy & Unni 1980, Roy 1983 NRSA reports 1977, 1978, 1979a & b, 1981 and 1988). These studies indicate that the space borne multispectral data has immense utility in forest type mapping and monitoring forest areas over a specified period. While the studies carried out so far have yielded encouraging results, several problems are also posed with respect to accuracy and its operationalisation. The present study deals with a case study carried out in the north eastern region of India wherein efforts are also made to address alternative techniques to improve the interpretation accuracy.

The study araea covers lower reaches of Arunachal Pradesh and is covered by four Landsat scenes (Fig. 1). Arunachal Pradesh covers a major part of eastern Himalayas having altitudinally controlled vegetation, dense in its growth and diverse in its rich species content. Its geographical location, climate and topography have all contributed to the characteristic vegetation and flora of the area. Forest, being the primary source of income, is established as the nucleus for its economical growth. Proper exploitation and management of the forest resources, thus has become a challenge for the forest managers of the Union territory. Due to its strategic location, till recently, the forest wealth of this part of the country was left to its destiny in majority of the areas. In the eastern part of the Union territory where most of the economically important timber species, viz.,Terminalia myriocarpa and Dipterocarpus macrocarpus grow, extraction procedures were existing. In the recent years, depleting forest resources in the neighbouring states and other parts of the country has put a lot of pressure on the forest resources of Arunachal Pradesh. The shifting cultivation, which is a common

Fig. 1



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practice in the north eastern region is not practised with same intensity throughout the union. The tribes, viz., Shedukpens, Mijis, Akas, Nishis, Sulunga, Tegins, few clans of Adi, Idu Mishmis, Singhhos, Tangsas, Nootes and Wanchos have been following this primitive technique. In the domain of such tribes only, shifting cultivation had posed serious problems of soil erosion, denudation, degradation and retrogression of forests. A forest resource map of the entire union territory is a prerequisite to make effective management decision. But so far no map has been produced which delineation tree clad forests with respect to their type, areal extent and their layout in relation to the non forest areas. The present study is a part of the integrated multidisciplinary survey of the union territory using remotely sensed multispectral data from Landsat.

Classification of forest types:

Champion and Seth (1962) in their "Revised forest types of India" have not classified the forests of Arunachal Pradesh. However, above authors and Forest Atlas of India (1976) have digrammetically put the areas under following categories

i) Tropical Wet Evergreen Forest

ii) Montane Wet temperate forest.

iii) Subtropical Pine forest,

iv) Subalpine, and

v) Alpine forests

The compilation of ground survey records suggest that Arunachal forest can be compared with the following types described by Champion and Seth (1962) for adjoining states:

Assam Valley tropical forest)1/B/C1)

These forest occur in Tirap district upto the altitude of 610 m. The main tree species of these forests are: Dipterocarpus macrocarpus, Shorea Assamica, Mesua ferrea Altingla excelsa, Dysoxylum procerum, Artocarpus chaplesha, Michellia sp, Stereospermum Personatu m, Amoorawallichii.

Upper Assam Valley tropical evergreen forest (1/B/C2)

Areas adjacent to Dulang RF of Assam can be put in this category where Kayea assamica and Mesua ferra, dominate in patches. Kayea forests have Dysoxylum procerum, Exhinocarpus sp. Mesua ferra, Pterospermum sp. Terminalia chebula, Amoora wallichii, Canarium sp as associates. Mesua forests have Ailanthus grandis, Echinocarpus sp. Michelia doltsopa, Quercus landlosa, Tetramples nudiflora, Dysoxylum hamiltonii, Altingia excelsa as associates.

Assam alluvial plains semi evergreen forest (2/B/C1/Ia)

A closed evergreen high forest include a varying proportion of deciduous trees mainly as a broken top storey. Buttresses are a common feature. These forest confine to the vicinity of tarai stream. No single tree is dominant in such forests. The main species in order of frequency of their occurrance in the top and the middle storey are as follows:

Ammoora waqllichii, Pterospermum acerifolum, Stereospermum chelnoides, Altingia excelsa, Duabanga sonneratoides, Bischofia javanica, Canarium bengalensis, Gmeline arborea, Toona ciliata, Sterculia villosa, Ailanthus grandis, Terminalia chebula, Artocarous chaplasha, Chukrassia tabularis, Cinnamomum ceeicodephne, Castanopsis, sp. Therminallia myriocarpa, Dillenia indica, Morus laevigata, Dysoxylum binectiferum, Talauma hoodsgonii, Macranga denticulatum, Kydia calycina, Anthocephalus cadamba, Gynocordis odorate, Ites chinensis, Garcinia sp.

Sub Himalayan light alluvial Semievergreen forest(2/B/C1 b/ISI)

The top storey is composed of an admixture of evergreen and semi deciduous and deciduous species. The trees in the middle storey are evergreen in nature dotted with semi deciduous and deciduous species. This form is stretched from Bhairabkund to Sonairupai river. The dominant species of these forest are: Phoebe goalparensi, Terminallia myriocarpa, Amoora wallichii, Artocarpus chaplasha, Tetramoles nudiflora, Bombox ceiba, Ailanthus grandis, Alstonia scholaris, Pterospermum acerifolium, Duabanga sonneratoides, Magnolia sp Kydia calycina, Sterculia villosa, Castanopsis sp Toona ciliata, Chukressia tabularis, Lannea granids, Altingia excelsa, Adina obigeocephela, Stereospermum chelnoides, Ficus sp Terminalia belerica, T. chebula, Artocarpus chaplasha, A. lakoocha, Morus laevigata, Dillenia indica, Mesuaferra and Talauma phellocarpa.

East Himalayan moist mixed deciduous forest (3C3/3B)

These forest occur in well-drained bhabhar terraces in the heavy rainfall zone of the eastern Himalayas. A tall, more or less closed forest in which the individual trees often run to large sizes. The composition of the forest is as follows: Bombax ceiba, Lagerstromea parviflora, Terminallia bellarica, Sterculia villosa, Schima wallichii, Dillenia indica, Delbergia sisso.

Eastern Hollock forest (Terminalia myriocarpa) (3/C/IS2)

This may be called an edaphic formation of semi-evergreen forests. Hollock (Terminalia myriocarpa) is the predominant species of this type. Common associates of this subtuype are the following: Dillenia indica, Terminalia belarica, Sizyzium qiminii, Albizzia lucida, Artocarpus chaplasha, Lagerstromea speciosa, Canarium resiniferum, Dysoxylum binecteriferum, Bischofia Javanica, Castanopsi sps.

East Himalayan subtropical wet hill forest (8/B/C1)

These are hill forest of good height and density. The dominant species being mostly evergreen, although, some large briefly deciduous trees occur (eg. Betula)in pure consociations at places. It is distributed in the lower slopes from about 1000m to 2000m. The main tree species of these forests are:Phoebe paniculata, Actinodaphne obovata, Alnus nepalensis, Phoebe attemiata, Beilschi-miedia roxburghiana, Engelhardtia, Quercus fenestrata, Calophyllum polyanthum, Wightia sp. Castanopsis indica, Evodia fraxinifolia, Quercus glauca, Stachyurus himalaicus, Savravia cerea, S. punduana, Ficus gasparrinniana, Bytyneria aspera, Bauhinia veriegata, Gynocar-dia odorata, Kydia calycina, Magnolia pterocarpa, Prunus nepalensis, Sterculia indica, Callicaroa arborea.

Subtropical Pine forest:

None of the subgroups described by Champion & Seth (1962) match with the Arunachal Pine forest. However, they closely resemble with the Himalayan subtropical Pine forests. Occurance of the

pine has been reported between 1000 m to 1800 m in the union. There are three species of pines viz., Pinus roxburghii, P. Wallichiana and P. armandi. These forests can be divided into two subtypes viz., medium pine and open pine. The latter subtype closely resemble with the Assam subtropical pine savannah. (III/9/DS_1).

East Himalayan wet temperate forest (IV/11/IIB/C1)

These are not so dense forest and have a open appearance. The storeyed nature is apparent. These forests occur between the altitude of 1750 m and 2750 m. Main tree species of these forest are: Quercus lamellosa, Quercus sps., Castanopsis indica (predominantly upto 2300 m). Acer Hookeri, A. eblorigum, A. pectinatum, Sympolcus spicata, Magnolia cambellii.

Naga hills wet temperate forest (IV/11/IIB/C_2)

Similar to type IV/11/IIB/C 1 , distributed in the higher hills along the Arunachal Pradesh/Burma border from 1800 m upward. Main tree species are Magnolia sp. Quercus sp. Michelia sp, Betula alnoides, Acer sp. Prunus sp, Bucklandia populnae, Alnus nepalensis.

East Himalayan mixed coniferous forest (IV/12/C_1/3a)

A dense evergreen forest type with the predominance of oak and Rhododendron. sometimes, deciduous species, viz. Most of the trees are hung with epihytic mosses. The altitudinal zone of this forest type is about 2300 m to 3000 m. The coniferous species of these forests are: Abies sp and Tsuga sp.

Abies delavayi forest (IV/12/C/3b)

These forest are reported between 2750 and 3350 m. This is a Chinese species (Abies delavalyi) and is common in pure stands near Piri. Rhododendron sp. are main associates.

East Himalayan subalpine Birch/Fir forest (V/C_2)

These forest have been reported from above 3000 m altitude, and are comprised mainly of coniferous species. The type of vegetation is characterised by Abies spectabilis, Cupressus torulosa,

Picea sp. Juniperus recurva, Larix griffithiana, Pinus wallichiana, Taxux baccata & Tsuga dumosa. The presence of some species show its dry temperate nature. Amongst the shrubs the common are: Barberis asiatica, B. Wallichiana, Eurya acuminata, Gaultherin fragranbissima, Photinia notomana, Vaccinium venosum.

Alpine scrub (VI/IS/C_3 and VI/16/C_1 and E_1)

The alpine vegetation occurs from about 4000 m to 5500 m altitude. Here tree species are generally replaced by shruby species, viz. Rhododendrop sp. Lerbanecop sp. Primula sp. Polygonum sp. Savssurea sp. Sedum sp. Saxifraga sp, etc.

Bamboo brakes

Open tract of Bamboos are found throughout the union territory upto the altitude of 1800 m. These conform to edaphic & serate type of semievergreen forest and can be put under secondary moist bamboo brakes (2B/2S). In the abandoned shifting cultivation areas bamboos are the pioneers. Common bamboo species of the union are Bamboosa palida, Bamboosa sp. Dendrocalamus hamiltonii. D hookeri, D. Strictus, Psuedostachyum polymorphum, Cepholastachyum latifolium, Chimonobambusa collosa.

DATA AND METHODOLOGY

The present study was carried out with following data inputs:

I. Remotely sensed multispectral data obtained from Landsat. The table I shows the path/row and date of the Landsat scenes.
II. Ground data collected from sample areas of the study area and
III. Ancillary data, like toposheets, earlier records and publications, etc.

Table I

Path/Row	Date of Scene
147 - 041	24.12.1975
146 - 041	16.11.1973
145 - 041	15.11.1973
144 - 041	23.10.1979

The study was accomplished in following seven phases

1. Preliminary visual interpretation of Satellite data to aid ground data collection
2. Ground data collection
3. Preliminary computer analysis
4. Field verification
5. Final classification
6. Image enhancement and reclassification
7. Map generation and area calculation

Preliminary visual interpretation

False colour composites were visually interpreted in order to stratify surface covers based on photographic elements. These were labelled during ground data collection.

Ground data collection

Ground data collection was planned to level preliminary stratification. The location of various forest cover types of not less than 20 acres were identified on topographical maps and information were documented in the ground truth proforma. Only areas having definite identification with respect to permanent ground features ie. rivers,lakes/ water bodies and hill ranges, were selected as training sets.

Ground data from representative cover types from approximately 150 locations widely distributed all over the study area, were collected. These locations were precisely marked on the toposheets and satellite imageries.

Preliminary computer classification:

Supervised classification technique was adopted to map the area on multispectral data analysis system (M DAS). Output of the preliminary classification was displayed on T.V. monitor. The renundant ground information were used to evaluatae accuracy of the classification. The training sets were changed or modified as required. Once the preliminary classification was completed, colour photographs of some selected areas showing classification of different surface covers were takenfor field verification.

Field verification

Classified output of doubtful areas were takento the field for the field verification. It was not possible t differentiate oak bearing

forest, therefore, such forests were put in broad forest type. Certain amount of misclassification with pine forest was observed in partially shadowed portion of the other forest types.

Final classification:

On the basis of field verification additional information was fed to the computer to improve upon the classification by deleting, adding or modifying the training sets. After appropriate modifications of the training set statistics, final classification was achieved. Each forest type and associated classes were givena separate colour.

Image Enhancement and reclassification

The linear contrast stretch and ratio techniques were used to enhance a part of scene 146-041 to enhance the different forest types/vegetation classes of the area. The images thus generated were visually interpreted. In addition to improve the accuracy of the forest classification band 4 of Landsat data was replaced by vegetation index and supervised classification was performed by using Multispectral Data Analysis System (M DAS).

Map generation and area calculation

The classified data were filmed in a interfaced optronic photo system. The colour transparencies thus generated, were printed in the form of map on 1:250,000 scale.The state boundaries and name of the important places were transferred from the toposheets.The state boundaries were also digitised through Data Grid Digitiser to calculate the area under different forest classes(Table 2).

RESULTS AND DISCUSSION

The classification stipulated in the present study is purelybased on the spectral properties of forest type. Therefore, the classes can not be directly compared with the classification of Champion & Seth (1962). However the classes identified through satellite remote sensing show considerable similarly with the forest types described on the basis of structure and composition. The following spectrally separable forest types and pure tree species have been identified.

TABLE 2
AREA UND ER DIFFERENT FOREST TYPE OF ARUNACHAL PRADESH PROJECT AREA

Sl. No.	Class Name	Area sq.km	%
1.	FOREST	26566.14	59.37
	1.1 Hollong	1283.22	2.87
	1.2 Nahor	639.84	1.43
	1.3 Semi evergreen type I	1657.65	3.70
	1.4 -do- II	5186.56	11.59
	1.5 Subtropical broadleaved	8538.87	19.08
	1.6 Subtropical pine	1248.85	2.79
	1.7 Temperate type I	6931.97	15.49
	1.8 -d o- II	338.80	0.76
	1.9 Conifer	145.59	0.33
	1.10 Open bamboo brakes	594.79	1.33
2.	SHIFTING CULTIVATION AND NON FOREST AREAS	6960.54	15.56
	2.1 Alpine grasslands	245.18	0.55
	2 2 Degra ded forest	1394.13	3.12
	2.3 Abandoned shifting cultivation Grassland/Bamboo/Shrubs	2242.18	5.01
	2.4 Denuded areas	2285.78	5.11
	2.5 Tea gardens	793.27	1.77
3,	OTHERS	11214.42	25.07
	3.1 Water/Swamp areas	132.17	0.30
	3.2 Hillshadow/Unclassified	6057.36	13.54
	3.3 Snow/Fog/Cloud/Sand	5024.89	11.23

I. Hollong forest:

These forest conform to Assam valley tropical wet evergreen forest types (I/1B/C1). Dipterocarpus macrocarpus is in pure form in these forest

II.Nahor forest:

These forest are similar to the sub group northern wet evergreen forest (I/1B/C, and I/1B/C2) Messua ferea is in pure form in these forest

III.Semievergreen forest type I

These forest conform to Assam alluvial plain semi evergreen forest(I/2B/C 1a)

Semievergreen forest type II

These forests conform to the Sub Himalayan light alluvial semi ever green forest (I/2B/C/ISI), east Himalayan moist mixed deciduous forest (I/3C/c/3b)

Subtropical broad leaved forest:

These forest conform with east Himalayan sub-tropical wet hill forest (III/8B/C1) and other secondary types

Sub tropical pine forest:

This forest typecomprises of medium to poor stocked pure pine species (III/8B/251 and III/9/C2)

Temperate forest type II

These forestconform with east Himalayan wet temperature forest (IV/11/IIB/C1) and east Himalayan moist temperate forest (broad leaved) (IV/12/C3a)

Temperate forest type II

These conform with Naga hills wet temperate forests (IV/11/IIB/C2)

Coniferous forest:

These forest resemble with east Himalayan moist temperate forest (IV/12/C3a) (Coniferous other than Pines)

Alpine Shrubs/Grass lands

This class includes shrubs/grass land of subalpine and alpine areas (VI/15/C3,VI/16/C1 and VI/16/E1)

Bamboo

Open pure bamboo brakes are classified under this type. The understorey bamboo bearing forests are not included.

Degraded forest

This represent open woodlands which are formed by degradation of forest by various reasons, like, edaphic or biotic. This also includes abandoned shifting cultivation areas.

Abandoned shifting cultivation areas and grass lands:

Abandoned shifting cultivation areas which have scattered trees and shrub growth have been classified under this category. In addition, open grass lands including high grasses of Apatani plateau have also been included in this type.

Shifting Cultivation areas and on forest

The area without any vegetation cover(clean shaved hills, settlements and fallow lands) has been classified in this category. Even standing crop has been included under this category.

OTHERS

Tea Gardens:

Tea gardens of Assam have also been identified partly.

Water features and Swampy areas:

Water bodies, rivers and swamp areas have been identified under this category.

Hill Shadow:

Due to hilly terrain spectral information of considerable part of the cover type is obscured by hill shadows. Such areas have been delineated in this category.

Cloud/Fog:

The terrain information under clouds and fog cannot be recorded by

optical satellite remote sensing techniques. So clouded and fogged areas have been put in this category.

The colour coded maps generated by computer aided classification show the areal distribution of forfest types and associated classes in the lower reaches of Arunachal Pradesh. The figure 2 shows the colour coded classified data of scene path/row 146-041.

The classification achieved by supervised classification showed the possibility of identifying the broad forest types and sometimes species when they occur in pure form in extensive area with fairly good accuracy. However, certain amount of misclassification was encountered in partial hill shadowed areas, subtropical pine forest showed considerable spectral similarity with other forest types.To overcome such problems a sample area was selected in scene path/row to test various enhancement techniques. It was found that linear contrast false colour composite can be used for preparing broad forest type map enabling the more accurate identification of subtropical pine, grasslands, bamboo brakes and temperate forest type I due to possibility of combining ground information and photographic elements.

The ratio techniques were also useful in identifying Nahor forest temperate forest type I, swamp areas and grassland areas. It was also possible to eliminate the partial hill shadow effect enabling the better identification of forest types.

A test area in a largerly hilly tract of scene 146-041 containing different forest categories was selected for reclassification by replacing Landsat band 4 by a band which enhanced the problematic forest classes. The supervised classification of Landsat multispectral data could not give high accuracy in case of degraded, bamboo, conifer (Fir) grasslands and swamp areas in the selected test area. The partial hill shadow has been main hinderance in classifying the fir forest and swamp areas. The classes like bamboo, degraded forests and grasslands got misclassified due to similar spectral properties. The established indices for quantifying vegetation, agriculture crop and soil moisture have been used to enhance problem forest/vegetation classes. The images derived using indices enhance swamp, grassland, bamboo, semi evergreen forest

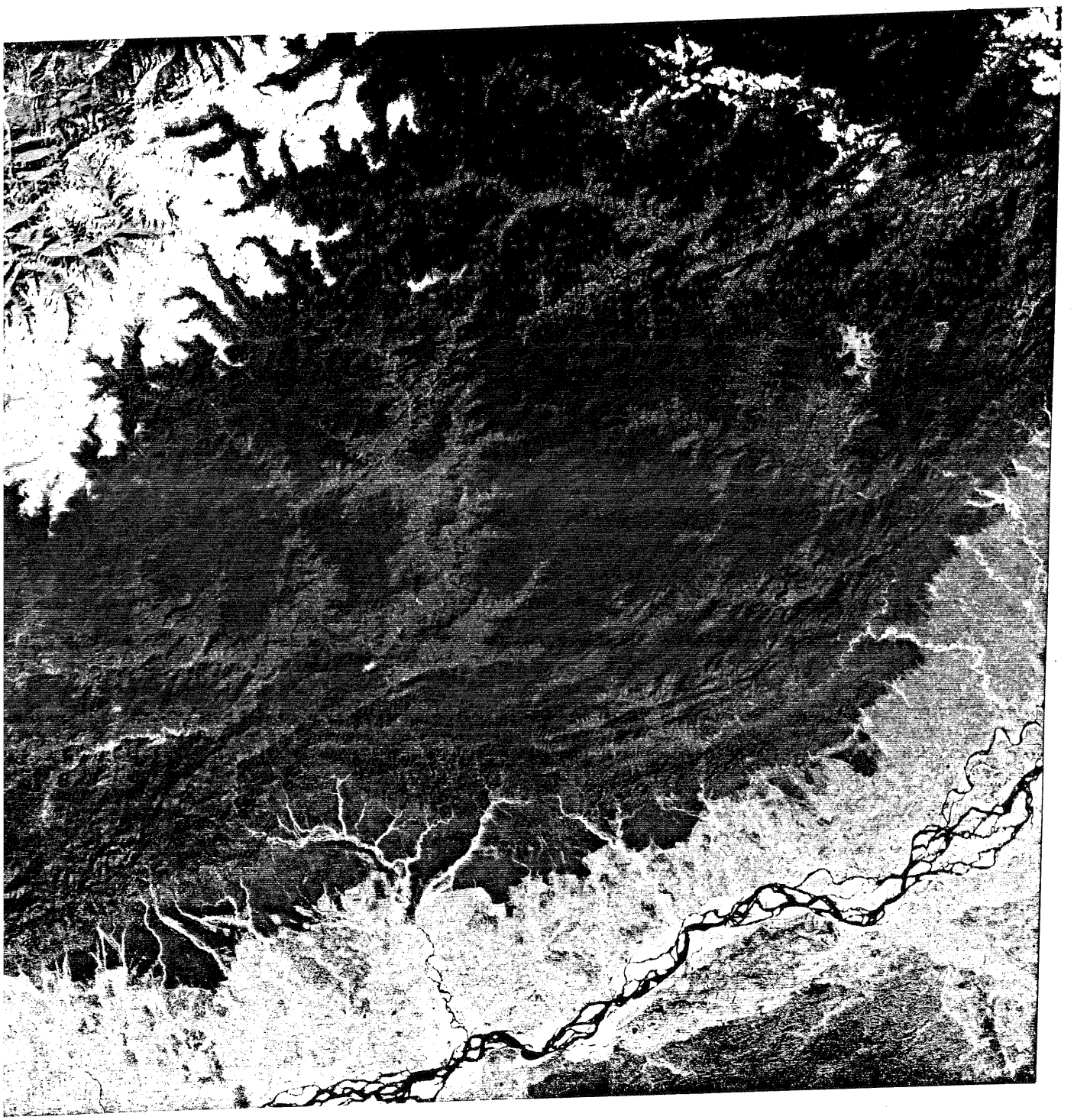
LEGEND

Semi evergreen forest type I	= Blue Green
Semi evergreen forest type II	= Greenish Blue
Subtropical broad leaved forest	= Green
Subtropical pine forest	= Purple
Temperate forest type I	= Bright Red
Bamboo brakes	= Cyan
Degraded forest	= Orange
Abandoned shifting cultivation/ grass land areas	= Ochre
Alpine shrubs and grasslands	= Bright Green
Denuded areas/shifting cultivation areas	= Bright yellow
Tea Gardens	= Grey
Water and swamp areas	= Blue
Hill shadow	= Black
Snow/Fig/Cloud	= White

FIG.2

Forest map of part of study area (Scene path/row 146-041) prepared by computer aided classification of Landsat MSS data.

Fig. 2



and degraded forest in different degrees. It was possible to eliminate partial hill shadow using various established indices. The vegetation index (7-5/7+5) showed best results and enhance most of the problem forest classes. On the basis of above observations band 4 of the normal Landsat data was replaced by vegetation index and supervised classification was performed using maximum likelihood classifier. The comparison of the classification results using normal Landsat bands and modified band combination showed that the later band combination not only provided the possibility of classifying more classes, like, Fir and tropical evergreen forest but the classification accuracy of the problem classes was improved by about 20%.

Thus, it can be concluded that although satellite remote sensing of forest can provide valuable information about broad type and distribution but when the requirement is detailed forest type mapping, coarse spatial resolution restricts its application. The enhancement techniques and use of ancillary information, like, altitude, aspect, slope will also help to improve the classification. The maps prepared in the study provide the synoptic view of the distribution of forest types and other landuse categories. They can be used as first level of information base for proper management and planning.

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