SILVICULTURE, MANAGEMENT AND UTILIZATION OF BAMBOO RESOURCES OF SOUTHERN INDIA (PHASE II) - ESTIMATION OF GROWING STOCK REMOTE SENSING TECHNIQUE

(Report of the project KFRI 135/92, sponsored by IDRC, Canada)

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CONTENTS

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INTRODUCTION

The possibility of cost effective mapping of natural resources including forests and other related features was realised when remote sensing data was made available in 1972. Forest resources being variable in space and also in time need to be quantified not only at one time, but also repeatedly at regular intervals to facilitate in monitoring these resources in interaction with other land use practices. The remote sensing technology has emerged with a promising potential to fill up the long felt gap of getting timely repeated and synoptic information on the natural resources. Remote sensing data represents a mixture of information pertaining to land surface features. The objective of a user is to extract information as much as precise as possible for his interest. The mapping of land cover and landuse pattern using remote sensing techniques often provides information of practical value in environmental planning and land development. Stratification of vegetation cover with respect to structural features is highly essential for resource evaluation. The estimation of actual area of different cover types and that of different strata in each vegetation cover in the most crucial part in resource evaluation.

The bamboos in Western Ghats are scattered throughout the forests both in evergreen and moist deciduous types. Most of the areas are inaccessable due to undulating terrain features. Due to highly heterogenous nature of the cover types, the distribution and deleniation of bamboo areas in the tropical region and the resource evaluation is an herculian task if we adopt the conventional ground survey methods. At the same time it is highly necessary to get an idea regarding the bamboo stocks, since more than 90% of the bamboo resource are getting from forest land in tropics. Hence, here an attempt is made, on experimental basis, to standardize the techniques of stock mapping using remote sensing data. Here, both satellite data (IRS-1A and Landsat TM) in the form of FCCs and CCTs and aerial photographs (1:15,000 Black & White) are used in the study. The identification and stratification of bamboo area with respect to its density status was the major aim of the study and thus to establish the feasibility of the use of remote sensing data in natural resource evaluation, especially in bamboo stock mapping.

Stock mapping using remote sensing data

The stock map depict forest types, density parameters, regeneration status and an idea about the available resources. The stock maps are used for classifying the crop into homogenous structure for planning enumerations and prescribing treatment to the forest land. The conventional method of making stock map is by ground survey and is made on a topographical base map. The stock mapping in the conventional method is easy in homogenous tracts. Due to various other resaons the forest compartments are highly heterogenous, especially in tropical regions. Hence the use of the conventional system of stock mapping has its limitations. Moreover the density of forest stand is fast changing. The difficult habitat conditions make ground survey extremely difficult and call for their minimization through appropriate strategies. This is essential not only for reducing the cost but also for making the inventory efficient. Looking to this changed situation, use of remote sensing techniques has become inevitable. Use of aerial photography in stock mapping in India was started by Tomar (1976) followed by Tiwari (1978) and Shedha (1979). Except the heavy cost and difficulty in procurement of aerial photographs, the aerial photographs are highly useful in stock mapping. The experiments on bamboo stocking mapping was done at this juncture, since large scale aerial photographs (1:15,000) are available for the selected regions. This existing latest photographs can be used for identification of forest communities and for density stratification. Similarly, satellite remote sensing has been successfully used in classifying forest types and even in density mapping (Kimothi et al., 1986; Jadhav et al., 1988; Dabral, 1992 etc.). Visual interpretation methodology to update stock map from high resolution IRS Liss II data has been demonstrated by Jadhav et al. (1987). According to them, the boundaries of forest types, drainage, encroachments, cultivation patches etc., are much more reliable in the use of IRS Liss II data. The manual published by Space Application Centre (SAC), Ahemedabad (1990) for forest mapping and damage detection will give many details for preparing forest stock maps. The information about site quality, distribution of species, cover types, and age can be made use of while revising the stock map. The crown density/stock density parameter that changes fast cannot be derived from the past record. Hence, for updating stock maps or for the preparation of new stock maps for forestry purposes required recent information regarding stock density stratification. This determination of density of crop is much time consuming task and strenuous in the conventional stock mapping procedure, which takes more than 80% time of the entire procedure. Again the conventional stock mapping has limitations like difficulty in transversing systematically, survey through criss crassing, approximation in boundary deleniation and occular judgement which leads to subjectivity. The satellite remote sensing technique coupled with aerial photographs has been found very useful in density stratification of forest types. This technique is not only for more accurate than the conventional one but is quick and cost effective also. This forest resource stratification using remote sensing data was proved as an invaluable tool to carry out multiphase sampling (Harding and Scott, 1978).

STUDY AREA

The study area in Muthanga range (Nulpuzha region) ($76^{o}18'$ to $76^{o}21'$E Long. and $11^{o}36'$ to $11^{o}38'$ N Lat.) in Wynad district and Attappady region ($76^{o}30'$ to $76^{o}40'$ Long. and $10^{o}56'$ to $11^{o}12'$ N Lat.) in Palghat district of Kerala State (Fig. 1) are rugged and hilly with an elevation of 800m to 1000m above m.s.l. The average annual rainfall in the area is about 2000 mm and the monthly temperature ranges between 13^{o}C to 32^{o} C. The presence of different forest types with a wide range of bamboo habitats favoured the selection of these sites for the study.

Vegetation

The vegetation exhibits considerable variation in floristic composition and structure. The major forest types recognized in the area (Champian and Seth, 1968) are: West Coast tropical evergreen forests, West Coast semievergreen forests, Southern moist mixed deciduous forests, South Indian Moist deciduous forests and southern tropical dry deciduous forests.

DATA USED

The remote sensing data used for the present study are of the following types:

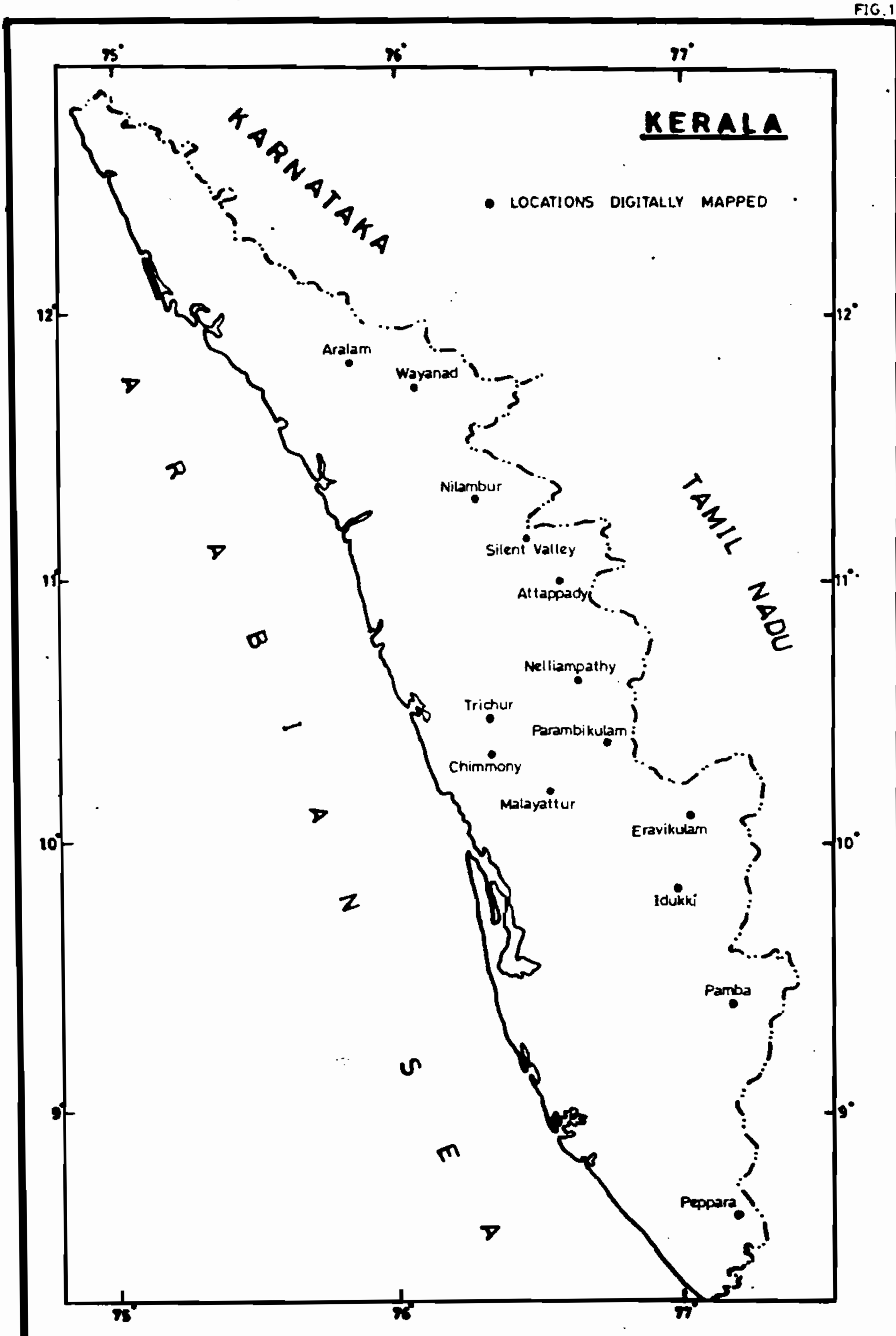
A) Satellite imagery

i. IRS 1A LISS-I FCC of band 2,3 and 4 of 1:250,000 - March 1988.

ii. IRS 1A LISS-II FCC of band 2,3 and 4 of 1:50,000 - March 1989.

iii. IRS 1A LISS I and LISS II CCTs of Feb. 1989 (path/row 25/61; 25/62 and 26/60 respectively)

FIG.1


KERALA
LOCATIONS DIGITALLY MAPPED
KARNATAKA
TAMIL NADU
ARABIAN SEA
Aralam
Wayanad
Nilambur
Silent Valley
Attappady
Nelliampathy
Trichur
Parambikulam
Chimmony
Malayattur
Eravikulam
Idukki
Pamba
Peppara
75°
76°
77°
12°
11°
10°
9°

B) Aerial photographs (Black & White) of the following specifications:

Scale - 1:15,000; Camera - RMK15/23, Focal length - 15.3 cm; Date of photograph - March/April 1986; Format size - 23 x 23 cm; Nature of print - Glossy and single weight; Overlap - forward 60 to 80%; lateral lap - 10 to 40%; Direction of flight - South to North; Film - Kodak XX aerographic panchromatic; Filter-D 12 x 256 cm.

C) Survey of India toposheets of 1:50,000 scale, 1:250,000 scale and 1:25,000 scale

D) Supplementary information available from Kerala Forest Department and ground truth information gathered during field visits.

METHODOLOGY

Visual interpretation

The standard remote sensing techniques based on various photoelements (Tomar and Maslekar, 1972) were adopted for visual interpretation of large scale aerial photographs (1:15,000 B & W). The photostratification scheme was adopted for the purpose of interpretation, using various photoelements such as tone, texture, pattern etc. Based on photoelements the necessary photointerpretation key was also prepared for the area (Table 1). The moist deciduous forests in the study area is further delineated into different sub-categories according to the density of bamboo. The bamboo mixed semievergreen patches are also delineated from other vegetation types. The maps thus prepared (FIGS. 2-5) was used for unit area estimation using Planix 5000 electronic planimeter. The classification of units into various height classes and density classes were also done using different photogrammetric methods. Based on the visual observations of homogenity and diversity, different stands of major vegetation types were selected for quantification study. The details are depicted in the flow chart (Fig. 6). The general classification of the area was done, using satellite false colour composite (FCC) of IRS 1 A LISS I, IRS 1 A LISS II and Landsat 5 TM and digital image processing of computer compatable tapes (CCTs).

Digital Analysis

The digital image processing was carried out on VAX 11/780 using VIPS-32 software available at Regional Remote Sensing Service Centre, Bangalore, using maximum likelyhood algorithm and supervised classification technique. The stratification of vegetation and deleniation of types were based don species composition and type physiognomy. The bands 4,3 and 2 in red, green and blue colours respectively, was used for preleminary appraisal of the study area and for F.C.C. preparation. The digital processing was done for different regions (Fig .1..).

TABLE 1. IMAGE CHARACTERISTICS OF THE LAND COVER CLASSES INTERPRETED AERIAL PHOTOGRAPHS AND SATELLITE IMAGERIES

Vegetation types	Aerial photographs			Satellite imageries	
	Tone	Texture	Pattern	Colour/tone	Texture
Semievergreen	Medium to light dark	Coarse	Smooth	Dull red	Medium
Semievergreen with Bamboo	Light dark	Medium	With intermittent	Light red	Coarse
Moist deciduous	Greyish	Coarse	Slightly rough pattern	Brownish	Coarse
Moist deciduous with Bamboo	Greyish white	Medium	With intermittent white patches	Greyish red	Medium
Pure Bamboo area	Greyish white to dull white	Fine/ Medium	Stellate, white circular patches with a point on the center uniform distribution	Greyish brown	Medium

Legend for Fig.2 & 3

....

EG	-	Evergreen
SE	-	Semievergreen
SED	-	Semievergreen degraded forest
MD	-	Moist Deciduous Forest
SA	-	Shola
MB	-	Bamboo Mixed (below 40%)
BM	-	Bamboo Mixed (40 - 80%)
B	-	Mainly Bamboo (81% and above)
SCO	-	Scrub open
SCD	-	Scrub dense
G	-	Grassland
PT	-	Plantation Teak
PP	-	Plantation Pepper
TB	-	Teak and Bombax
T	-	Mainly Teak
SO	-	Silver Oak
FB	-	Forest Blank
SP	-	Swamp
S	-	Shadow
A	-	Paddy Field
A1	-	Mixed Plantation
H	-	Habitation

DENSITY CLASS

1	-	Low Density
2	-	Medium Density
3	-	High Density

PLANTATION

Y	-	Young
O	-	Old

ANNOTATION EXAMPLE

MD/3 - Forest Cover Type/Density Class

SOI TOPO 49 M/13 - WAYANAD REGION

GRID INDEX

FIG.2

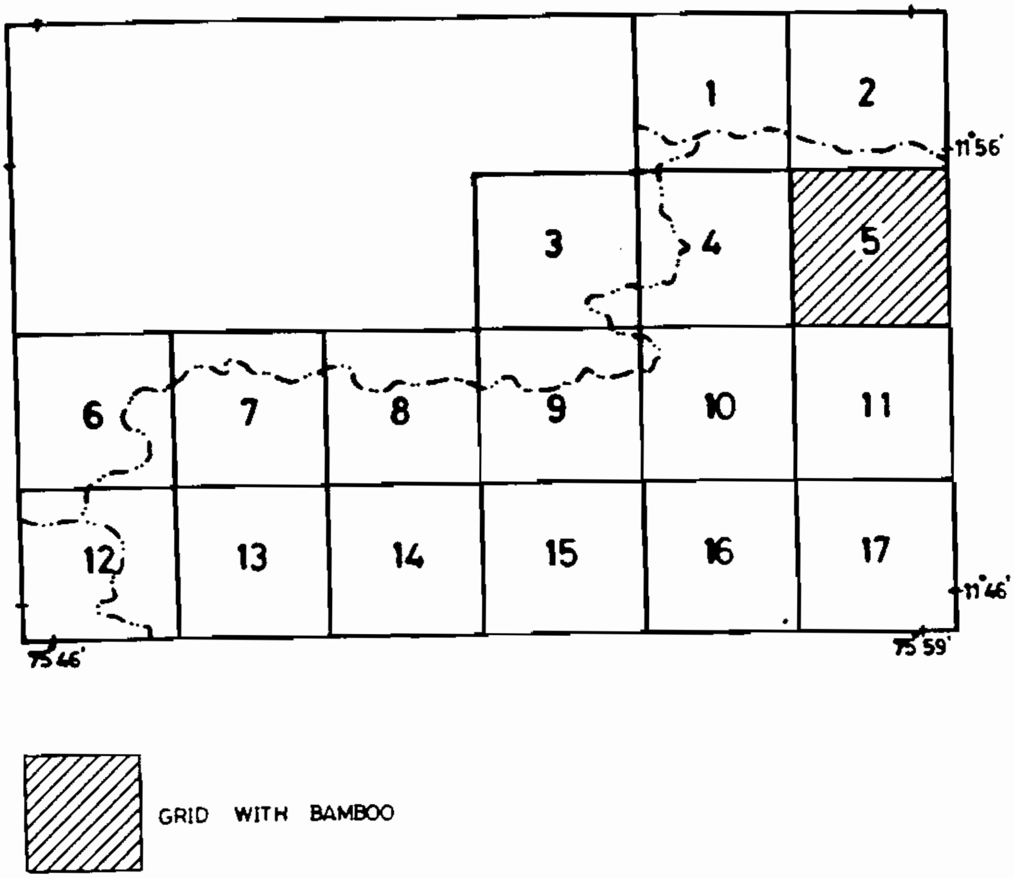


FIG. 2.1 ⑤

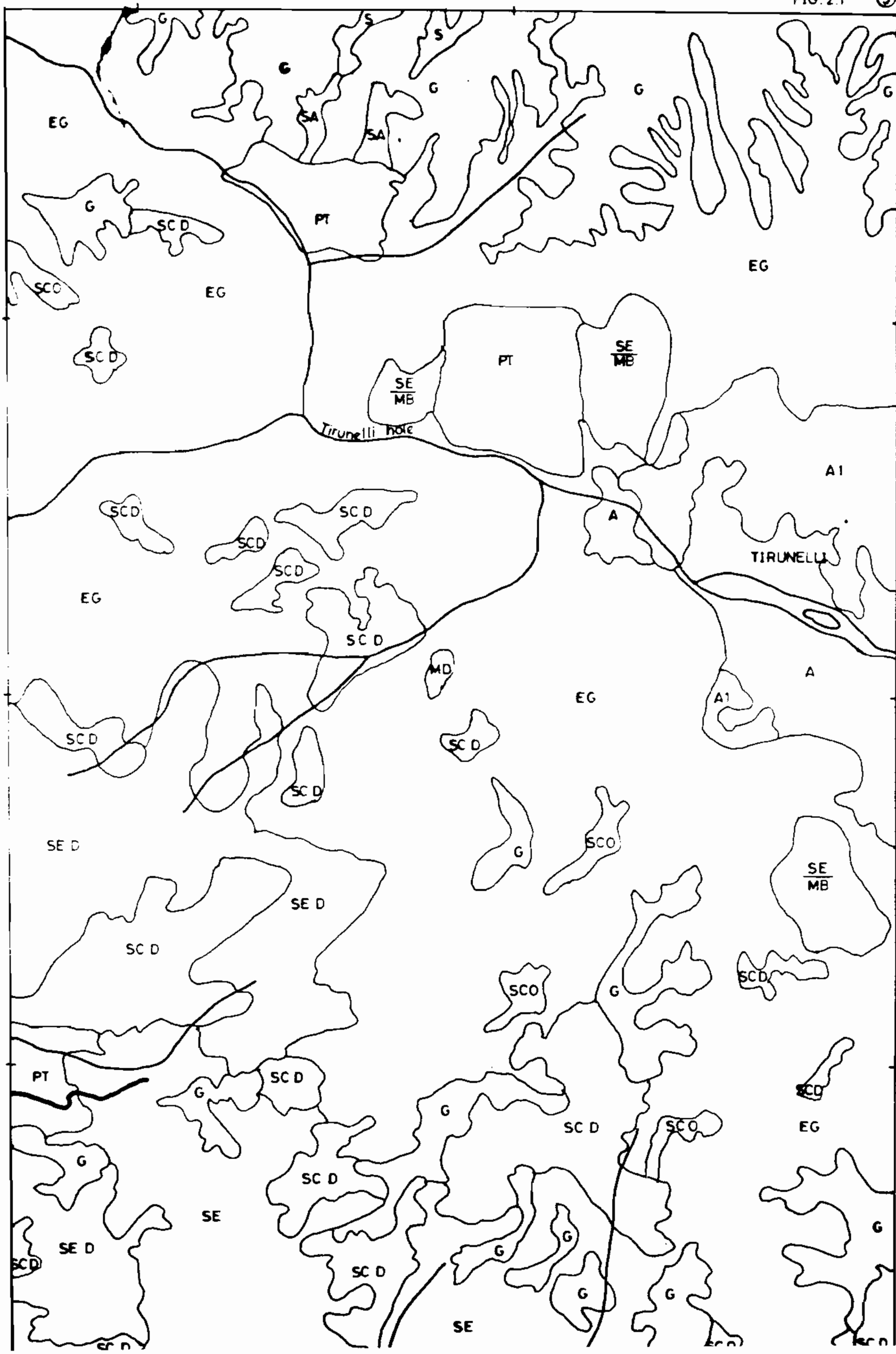
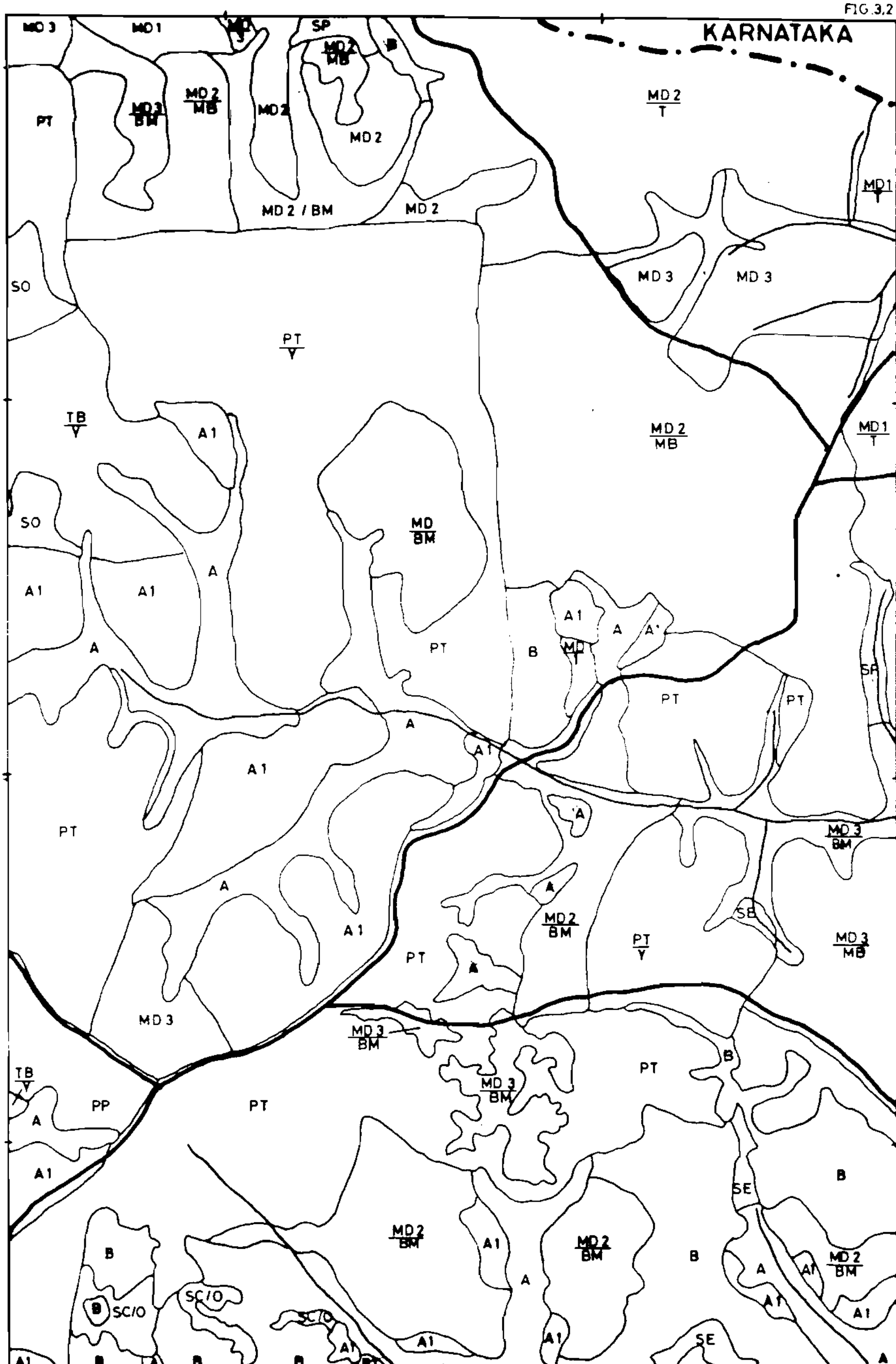

G
S
S
G
G
G
G
SA
SA
EG
G
SC D
PT
EG
SCO
EG
SC D
PT
SE
MB
SE
MB
Tirunelli hole
A1
SCD
SC D
SCD
A
TIRUNELLI
SCD
EG
SC D
MD
A
EG
A1
SC D
SC D
SC D
SE D
G
SCO
SE
MB
SE D
SC D
SCD
SCO
G
PT
SC D
G
G
SC D
SCO
EG
SCD
G
SC D
SE
SE D
G
G
SCD
SC D
G
G
G
SE

FIG. 3.2



KARNATAKA
MD 3
MD 1
SP
MD 2/MB
B
PT
MD 3/BM
MD 2/MB
MD 2
MD 2 / BM
MD 2/T
MD 1/T
MD 3
SO
PT/Y
TB/Y
A 1
MD/BM
MD 2/MB
A
PT
B
MD/T
SP
A 1
MD 3/BM
SE
MD 2/BM
PT/Y
MD 3/MB
MD 3
TB/Y
PP
B
SE
B
MD 2/BM
A 1
MD 2/BM
SC/O
SE
76 18'
76 19'

FIG.3.1

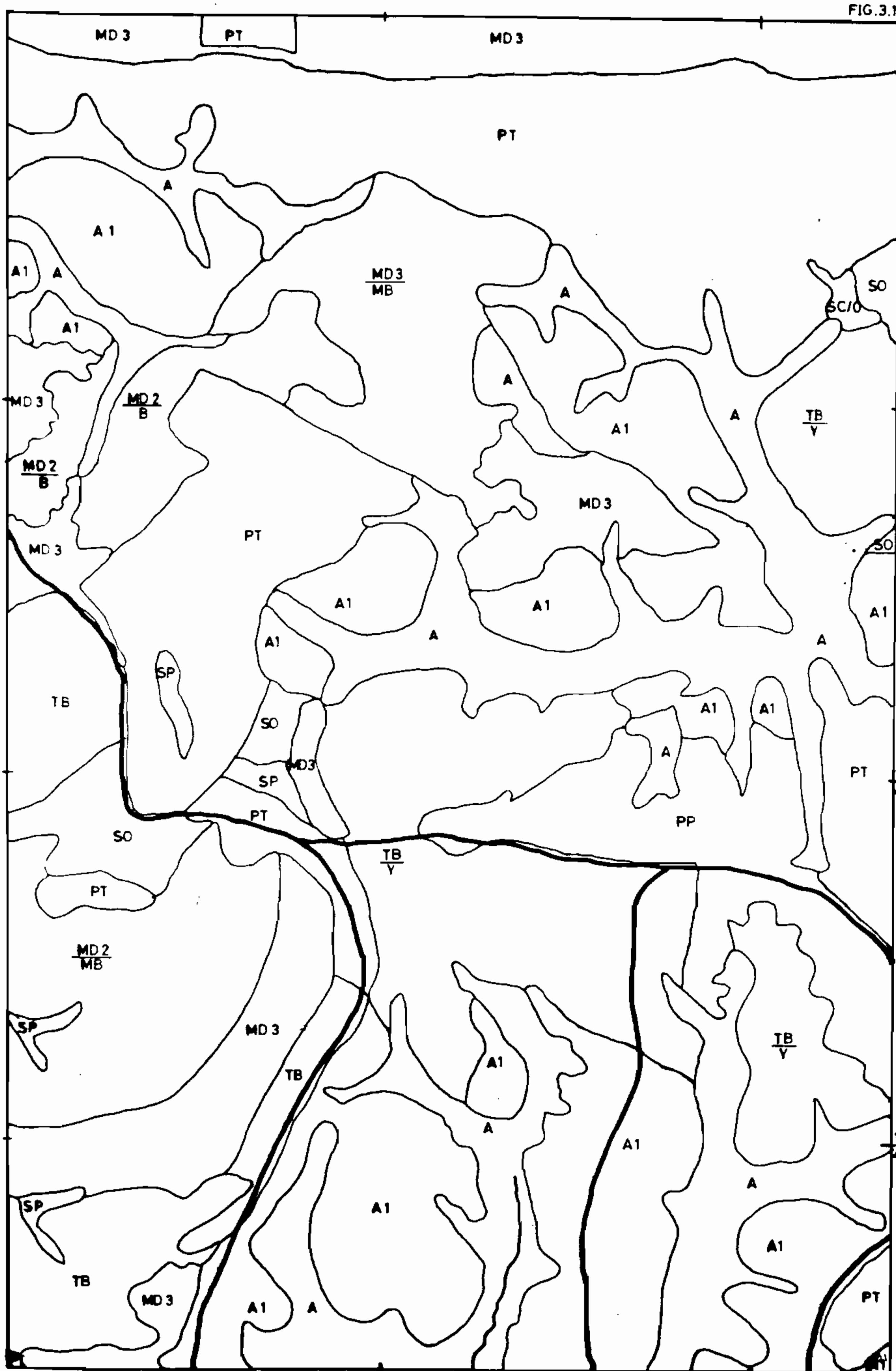
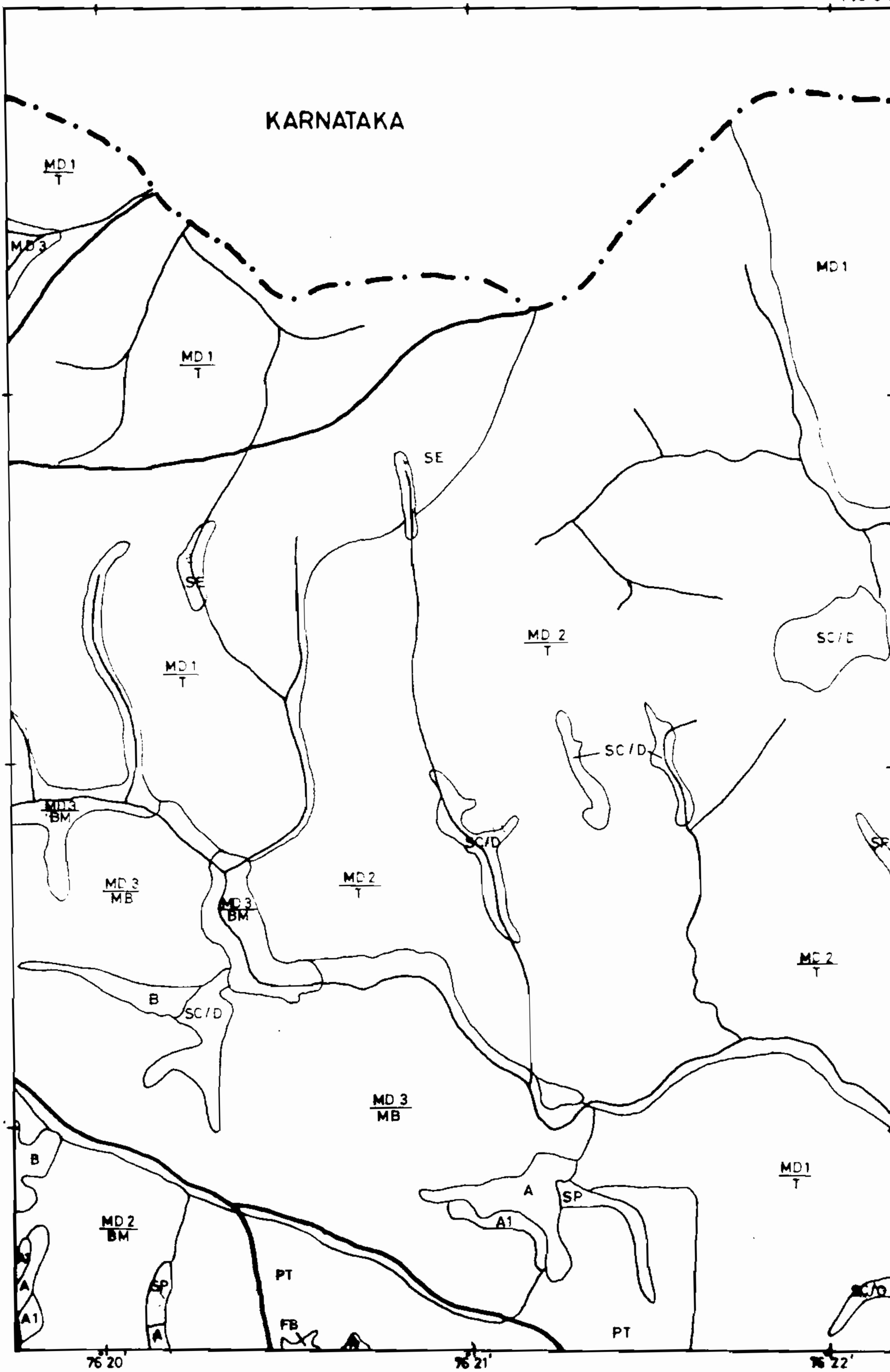

MD 3
PT
MD 3
PT
A
A 1
A1
A
A1
MD 3
MB
MD 3
MD 2
B
MD 2
B
MD 3
A
A
A1
A
TB
Y
SO
SC/0
MD 3
PT
A1
A1
A1
A
SO
A1
A
SP
TB
SO
MD3
SP
PT
A1
A1
A
PT
PP
SO
TB
Y
PT
MD 2
MB
SP
MD 3
TB
A1
TB
Y
A
A1
A
A1
SP
A1
TB
MD 3
A1
A
PT

FIG 3.3



KARNATAKA
MD 1/T
MD 3
MD 1/T
MD 1
SE
SE
MD 1/T
MD 2/T
SC/D
SC/D
SC/D
SC/D
MD 3/BM
MD 3/MB
MD 2/T
MD 3/BM
MD 2/T
B
SC/D
MD 3/MB
B
MD 1/T
A
SP
A1
MD 2/BM
PT
SP
A
A1
FB
PT
SC/D
76°20'
76°21'
76°22'

FIG.3.4

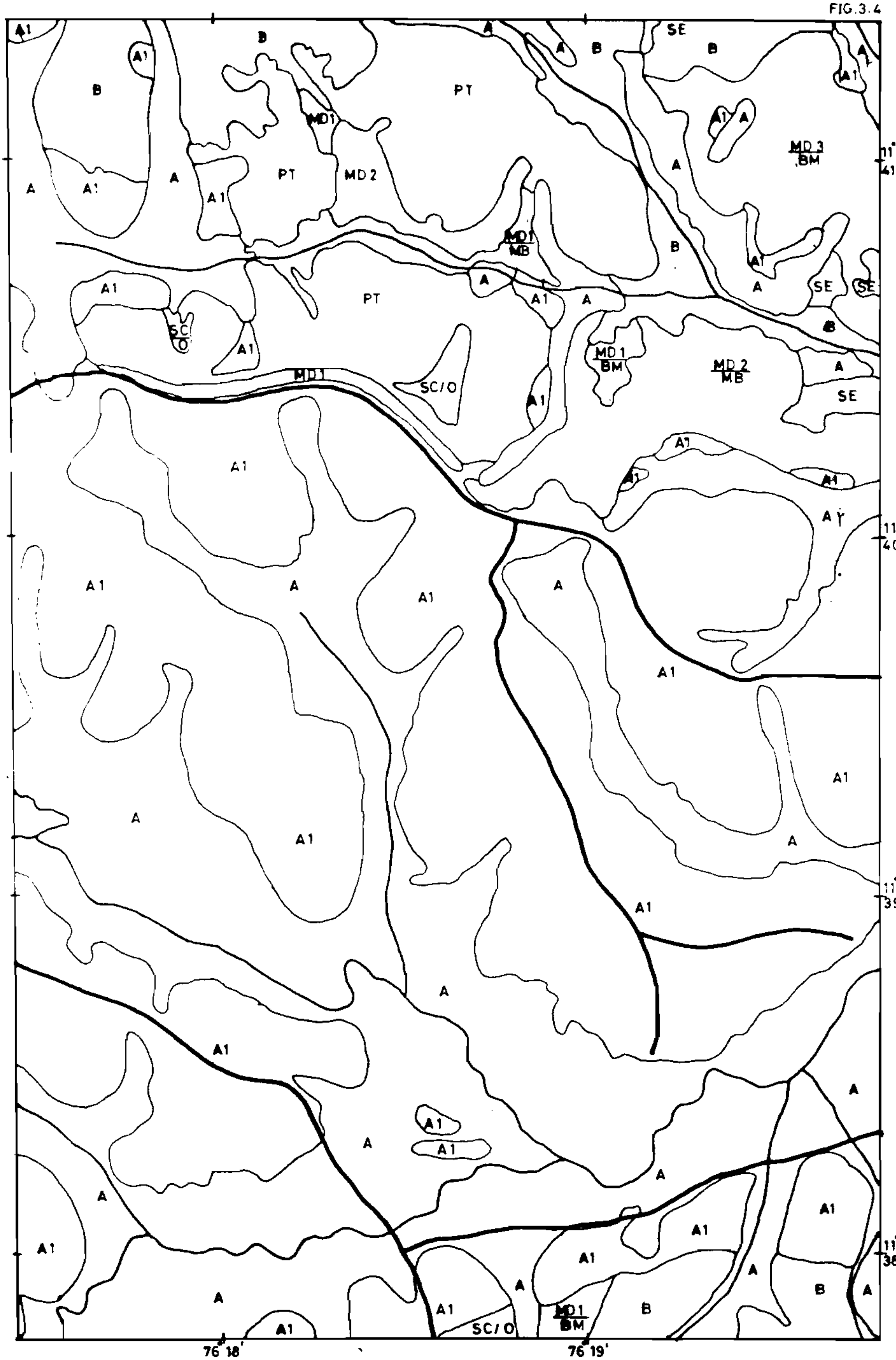
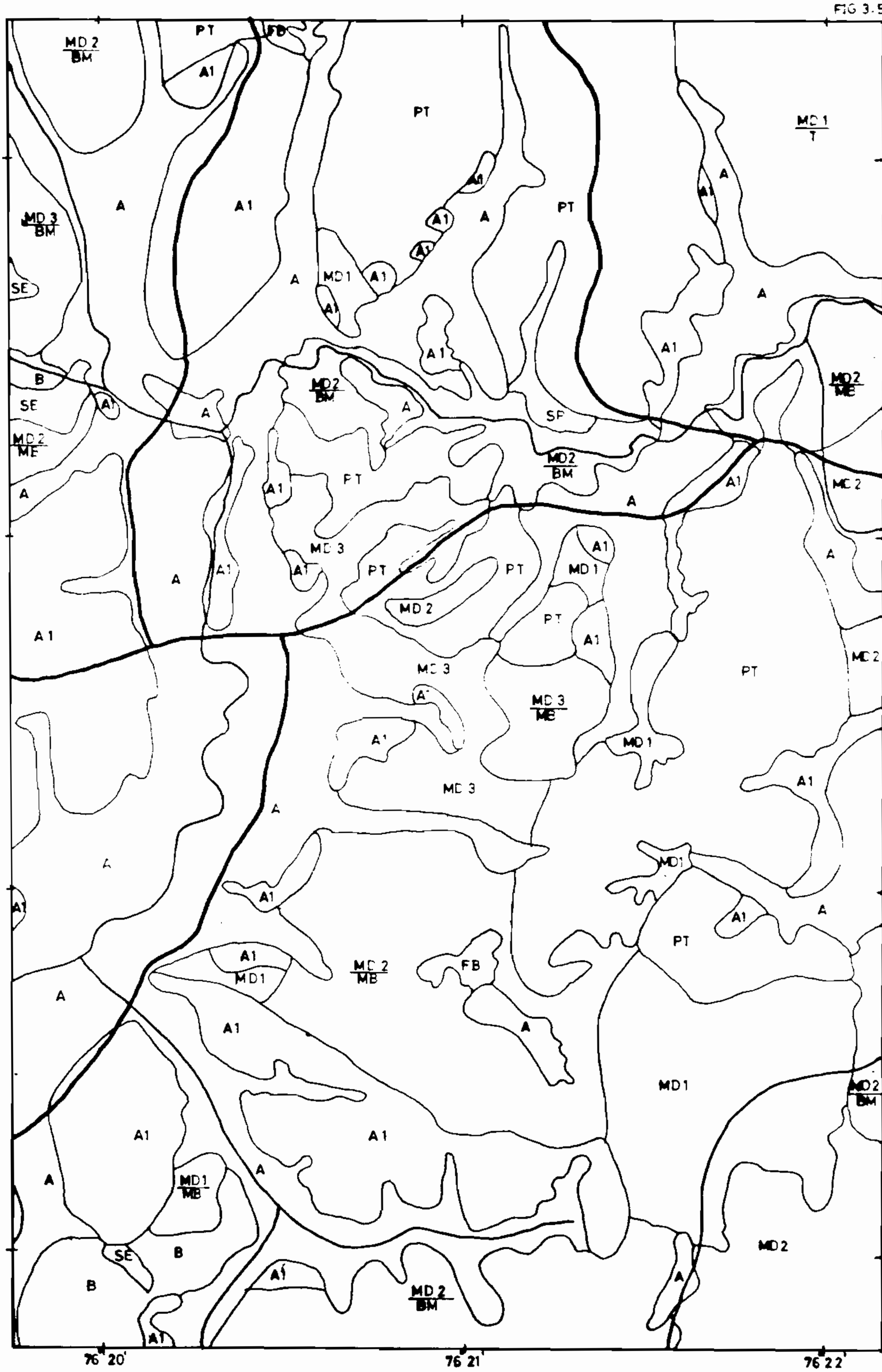


FIG 3.5



76°20'
76°21'
76°22'
11°41'
11°40'
11°39'
11°38'
MD 2 / BM
PT
FB
A1
MD 1 / T
MD 3 / BM
A
SE
MD 1
B
MD 2 / ME
MD2 / BM
SP
MD 2
MD 3
MD 3 / ME
MD 2 / MB
MD1 / MB

FIG.3.6

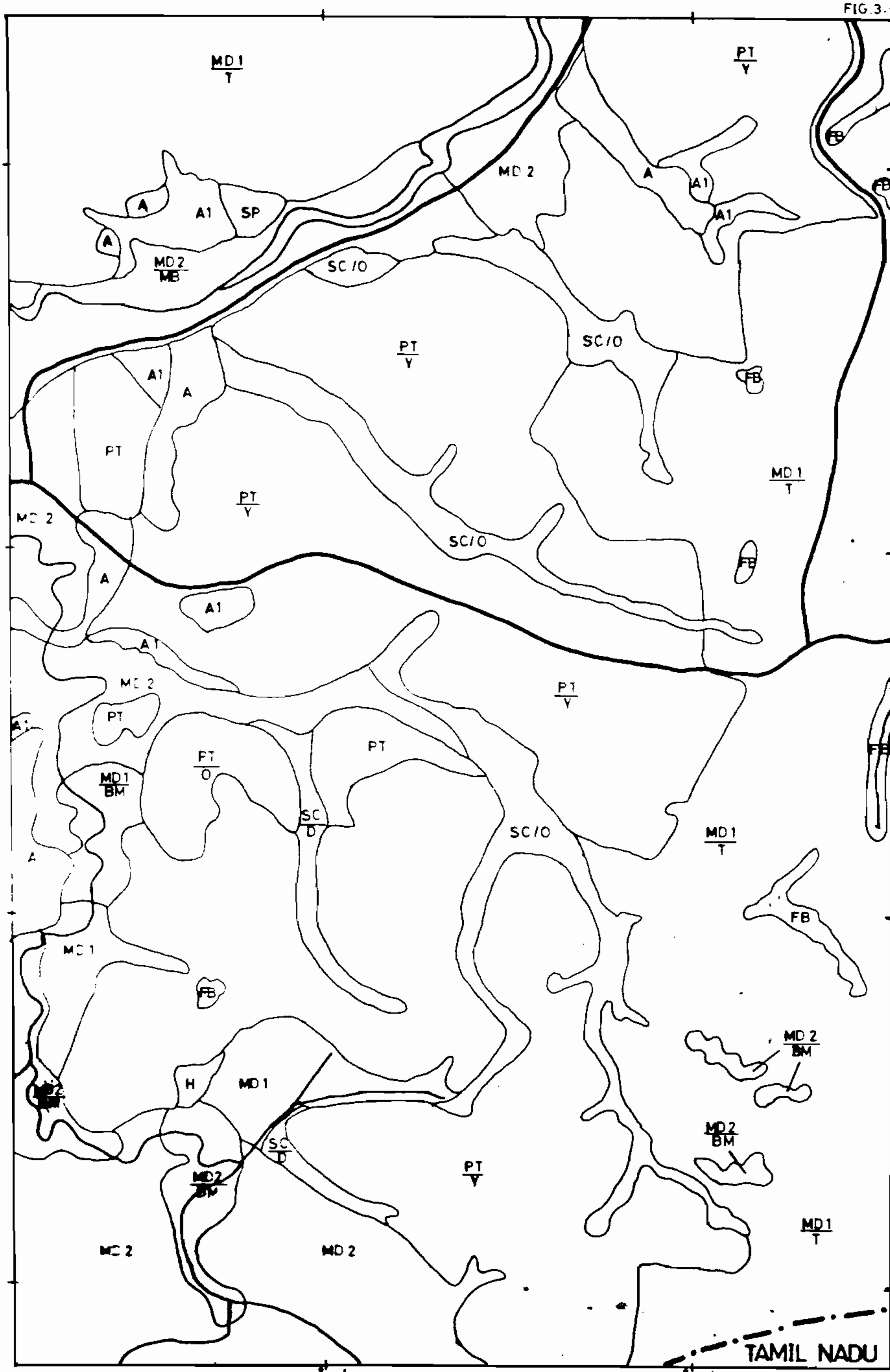
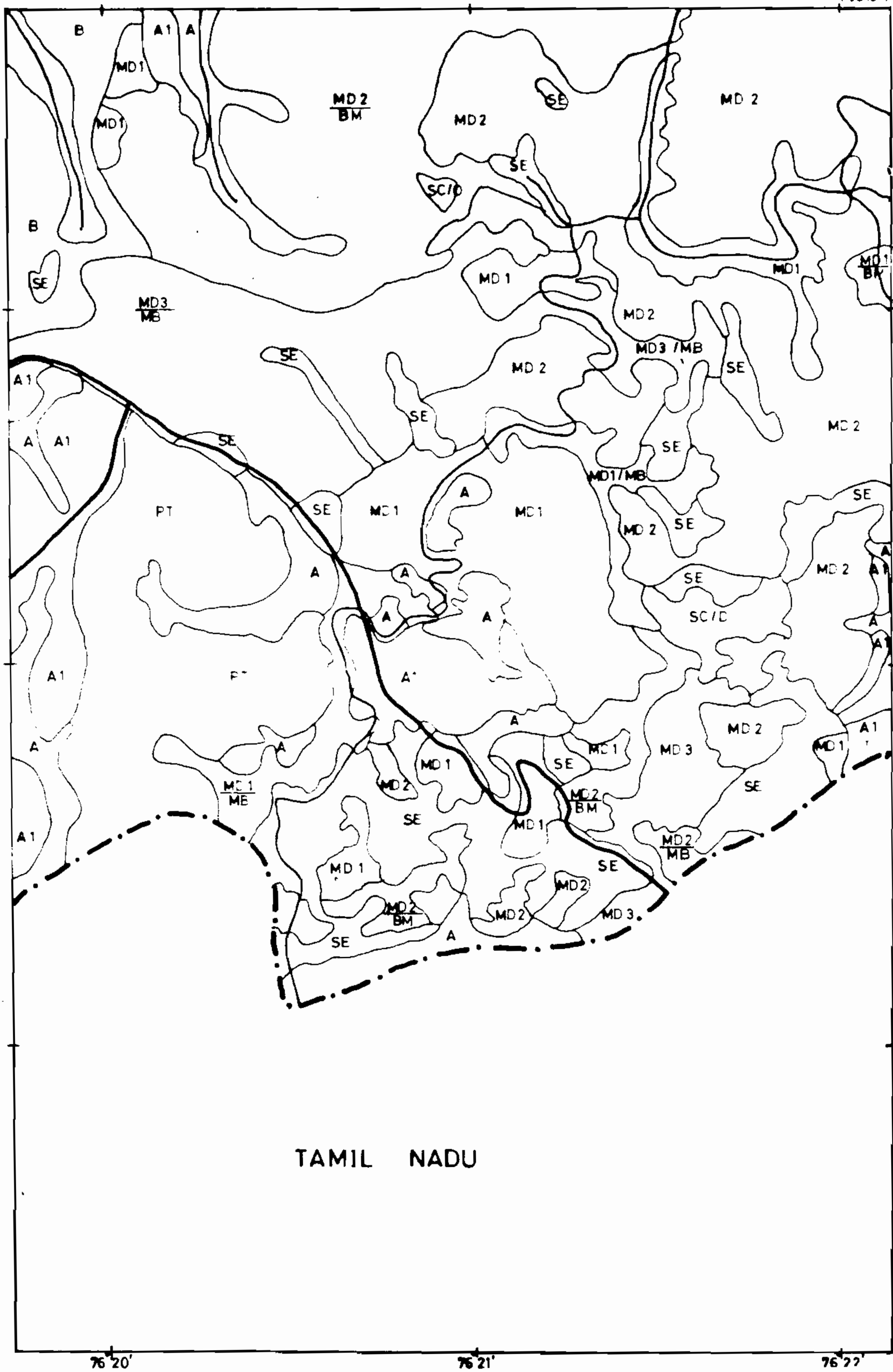

MD1
T
PT
Y
MD 2
A
A1
SP
MD2
MB
SC/O
FB
PT
Y
SC/O
A1
A
PT
MD1
T
MD 2
PT
Y
SC/O
A1
A
PT
Y
MD 2
PT
PT
O
PT
MD1
BM
SC
D
SC/O
MD1
T
A
FB
MD 1
FB
MD 2
BM
H
MD 1
SC
D
MD2
BM
PT
Y
MD2
BM
MD1
T
MD 2
MD 2
TAMIL NADU

FIG.3.7


TAMIL NADU
76°20'
76°21'
76°22'
MD 2/BM
MD3/MB
MD1/MB
MD3/MB
MD2/BM
MD2/MB
MD 2
MD 1
MD 3
SE
SC/D
PT
A
A1
B

SOI TOPO 58 A/12 - ATTAPPADY REGION

GRID INDEX

FIG.4

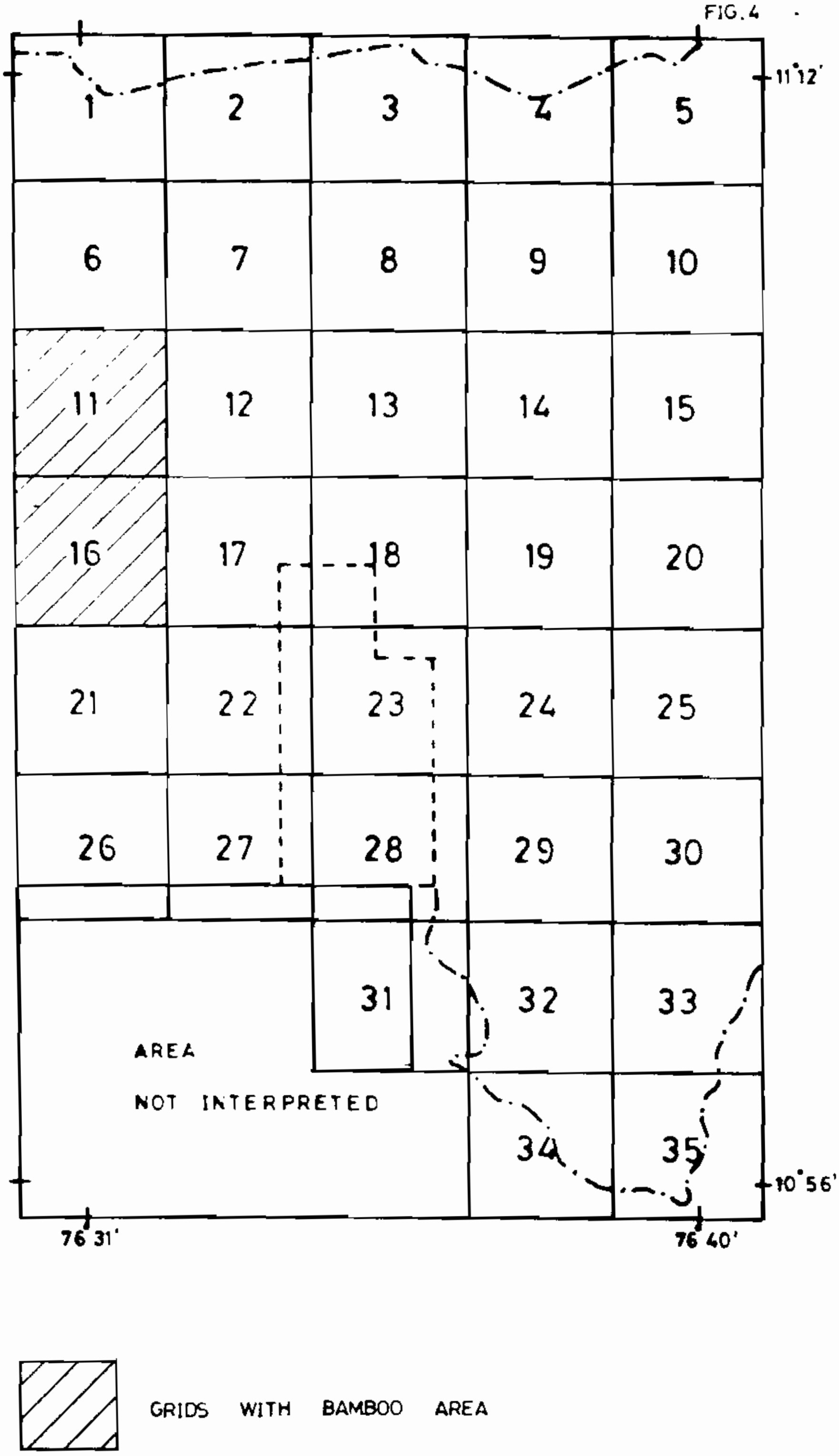
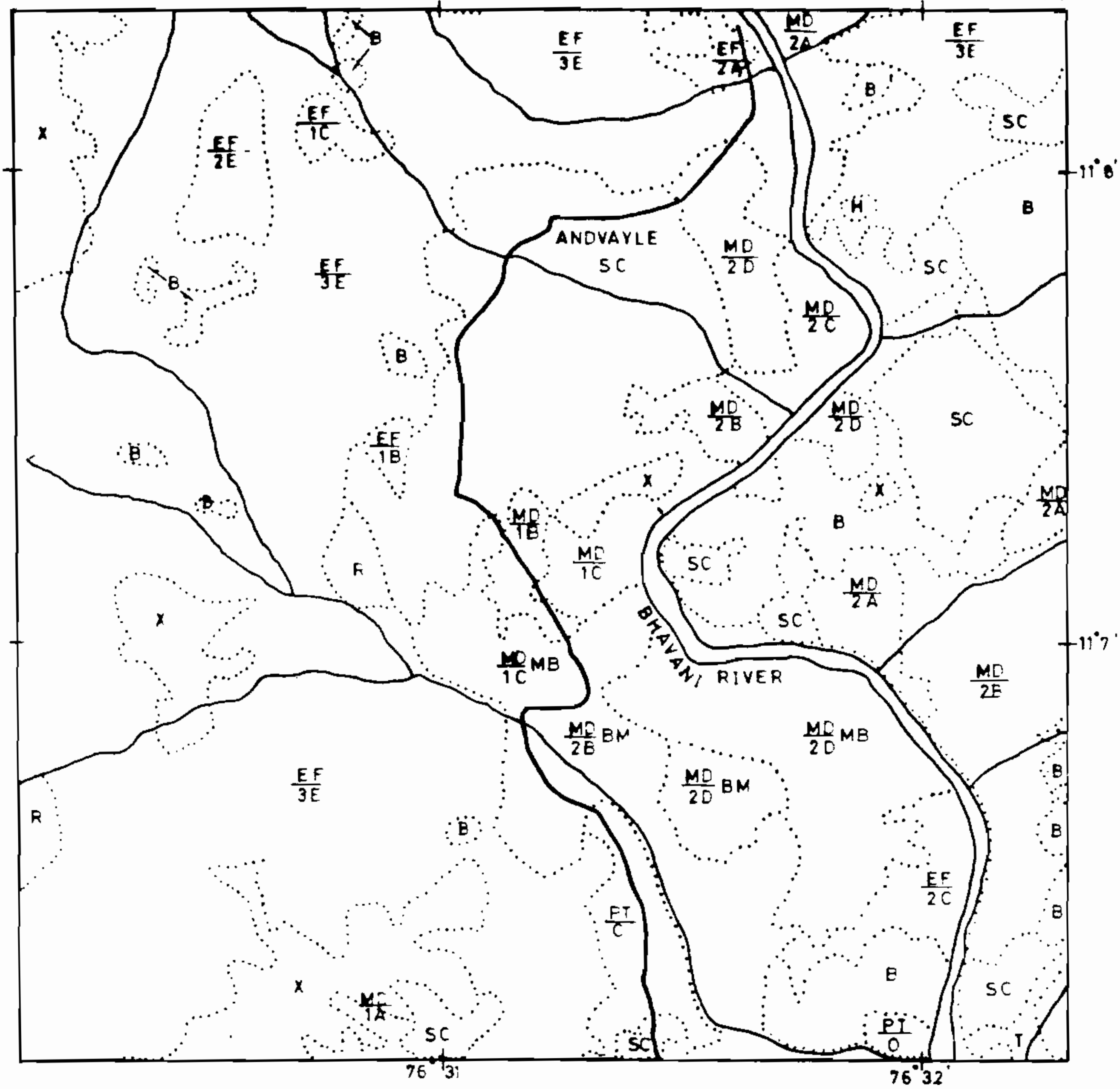


FIG.4.1



Land Cover Map of Attappady Region (Kerala)

prepared from 1:15,000 B&W Aerial photographs

LAND COVER TYPE CLASSES

Evergreen forest	EF
Moist deciduous forest	
without bamboos	MD
with < 50% bamboo cover	ME
with > 50% bamboo cover	BM
Dry deciduous forest	DD
Scrub	SC
Plantations	
Rubber	PR
Teak	PT
Eucalyptus	PE
Coconut	PC
Cashew	P/CS
Mixed/Miscellaneous	PM
Agriculture	A
Forest Blanks	B
Exposed Rocks	X
Water bodies	W
Habitation	H
Terraced land	T

DENSITY CLASSES

5-20%	A
21-40%	B
41-60%	C
61-80%	D
> 81%	E

HEIGHT CLASSES

Forest	
< 15 m	1
15-25 m	2
> 25 m	3
Plantation	
young < 5m	Y
old > 5 m	O

ANNOTATION EXAMPLE

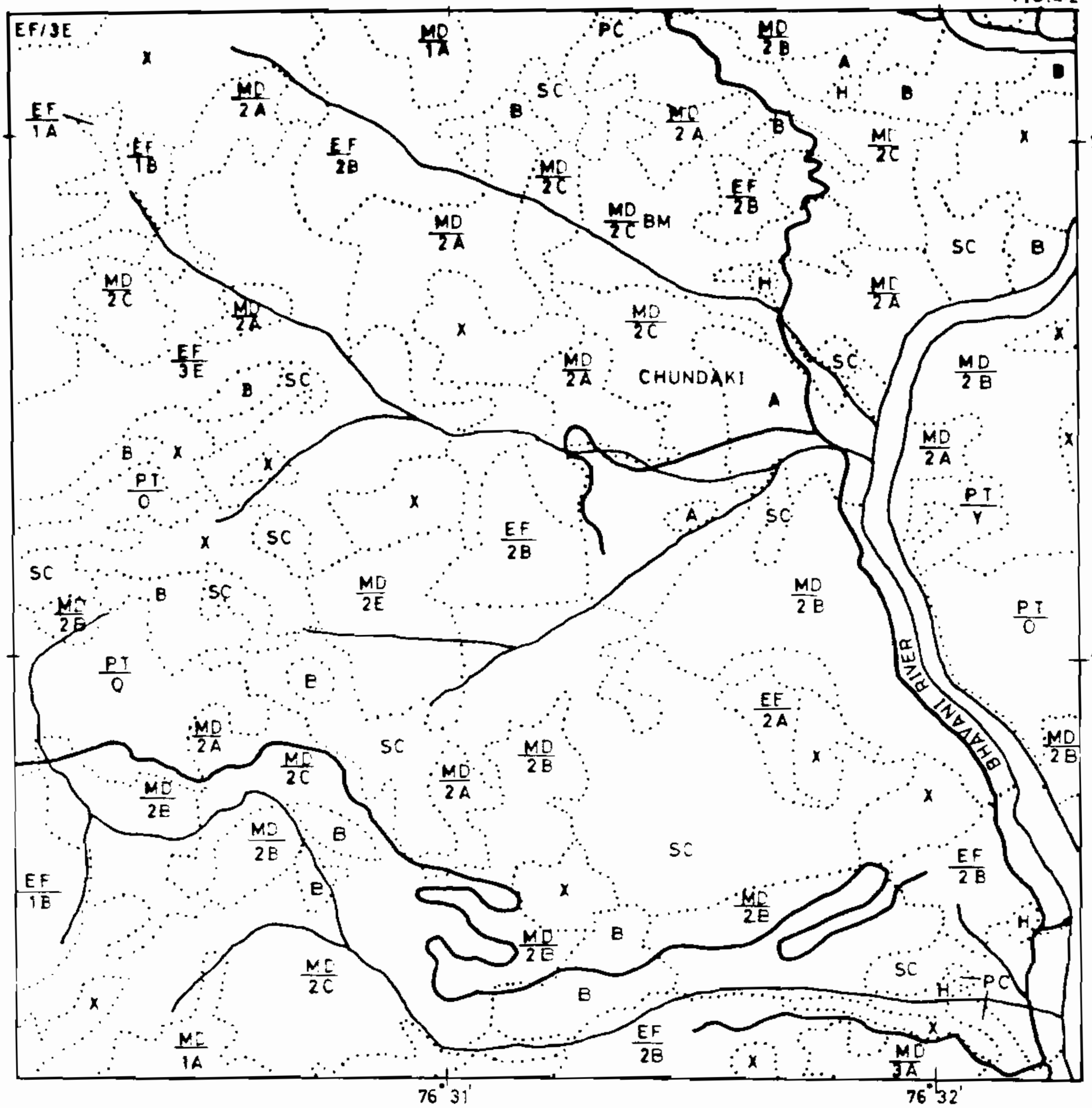
EF = forest cover type / 3E = height /density class

Map boundary
Study area
Roads
Metalled
Un metalled
Path /track
River
Streams
Flying gaps

Scale 1:25,000

N

FIG.4.2



Land Cover Map of Attappady Region (Kerala)

prepared from 1:15,000 B&W Aerial photographs

LAND COVER TYPE CLASSES

Evergreen forest	EF
Moist deciduous forest	
without bamboos	MD
with < 50% bamboo cover	ME
with > 50% bamboo cover	BM
Dry deciduous forest	DD
Scrub	SC
Plantations	
Rubber	PR
Teak	PT
Eucalyptus	PE
Coconut	PC
Cashew	P/CS
Mixed/Miscellaneous	PM
Agriculture	A
Forest Blanks	B
Exposed Rocks	X
Water bodies	W
Habitation	H
Terraced land	T

DENSITY CLASSES

5-20%	A
21-40%	B
41-60%	C
61-80%	D
> 81%	E

HEIGHT CLASSES

Forest	
< 15 m	1
15-25 m	2
> 25 m	3
Plantation	
young < 5m	Y
old > 5 m	O

ANNOTATION EXAMPLE

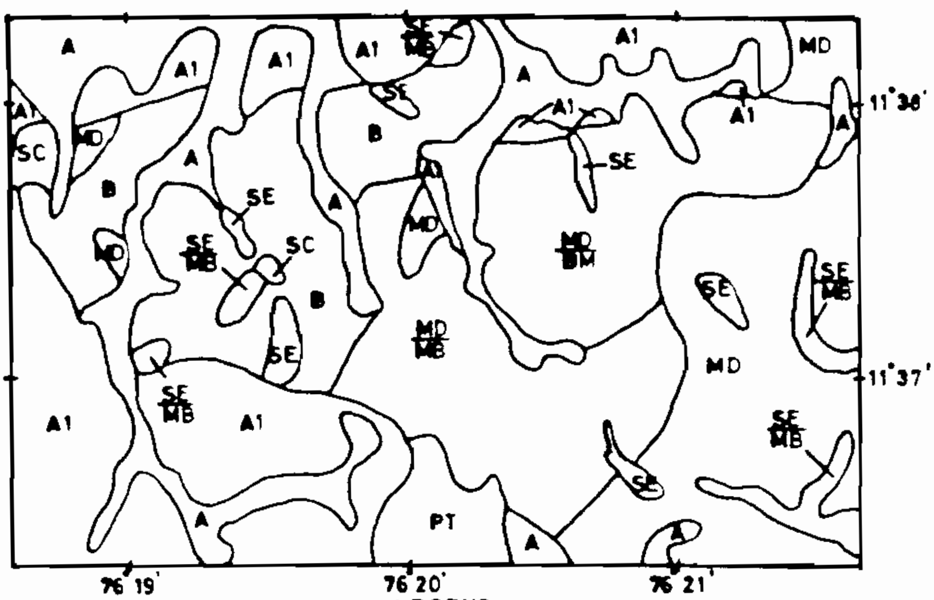
EF forest cover type
31 height /density class

Map boundary
Study area
Roads
Metalled
Un metalled
Path /track
River
Streams
Flying gaps

Scale 1:25,000

SOI TOPO 58 A/6-WAYANAD REGION

Fig.5 STUDY AREA (prepared from 1:50000 LANDSAT TM,1985)



LEGEND

SE SEMIEVERGREEN
MD MOIST DECIDUOUS
SC SCRUB
PT PLANTATION TEAK
A PADDY FIELD
B MAINLY BAMBOO (81% and above)
BM BAMBOO MIXED (41 - 80%)
MB BAMBOO MIXED (below 40%)
A1 MIXED PLANTATION

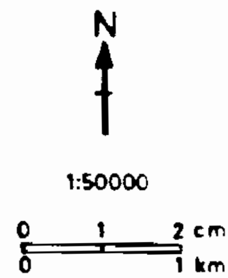
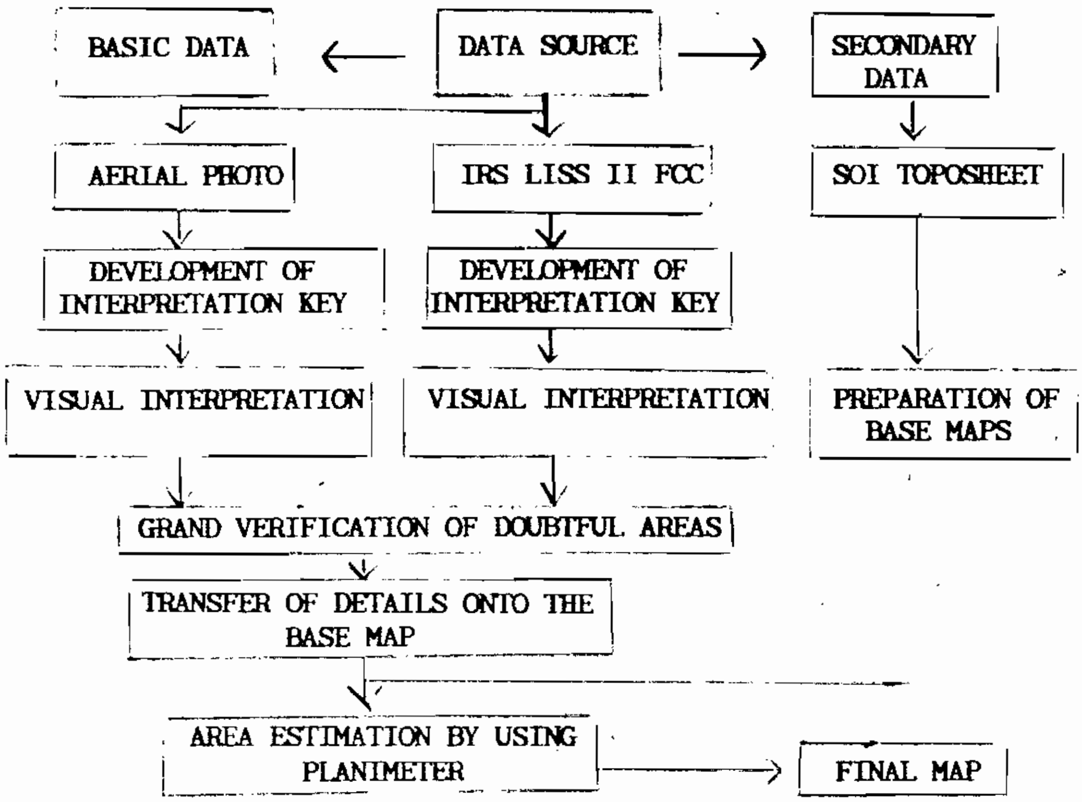


Fig. 6. Flowchart for forest cover mapping for visual interpretation



An area approximately 1360 Km^2 was selected for processing at a stretch in very scene (512 x 512 pixel size). The FCC generated by various combinations of enhanced outputs and raw data were initially assessed for their visual interpretability. In addition of statistical functions, other functions like stretching and enhancement, class separability, classification, rationing, smoothening etc., were done using appropriate software packages. The separability of signatures of various forest types (Table 2.3) and land cover types has been evaluated using training site statistics. The mean spectral plot, bivariate distribution, divergence matrix analysis, confusion matrix comparison etc. were used for achieving the best possible classification of IRS 1A digital data.

The hard copy output was taken using Dunn camera attachment (Fig. of the area. Based on the classified output, areas were selected for detailed investigation using large scale aerial photographs.

Base Map preparation

Base maps in 1:50,000 and 1:25,000 scale are prepared from Survey of India toposheets for the study localities. The interpreted data are transferred to these basemaps after field checking and scale correction. Hence the topographic features of the final maps are based on SOI toposheets.

Status evaluation of sample plots

The vegetation data from selected localities were collected from sample plots using 'Census quadrat' technique. The sample plots were selected randomly. The quadrat size and shape are changed at times as per the terrain features and vegetation cover types. Thus supplementary data can be used for futher resource evaluation programme.

Table 2. **Percentage distribution of pixels of Bamboo area (Semievergreen forests) in other vegetation types in Wynad area**

(based on Digital image processing of IRS-1A data)

....

SEMIEVERGREEN WITH BAMBOO (57.33)

→ Semievergreen Non Bamboo (10.67)
→ Moist deciduous Non Bamboo (3.11)
→ Moist deciduous with Bamboo (12.89)
→ Plantation Coffee (15.11)
→ Plantation Rubber (0.44)
→ Reject Class (0.44)

Table 3. **Percentage distribution of pixels of Bamboo area (Moist deciduous forests) in other cover types in Wynad area**

(based on Digital image processing of IRS 1A Data)

MOIST DECIDUOUS WITH BAMBOO (67.97)

→ Semievergreen Non Bamboo (11.72)

→ Semievergreen with Bamboo (6.25)

→ Moist deciduous non Bamboo (12.50)

→ Plantation Coffee (0.78)

→ Reject Class (0.78)

Plate 1


WAYANAD
AND ITS
ENVIRONS
FALSE COLOUR
COMPOSITE
IRS LISS-I
6 FEB 1989
KFRI/RRSSC-B

PLATE .1

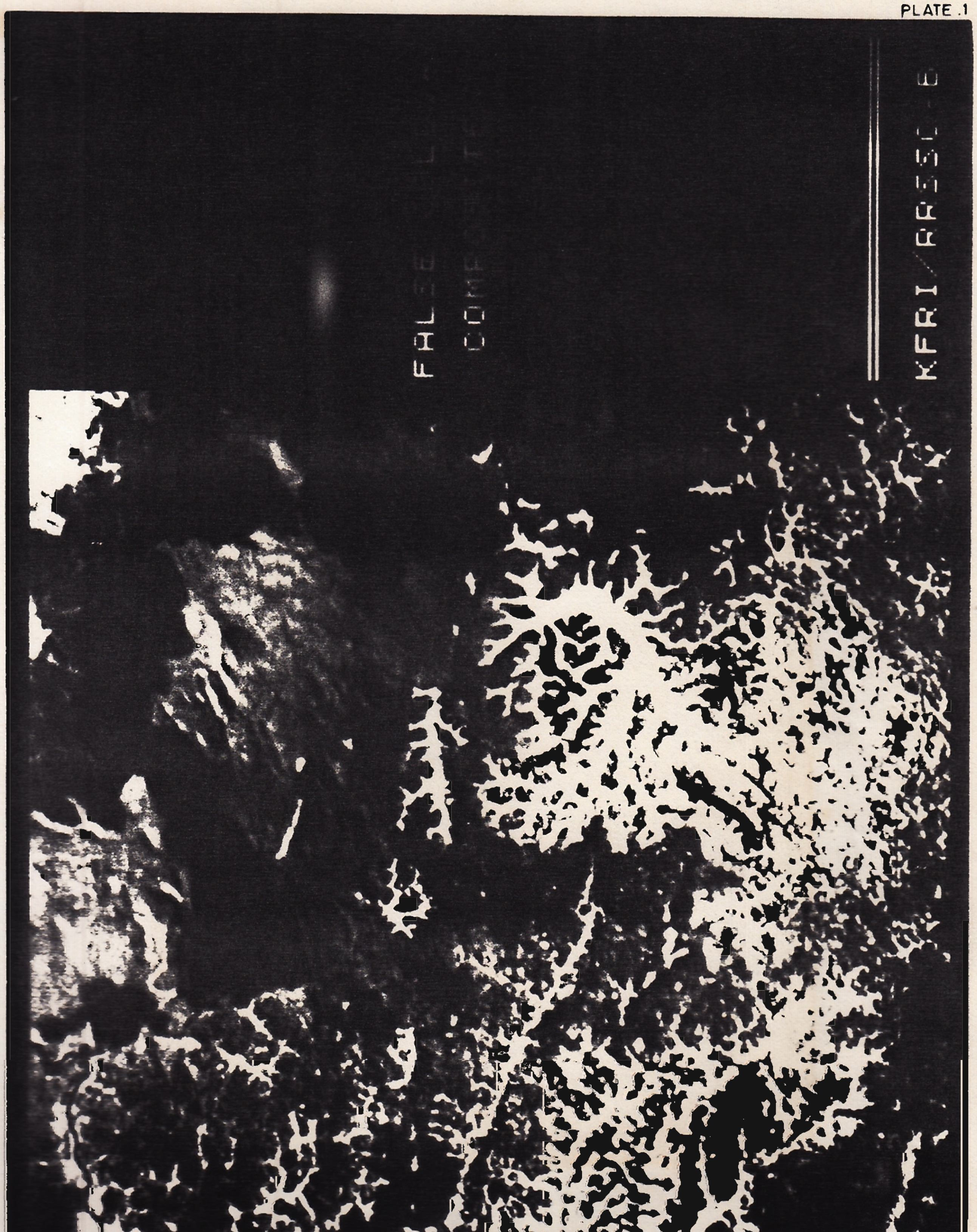


Plate 2

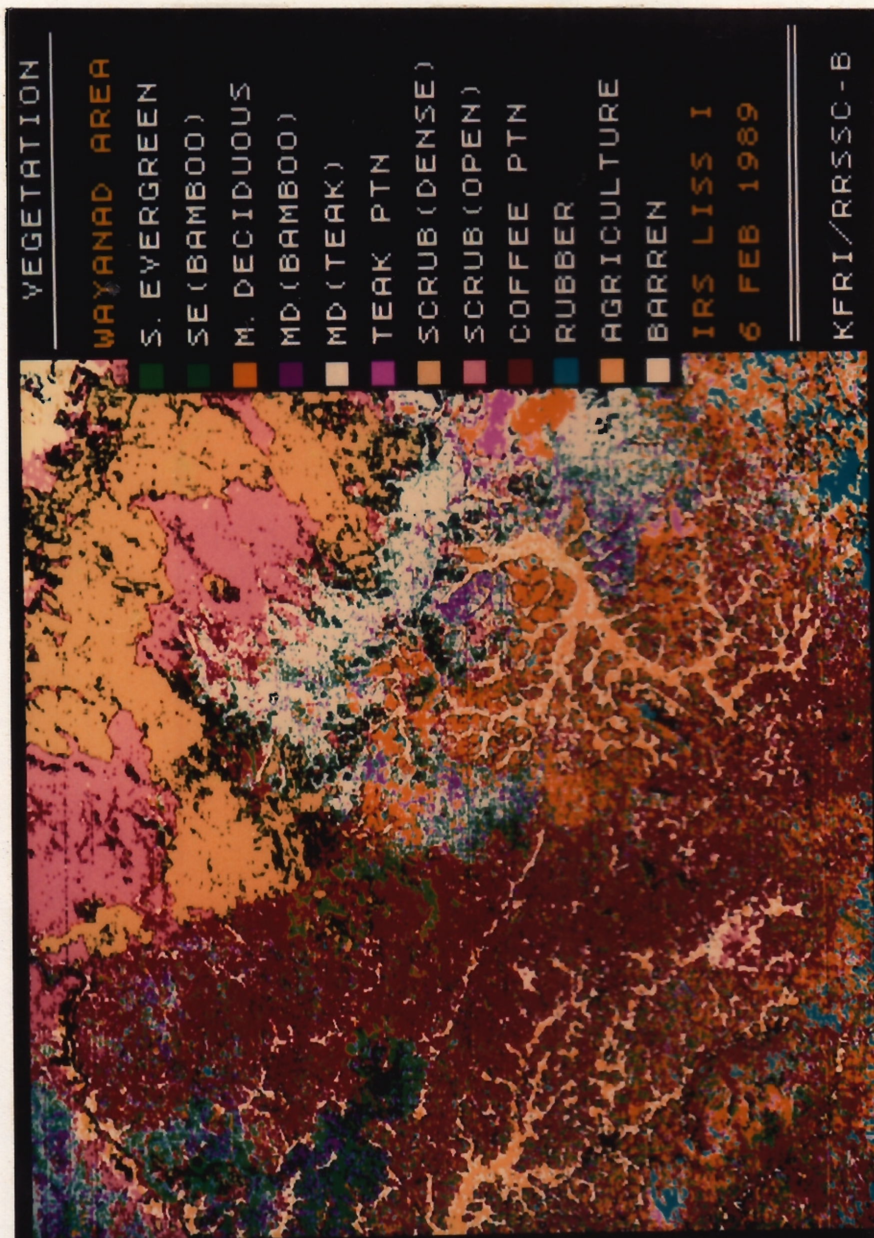

VEGETATION
WAYANAD AREA
S. EVERGREEN
SE(BAMBOO)
M. DECIDUOUS
MD(BAMBOO)
MD(TEAK)
TEAK PTN
SCRUB(DENSE)
SCRUB(OPEN)
COFFEE PTN
RUBBER
AGRICULTURE
BARREN
IRS LISS I
6 FEB 1989
KFRI/RRSSC-B

PLATE.2

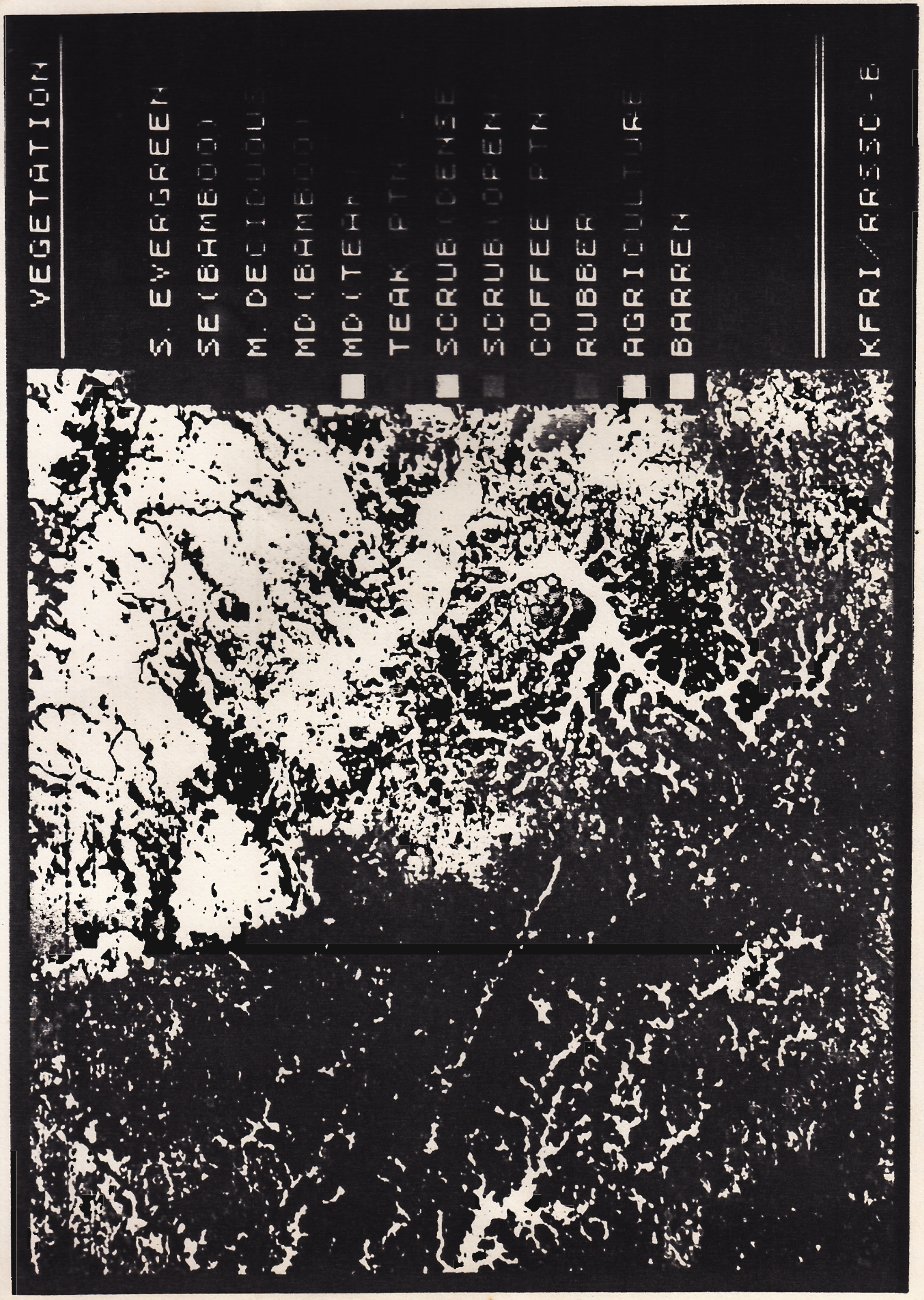
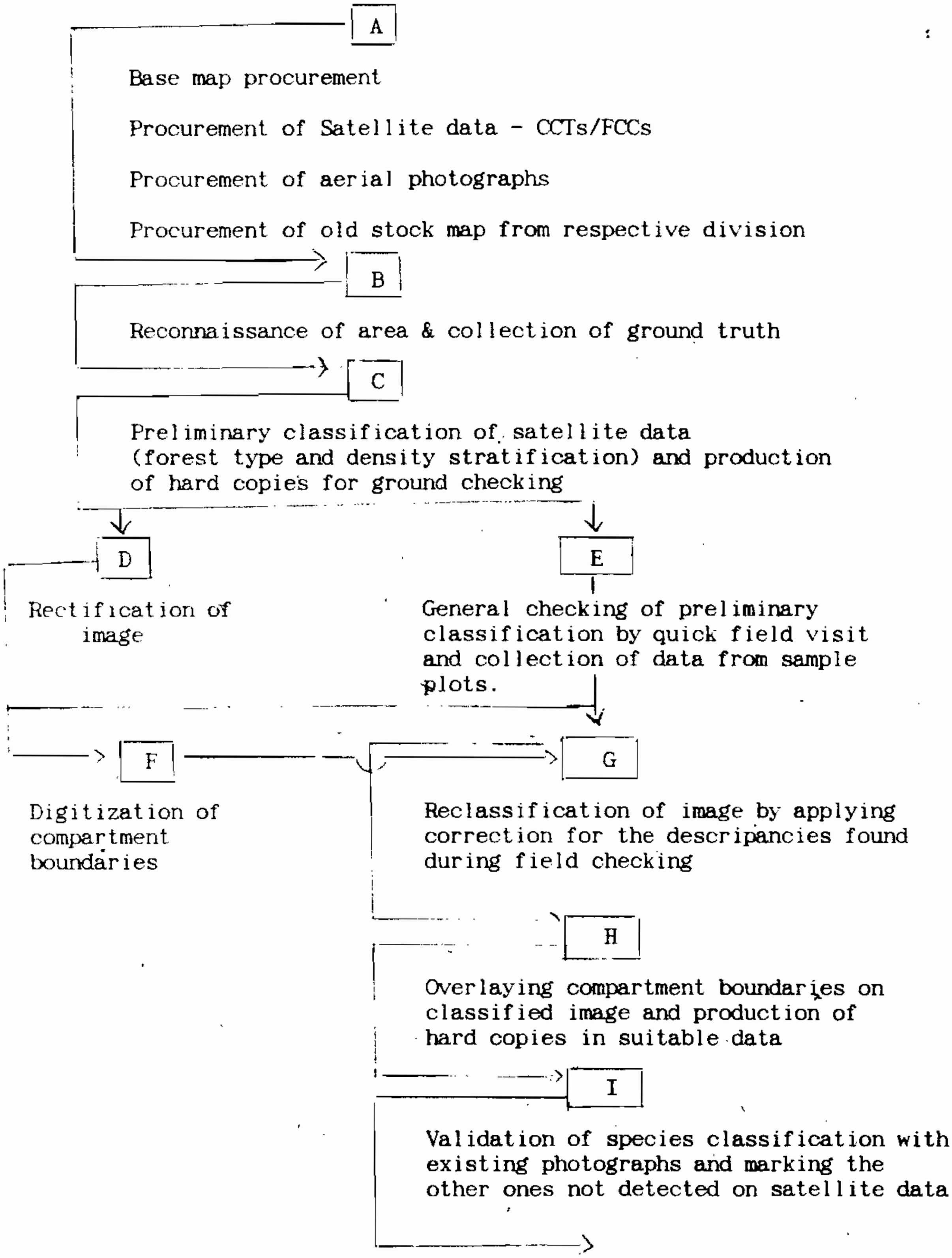

VEGETATION
S. EVERGREEN
SE(BAMBOO)
M. DECIDUOUS
MD(BAMBOO)
MD(TEAK)
TEAK PTN
SCRUB(DENSE)
SCRUB(OPEN)
COFFEE PTN
RUBBER
AGRICULTURE
BARREN
KFRI/ARSSC-6

Fig. 7. **Methodology for preparing stock map**

Flow chart



(Contd.)

Fig. 7 (contd.)

J

Planning enumeration statistically by using above classification as basis for stratification

K

Plan and organize enumeration in field

L

Enumeration in field,

i) Writing compartment description by visiting each compartment and carrying out final validation and correcting stock map for density & species.

ii) Collection of sample plot data.

M

Fair drawing of stock map.

OBSERVATION

An observation of ground stereograms of the black and white aerial photographs of the area revealed that bamboo patches are more or less stellate in appearance and stand out prominently in moist deciduous forest. Scattered bamboo clumps in open stands in dry weather after leaf fall present a pattern of white circular patches with a point on the centre.

Moist deciduous forest with bamboo shows greyish white tone, medium texture and with intermittent white patches. Moist deciduous forest without bamboo shows greyish tone, coarse texture with slightly rough pattern. Bamboo areas (more than 80% of bamboo cover) are more lighter in tone than that of broad leaved species. It can easily distinguishable from its surroundings by its greyish white/dull white tone, uniform distribution and fine texture (Table 4).

In semievergreen forests, individual bambooclads are clearly visible in 1:15,000 B & W aerial photographs by its lighter tone and stellate appearance from the more datk tone and medium texture of surrounding semievergreen trees.

In Landsat TM, bamboo areas shows greyish brown in colour and medium texture. Bamboo mixed moist deciduous forests have greyish red in colour and having medium texture. Moist deciduous forest without bamboo shows brownish red in colour and in having coarse texture. Semievergreen forests with bamboo shows lighter tone and coarse texture than semievergreen forest without bamboo.

Accuracy evaluation

In the use of remote sensing data for landuse and landcover mapping a major concern is the accuracy of the maps produced. The forest estimates were subjected to two types of errors, viz.; sampling errors and non-sampling errors: Non-sampling errors such as use of inappropriate tree volume tables/equations,

Table 4. **Comparison of major thematic classes on Satellite data and aerial photographs**

Thematic class	Satellite (FCC)	Aerial photographs (B & W)	Remarks
1. Evergreen	--	--	No additional information on aerial photographs
2. Moist deciduous	2 density Classes (< 20% greenness and > 20% greenness)	3 type classes & 5 density classes. (<50% bamboo cover, >50% bamboo cover; those without bamboo; 5-20% Density; 21-40% Density; 41-60% Density; 61-80% Density and more than 80% Density)	Bamboo areas could not be identified on satellite data whereas 3 additional classes are distinct on aerial photographs.
3. Scrubs	2 classes (Scrub dense & open)	--	One additional class on satellite data
4. Dry deciduous	1 classes (<30% density, >30% density)	3 Density classes (5-20%; 21-40% & 41-60%)	One additional class on aerial photograph
5. Plantations	2 classes (rubber mixed)	6 classes (rubber, mixed, teak, eucalyptus, cashew, coconut)	6 categories of individual plantations & two age groups

incorrect identification of trees, errors in measurement, recording, classification of structure, determination of stratum area and compilation were kept to minimum with repeated checks in the field work. Sampling errors are kept to the specified limit by doing proper design of the forest inventory, that is based on the available structural information.

Two variables were involved in volume estimate, i.e., area and volume per unit area and both of them were subject to sampling errors. But the study area had a complete coverage of recent aerial photographs of 1:15,000 scale. Hence after interpretation of photographs repeated field checking was carried out to get consistancy in determining the exact area of a stratum from the map of selected region.

There are a number of sources of errors that can be identified, notably, the quality of the remotely sensed data, the method of interpretation and the area measuring practices (Lo, 1988). In general there are two commonly employed methods to check the accuracy of the landuse map. One method assess the 'non-site specific accuracy' by comparing the measured areas of the individual landuse categories from the interpretation against the corresponsing areas acquired from a more reliable map. Another method assess the 'site specific accuracy' by comparing two maps point by point' Research continues in the development of statistical methods to evaluate the accuracy of the landuse and land cover maps. Rosenfield (1982) drew attention to the analysis of variance method which could simultaneously compare the classification accuracy of different categories for two or more classes of land use and land cover mapping.

In order to prepare a correct map, the accuracy of interpretation was checked by visiting several sample plots in the field. The ground situation was compared with the map information and the accuracy of interpretation worked out. It has been found that the aerial photographs gave about 95% accuracy and the satellite imagery gave about 80% accuracy. In digital processing of the selected area, 'confusion matrix' were generated to evaluate classification accuracy and the percentage mixing of different cover classes were evaluated (Table 2 & 3), and strands with more than 80% purity were selected for final classification of the scene.

Results and Discussion

Forest mapping has been carried out on 1:250,000 scale with IRS Liss I data and 1:50,000 with IRS Liss II data (Madhavan Unni et al., 1991) in Wildlife sanctuaries of Orissa, with mapping accuracy as 83%. Stratification of population into more or less homogenous group is one of the effective ways of reducing the sample size without affecting precision (Cochran, 1963). In addition to forest cover classification, density stratification to two to three categories were also done in the present study and the study reveals that overlaying forest compartment boundaries through digital techniques on geometrically corrected images in the form of raw data and digitally classified data provide valuable stock information making it very useful for practical field forestry. For estimating commercial and non commercial forest resources of Andaman & Nicobar islands Sing and Roy (1990) used similar stratified random sampling based on visally interpreted map from Landsat TM FCC of 1:50,000. The results of studies conducted by Roy and Sahai (1990), hold promise to use spectral methods for quantitative estimation of forest resources.

The land cover maps showing the distribution of bamboo area along with other cover crops are prepared for selected localities (Figs. 2-5) in 1:25,000 scale, to analyse the feasibility of the use of remote sensing data in bamboo resource evaluation. The mapping accuracy was evaluated and it was found to be 90% in the case of aerial photographs. The classification accuracy of satellite data products was found to be 65-70% (Table 2). The area estimates of different density strata along with the sampled information of bamboo area will substantiate the resource stock evaluation at a given time. The study confirms that the mapping and resource evaluation of bamboos in natural tropical forestry can be effectively and efficiently done using large scale aerial photographs, since there is clear tonal variation in aerial photographs; the areas with and without bamboos can be deleniated with less effort. Due to more clear textural variation in aerial photographs, with respect to crown density status of bamboo, the feature can be efficiently used in stock mapping of bamboos. Moreover the aerial photographs with their 3-D effects will give better resolution for photostratification of types. Broad classification of forest types alone can be differentiated in stellate data, since colour and tone are the two important photoelements available for effective use. Due to 3-D effects of aerial photographs, the textural characteristics of the feature can also be used for stratification of units. This is very much important in bamboo stock map preparation. The tonal and textural variations of bamboo in flowering season and the satellite appearance of sympodial bamboo units in ground stereograms etc. are the other added advantage in this technique.

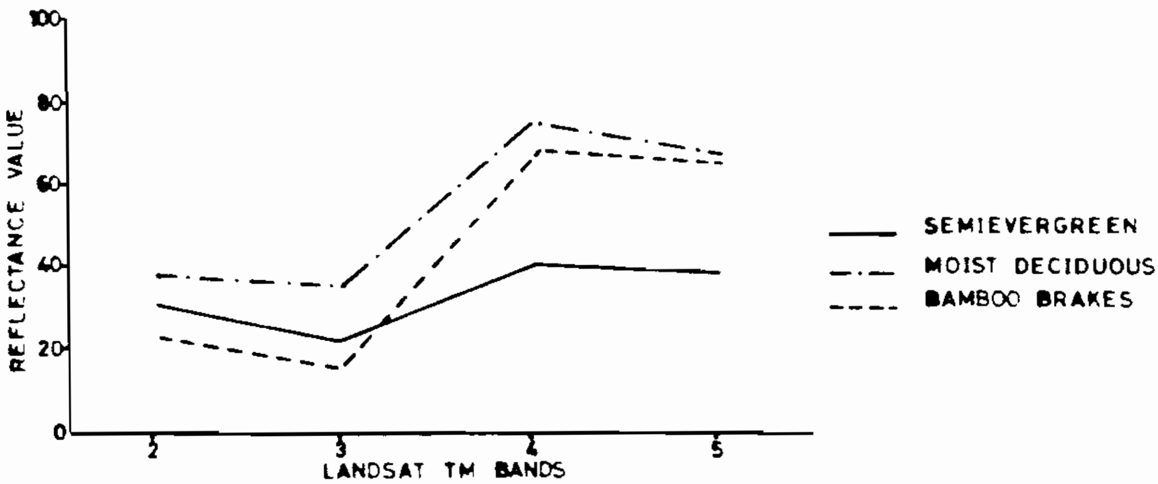
The advantages of aerial photographs of a scale like 1:15,000 and the feasibility of its use in mapping forests vegetation especially in mapping distribution of species are highly commentable. In an area such as one analysed in the present study natural forest vegetation is highly diverse and lacks exclusive dominance of a single species. Forest type differ more with respect to the degree of evergreenness/deciduousness, which gets as effectively expressed in the satellite data and in aerial photographs. Considering the 'pattern and shape' of the canopy, the aerial photographs are more useful for identifying plantation areas.

Transformation of remotely sensed data into thematic outputs involves basically two steps, (i) identification of spectral signatures/image characteristics specific to different classes which need to be mapped and (ii) extrapolation of defined spectral signatures/image characteristics to a larger area. While analysing data of highly heterogenous landscape and of hilly terrain, where wide variation in spectral response exists, a single land cover type is common. Because of varied illumination geometry, establishing the theme specific spectral signature become a difficult task in such situation. The potentiality of high resolution data for extracting vegetation related information in forestry sector is well established (Franklin, 1986; Hack et al., 1987, Hopkins et al., 1988; Horler and Ahera, 1986; Irons et al 1985 etc.).

Sensor related technological advancement of improved resolution in the Landsat Thematic Mapper (TM) are likely to yield more detailed and precise vegetation classification and mapping in comparison with what is possible with Multi-spectral Scanner data (MSS). The two most important Landsat TM bands for studying vegetation cover are Band 2 (0.52 - 0.62 um) and Band 4 (0.76 - 0.90 um). The reflectance in band 2 is an indicator of the amount of photosynthetic activity taking place and reflectance in band 4 indicates high cellular reflectance. Earlier studies have emphasized the selection of optimal band combinations or their transforms, so as to maximize descrimination of vegetation types in the false colour composite (FCC) and thereby improve upon vegetation mapping through visual interpretation (Benson and DeGloria, 1985). In the present study standard FCC created using band 4,3 and 2 in red, green and blue respectively was used for visual interpretation. When compared to semievergreen forests or moist deciduous forest without bamboo, bamboo brakes have low reflectance in band 2; i.e., high photosynthetic activity than moist deciduous forest and semievergreen forests and low reflectance than moist deciduous forests (Fig. 8).

The importance of foliar reflectance is well recognized and is accepted as the most important parameter in the identification of vegetation cover from remotely sensed data. Foliar reflectance characterizes different types of vegetal cover because it is uniqueness for each cover type. In the humid tropics such as Western Ghats, January-March are the driest months and various forest types such as tropical evergreen, moist deciduous, dry deciduous, plantations etc. shows maximum tonal contrast. Many species in moist and dry deciduous forest, are in the stage of defoliation by 15th January. Bamboo leaves also become pale and appear in light gray tone. By the end of March there are some premonsoon showers and the crown of deciduous species become

Fig. 8. SPECTRAL SIGNATURE OF VEGETATION CLASSES



flushy by middle of April. Thus, after mid April it become difficult to distinguish evergreen and semievergreen forest from the moist deciduous forest. In tropical mixed deciduous or evergreen forest a few species forming gregarious stands and showing typical phenological characters at the time of photography, such as Teak, Dipterocarps, Bamboo, Palms etc., and such species can be recognized specially on 1:15,000 scale. The greatest contrast in reflectance within the same tree crown will be observed due to the leaf ontogeny. This often results in crown pattern seasonally conspicuous in large scale images and helps in the identification of some tree species. Therefore, the remote sensing data for the period from January to March appears suitable for the identification of bamboo brakes.

Broad leaved species often showsinfraspecies variation in spectral signatures due to developmental hetarophylly (crown shape changes with age). This make identification in tropical forests difficult. If hairs or thick wax coating are present on the leaf surface, then the spectral reflectance in the visible spectrum will be increased considerably. Bamboo leaves are hairy and having a races of wax. This will enhance the identification of bamboo brakes in black and white aerial photographs. Hence in aerial photographs we can demarcate bamboo areas according to its density and forest type in which it comes into four groups as follows.

i) Pure bamboo areas (bamboo areas with scattered trees) - more than 80% of bamboo cover.

ii) Moist deciduous forest with mainly bamboo (40 to 80% of bamboo cover).

iii) Moist deciduous forests with bamboo mixed (below 40% of bamboo cover)

iv) Semievergreen forest with bamboo (below 40% of bamboo cover).

In Landsat TM FCC and IRS Liss I and Liss II FCCs, bamboo areas can be deleniated as in aerial photographs, but moist deciduous forest and moist deciduous forest with bamboo, cannot be deleniated as accurately as in aerial photographs (Fig. 5). Similarly, there is mixing of high and low density bamboo area within moist deciduous cover type, even in digitally processed scene (Plate 2). Bamboo areas and semievergreen forest mixed with bamboos can be deleniated more accurately. While considering the scale aspects of various remote sensing data, Landsat TM imagery and IRS Liss II data are most useful for bamboo deleniation.

Limitations

There are certain limitations in the study performed with regard to satellite data products, only one time data was procured from National Remote Sensing Agency, Hyderabad. The data pertaining to Feb.-March period was selected for digital processing and visual interpretation, taking advantage of the deciduous nature of certain cover types. The interpretation of different time data may leads to more information regarding the cover type. The selected aerial photographs were having wide variations in scale, due to rugged and hilly nature of terrain. Although the prescribed scale was 1:15,000 it was found to be varying even upto 1:10,000 and in some cases the scale is more than the prescribed one. Some of the minor classes interpreted in the large scale photographs are getting vanished, while transferring. Yet another limitation of the application of aerial photography in forest inventory/survey is that it cannot adequately take into account of well developed structure in terms of layering. The aerial photographs focus attention to the uppermost layer, the tree canopy. As a result, the subordinate layers tend to be ignored (Shaw, 1971). Fortunately, limited degree of correlations exist is between the canopy and the other layers of the forest.

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