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# LAND USE MAPPING OF UPPER YAMUNA CATCHMENT USING REMOTELY SENSED DATA

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SUMMARY

Remotely sensing techniques seek to recognize and classify objects and their conditions through their characteristic electromagnetic signatures. Remote sensing can best help in identifying the land surface cover and this can be used to infer the hydrological features like runoff potential ,infiltration, evaporation potential etc. In the present study a land use map of Upper Yamuna Catchment upto Tajewala has been prepared by visual interpretation of Landsat imagery and digital analysis of CCT data has been done to classify land use features of 2 test areas. Also relevant information have been collected for Geology, soil, geomorphology and drainage pattern of the area.

The Upper Yamuna Catchment lies between east longitudes 77°00' to 78°40' and north latitudes 30°15' to 31°30'. The Yamuna River originates in Tehri Garhwal district of Uttar Pradesh from the Yamnotri glacier. The main tributaries of Yamuna comprising the Upper Yamuna Catchment are the Yamuna, the Tons, the Giri and the Asan It lies in the physiographic belts of the Lesser Himalaya, the Doon Valey and the Siwalik.

The area is covered under four frames of Landsat imagery: 157-039, 157-038, 158-039, 158-038.

The land use classification of Upper Yamuna Catchment has been done with hydrologic point of view. The various categories of Land use in the area recognized by visual interpretation of Landsat imagery and digital

processing of CCT data are as follows:

1. Thick Forests
2. Thin Forests
3. Barren with sparse clusters of trees, agricultural fields and built-up area.
4. Cultivated area
5. Snow
6. River channels

Two test sites viz.Asan river sub-catchment and Giri river sub catchment have been analysed with digital processing. The effect of sun shadow was minimised by using MSS $2^2$/MSS 4 band ratio image file. For Asan river sub catchment, the difference between visual and digital processing has been minor but for Giri river sub catchment the differences are considerable due to effect of shadow.

Stream orders and bifurcation ratios evaluated from the drainage map prepared indicate that effect of geologic formation in distorting the drainage pattern is not there and hydrograph will neither have sharp nor extended peaks.

# 1.0 INTRODUCTION

Remote sensing techniques being exploited for surveying the earth resources seek to recognize and classify objects and/or their conditions through their characteristics electromagnetic signatures. The whole edifice of remote sensing is built on the premise that all earth surface materials have different characteristics spectral signatures, which directly or indirectly lead to the identification of an object. This makes remote sensing an excellent tool to map the land cover of an area. Moreover, both aerial photographs and satellite imagery offer a number of advantages over conventional survey techniques:

1. Areal synoptic coverage(gives aerial information as against point information through conventional techniques).
2. Repetitive global coverage ( for monitoring change).
3. Real-time processing
4. Sensing of surrogates rather than the desired specific observation.
5. Multispectral coverage
6. More automation i.e.less human error.

It transpires from these advantages stated above that remote sensing data provide an unique platform to study the land and water resources of a particular area/region/catchment in its totality and as an entity. It helps to analyse the cause and effect relationship of land water resources management problems. As such, remote sensing data form a very viable data base for the various problems of hydrology, wherein a multidisciplinary approach is the essential prerequisite.

## 2.0 REVIEW

### 2.1 Land Use Classification

Land use refers to 'man's activities on land, which are directly related to land' (Clawson, 1965). Landcover denotes the vegetational and artificial constructions covering the land surface (Burley 1961). The remotely sensed data record information essentially on land cover from which the information on landuse has to be deduced and inferred.

The landuse classification, currently used in the country was adopted in 1950-51 (Baldev Sahai, 1983). It gives the land utilisation classes as follows:

1. Forests
2. Area under non agricultural uses
3. Barren and uncultivable land
4. Permanent pastures and other grazing lands
5. Miscellaneous tree crops and groves not included in the net area sown
6. Culturable waste.
7. Fallow land other than current fallows
8. Current fallows
9. Net area sown

This classification scheme is quite incompatible with remotely sensed data(Baldev Sahai, 1983).

Many researchers believe that no single classification system could be used with all types of imagery and all scale (Nunnally, 1974).

It is often very difficult to fit interpretations of landuse from remote sensor imagery into existing land use classifications. The research for a single land use classification system which will serve all users for all time is a fruitless one. However, a need exists for recognising some common ground which will permit the interchange of the data from a system to another" (Anderson 1971).

Nunnally, Whitener and Anderson were some of the earlier workers, who took the initiative of tackling the problem of defining an effective land use classification system in 1970-71. In 1971 Anderson came up with two schemes of land use classification. Scheme I: A tentative classification scheme for use with orbital imagery and with some supplementary information for making landuse maps for the United States ranging in scale from 1:250,000 to 1:2,500,000.

Scheme II: A tentative classification scheme for use with orbital imagery but with little or no supplementary information for making landuse maps ranging in scale from 1:250,000 to 1:2,500,000.

The type and distribution of land uses within a watershed are important determinants of hydrologic response of a watershed. Remotely sensed data have been used successfully to measure land use distribution within a watershed as well as the land use changes with time (Stafford, et al.,1973).

Anderson revised his classification scheme proposed in 1971 and developed the commonly referred USGS classification system in 1976 (Table-1).

## 2.2 Land Use Mapping in India

Land use/land cover surveys using remote sensing techniques have been primarily conducted in the country by the National Remote Sensing Agency, Hyderabad; Indian Institute of Remote Sensing, Dehradun, Space Application Centre, Ahmedabad, Centre of Studies in Resources Engineering, I.I.T.,Bombay; Civil Engineering Department, Earth Sciences Department and School of Hydrology, University of Roorkee, Roorkee; All India Soil and Land use Survey Organisation and Survey of India. This list is illustrative and not exhaustive.

NRSA has contributed significantly to the Land use/ Land cover mapping using remote sensing techniques. Land-use maps in the scale of 1:250,000 using Landsat imagery have been prepared for various regions of Andhra Pradesh, West Coast, Nagaland, Mizoram, Orissa, Uttar Pradesh, Tripura and Arunachal Pradesh.

At SAC extensive studies have been carried out for Panch Mahals-Ahmedabad region. Eight level I and level II categories corresponding to USGS classification system could be delineated using Landsat imageries and aerial photographs. In Idukki district of Kerala, level I, level II and some level III categories have been delineated through visual interpretation of Landsat imageries and colour composites. Similar studies have been carried out in Ukai Catchment.

Table 1: U.S.GEOLOGICAL SURVEY LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTELY SENSED DATA

| Level I | Level II |
|---|---|
| 1. Urban or Built-up Land | 11 Residential |
| | 12 Commercial & Services |
| | 13 Industrial |
| | 14 Transporation, Communication & Utilities. |
| | 15 Industrial & Commercial Complexes. |
| | 16 Mixed Urban or Built-up Land |
| | 17 Other Urban or Built-up Land |
| 2. Agricultural Land | 21 Cropland and Pasture |
| | 22 Orchards, Greves, Vineyards, Nurseries and ornamental horticulture |
| | 23 Confined Feeding Operations |
| | 24 Other Agricultural Land |
| 3. Range Land | 31 Herbaceous Range land |
| | 32 Shrub and Brush Range Land |

| | | |
|---|---|---|
| | | 33 Mixed Range Land |
| 4. | Forest Land | 41 Deciduous Forest Land |
| | | 42 Evergreen Forest Land |
| | | 43 Mixed Forest Land |
| 5. | Water | 51 Streams and Canals |
| | | 52 Lakes |
| | | 53 Reservoirs |
| | | 54 Bays and Estuaries |
| 6. | Wet Land | 61 Forest Wetland |
| | | 62 Nonforested Wetland |
| 7. | Barren Land | 71 Dry Salt Flats |
| | | 72 Beaches |
| | | 73 Sandy Areas Other than Beaches |
| | | 74 Bare Exposed Rock |
| | | 75 Strip Mines, Quarries & Gravel Pits |
| | | 76 Transitional Areas |
| | | 77 Mixed Barren land |
| 8. | Tundra | 81 Shrub and Brush Tundra |
| | | 82 Herbaceous Tundra |
| | | 83 Bare Ground Tundra |
| | | 84 Wet Tundra |
| | | 85 Mixed Tundra |
| 9. | Perennial Snow or Ice | 91 Perennial Snow fields |
| | | 92 Glaciers |

## 3.0 STATEMENT OF THE PROBLEM

The various hydrologic variables are required to be examined for their amenability and adaptability to remote sensing and subsequent use in hydrologic modelling. Remote sensing can best help in identifying surface cover and other land surface features and this can be used to infer the hydrologic features like run-off potential, infiltration, evaporation potential etc. A hydrologically significant land use map is of immense use to infer about runoff potential of each category of land use and could be a valuable input for hydrologic modelling of watershed.

The Upper Yamuna Catchment upto Tajewala has been chosen for study as a number of dams, barrages and irrigation projects are being developed in the area at Barkot, Damta, Kishau, Lakhwar, Vyasi, Ichari, Dakpathar and Tajewala. Landuse/landcover and related information of the basin is required for rainfall-runoff modelling for different sub-catchments at various project sites.

The objective of this study is to collect land cover/land use, geologic, soil and drainage details for Upper Yamuna Catchment upto Tajewala for subsequent hydrologic modelling.

## 4.0 DESCRIPTION OF STUDY AREA

### 4.1 Upper Yamuna Catchment

The area under study (Fig.1) is the Upper Yamuna Catchment upto Tajewala. The catchment has an area of 11550 sq.km. and lies between east longitudes 77°0' to 78°40' and north latitudes 30°15 to 31°30'. The catchment has an irregular shape. It is bounded on the north and west by the Himalayan catchment of the Sutlej and on the east by Ganga catchment.

The Yamuna river originates in Tehri Garhwal district of Uttar Pradesh from the Yamnotri glacier on the Western slopes of Bandarpunch at an elevation of 6,320 m. The Rishiganga, a tributary of the Yamuna rises 3 km further northwest and joins the Yamnotri stream on its right bank near Banas. The Unta, rising from the Jakhal glacier and the Hanumanganga rising from the Chaian Barmak glacier south of Bandarpunch meet the main stream on its left bank. The Tons, the largest Himalayan tributary of the Yamuna rises from the north eastern slope of Bandarpunch at an elevation of 3900 m. It joins the Yamuna from behind the Mussoorie hills. The confluence is joined by the Giri and Asan rivers, which drain the area between the Bandarpunch and Chor peaks. The Yamuna then forces its way through the Siwalik range of hills and emerges from the hills at Tajewala where it has been tapped for irrigation at Tajewala headworks. From here two important canals -(i) Western Yamuna and (ii) Eastern Yamuna take off. The catchment of Yamuna system upto this point where it emerges from the hills at Tajewala is the Upper Yamuna Catchment.

The catchment has been divided into six sub-catchments on the

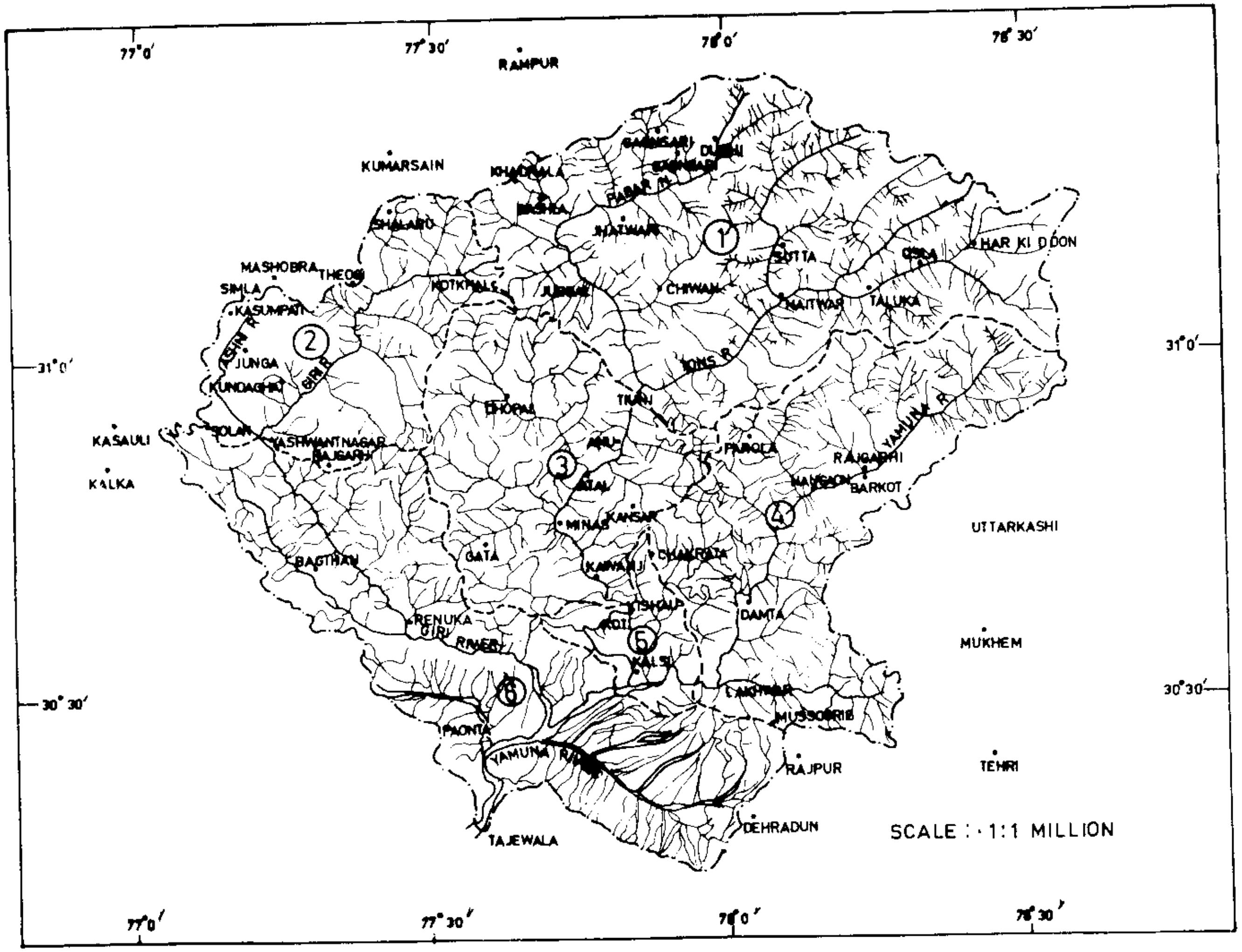

Fig. 1 Study area

basis of river gauge sites. The six sub-catchments are:-

| | Sub-catchment | | Area |
|---|---|---|---|
| 1. | Tons upto Tiuni | | 3367 $km^2$ |
| 2. | Giri upto Yashwant Nagar | | 1412 $km^2$ |
| 3. | Tons from Tiuni upto Kishau | | 1585 $km^2$ |
| 4. | Yamuna upto Lakhwar | | 2260 $km^2$ |
| 5. | Yamuna from Lakhwar and Tons from Kishau upto Dakpathar | | 358 $km^2$ |
| 6. | Yamuna from Dakpathar and Giri from Yashwant Nagar upto Tajewala | | 1565 $km^2$ |
| | | Total | 11547 $km^2$ |

4.2 Physiographic Setting and Geomorphology

In Upper Yamuna Catchment the drainage system and the character of landforms are closely interdependent and inter-related. The Upper Yamuna Catchment falls into 3 well defined physiographic belts: the Lesser Himalaya, the Siwalik and the Doon Valley.

1. LESSER HIMALAYA: The Lesser Himalaya ranges from 4,000 m to 1000m in height. It has a mild and mature topography with gentle slopes and deeply dissected Valleys which suggest that rivers and streams are still furiously at work. The physiography of Himalayan region of the basin can be further subdivided into 2 regions.

i) High to very high mountains have been demarcated by 3000 m contour. These consist of seasonally snow capped high mountains and glaciated high mountains with Bandar punch glaciers, Jamadar Bamak and Deokhera Bamak of Yamuna and Tons sub-catchments. The asymetrical slopes form the characteristic features of the region. The retreating movement of Bandarpunch, Jamadar Bamak, Deokhera Bamak and their tributary glaciers still may be observed in the form of 'V' shaped valleys with morains and smooth and aggradational slopes. The repose slopes of glaciated mountains have gradient 25 to 50 per cent while repose slope of seasonally snow covered mountains have gradient 25 to 80 per cent. Fracturing is caused by tectonic alignments and debris from landslides is accumulated at the base of escarpments.

ii) Low to moderately high mountains occur in between the altitudes of 1000 m and 3000m above m.s.l. It is massive mountainous tract with series of ridges and spurs divided by river valleys. The slope varies from 25 to 50 per cent or even upto 80 per cent. The rivers and their tributaries carve out the repose slopes and form intrenched valley at higher reaches while engrown valleys at lower reaches. The rivers are forming depositional terraces at a number of places and are causing headward erosion.

SIWALIKS: The Siwalik hills are formed as a result of intense dissection by fine textured pattern of drainage lines. They are a long prominent ridge trending NW-SE with altitudes 750 to 1500 m. The ridge is composed of a gentle northern slope and a steeper southern slope. A water divide is located more or less half way through this ridge. It is drained with numerous parallel to sub-parallel streams flowing towards north or south in consequent entrenched channels.

The Siwalik or the Outer Himalayan range is a youghful range, separated from the Lesser Himalaya by the Main Boundary Fault. It seems to be tectonically active and is presumably still rising (Valdiya, 1980).

DOON VALLEY: The Doon Valley is a long tectonic synclinal structure of the Outer Himalaya. It lies within the ranges of Lesser Himalaya to the north and the Siwalik range of the Outer Himalaya towards south. It is a low lying region between the two ranges with altitude not more than 500 m to 750 m above m.s.l. The doon gravels composed of boulder and gravel beds with this clay bands constitute the piedmont slopes. Low value of stream frequency and drainage density is owing to the poor development of drainage due to porous and permeable characteristics of the bed rocks.

## 4.3 Drainage Pattern

The Yamuna Catchment is drained by rivers Yamuna, Tons, Pobar, Giri, Aglar and Asan out of which Yamuna and Tons are fed by glaciers i.e.Pardar Punch glacier and its tributaries and originate from the Great Himalayan range. These are antecedent rivers and flow transverse to the structural axes in gorgeous channels with irregularly terraced patches of subrecent gravelly and sandy deposits along their paths in the inner sedimentary belt with comparatively gentle gradient and milder topography. These riverine terraces have usually three prominent levels, the difference of elevation between the upper two being often more than 50 m.

The small streams ( gads) and ravines ( gadhera) feeding the main rivers flow parallel to the structural strike and drain the areas either eastward or westward. These are subsequent streams, which are mostly fed by streams and rarely by obsequent streams. Thus a trellis type drainage or dendritic drainage has developed in the Lesser Himalayan region of the basin except in the granite intrusive-region at Chaur (30°52'N, 77°27'E) where a radial pattern is observed. The drainage is parallel to sub-parallel in the Siwalik region.

## 4.4 Soil Cover and Lithology

The Atlas of Agricultural Resources of India in Soil Regions-Northern India Plate shows that the soil cover in the northern part of the catchment in Mountain meadow soil ( Cryoborolls) and submontane soil ( Hapludalfs ) in the Lesser Himalayas. The Doon Valey has a soil cover of brown, red and yellow soil (Palehumults) and Bhabar soils (Ustorthents). The siwaliks have brown, red and yellow soils (Palehumults).

The geology of the area( Valdiya, 1980) is shown in Table 1.

Table 2: Geology of Upper Yamuna Catchment Area

| Formation | Lithology |
|---|---|
| Chakrata Formation | Graywackes, siltstones, slates |
| Routgara Formation | Muddy quartzite(Subgraywacke),sparse lentils of conglomerates, slates, basic sills-dykes and lava flows, oxidised to deep red |
| soils. | soils. |
| Deoban Formation | Stromatolite bearing dolomite and dolomitic limestone, limestone shale slate & quartzite. |
| Mandhali Formation | Black carbonaceous pyritic phyllites/slates limestones, paraconglomerates. |
| Chandpur Formation | Phyllite, Metasiltstone, fine-grained wackes, local metavolcanics, shales, slates, limestone. |
| Nagthat Formation | Orthoquartzites, slates, tuffaceous phyllite, quartzite, basic volcanics, grits, shales. |
| Berinag Formation | Massive, coarse grained to pebbly or even bouldery and usually sericitic quartzite, metamorphosed basalts, tuffites-schists and |

| | |
|---|---|
| | amphibolites. |
| Blaini Formation | Conglomerate, siltstone, greywacke, slates, limestone, sandstone, turbidites. |
| Krol Formation | Limestones, shales, slates, siltstone, dolomite. |
| Tal Formation | Black carbonaceous pyritic mudstone, phosphatic chert, limestone, pebbly mudstone, sandstone, quartzite with limonitic stains, slate. |
| Bansi Formation | Sandy, colitic and shelly dense limestone grading into calcareous sandstone. |
| Subathu Formation | Greywackes, siltstone, mudstone, numulitic and shelly limestone, shale |
| Upper Siwalik | Coarse conglomerates, sandstone, grits, sands & some clays, greywacke. |
| Middle Siwalik | Brown or landgray sandstones, drab shales, gravel beds and orange clays, grey-wacke. |
| Lower Siwalik | Bright red shales & sandstones, Hard red sand-stones, purple shales, and Pseudoconglomerates, grey-wacke. |

The geological map ( fig.2) shows approximate delineations of these various formations. The map is based on the geologic map compiled by J.Rupke and R.P.Sharma on the basis of photogeological and field studies completed with data from official published maps.

A glance at the geologic map of Upper Yamuna Catchment would make it obvious that a very large part of the Lesser Himalayan region is made up of sedimentary rock formations lying in tangled confusion and intruded by granite and basic volcanics. The northern part has been subjected to low grade metamorphism.

## 4.5 Climate

The Himalaya exercises a dominating influence on climate in the northern region of Upper Yamuna Catchment. The winter is very cold while summer is moderate.

Most of the runoff in the river cover from Himalayan portion of the basin because of physiographical and geological features. Average annual rainfall in this region varies between 1500 mm to 400 mm. The entire catchment comes under the influence of south-west monsoon and major part of the rainfall is received between June to September. Winter rainfall is scanty but occurs between December and February.

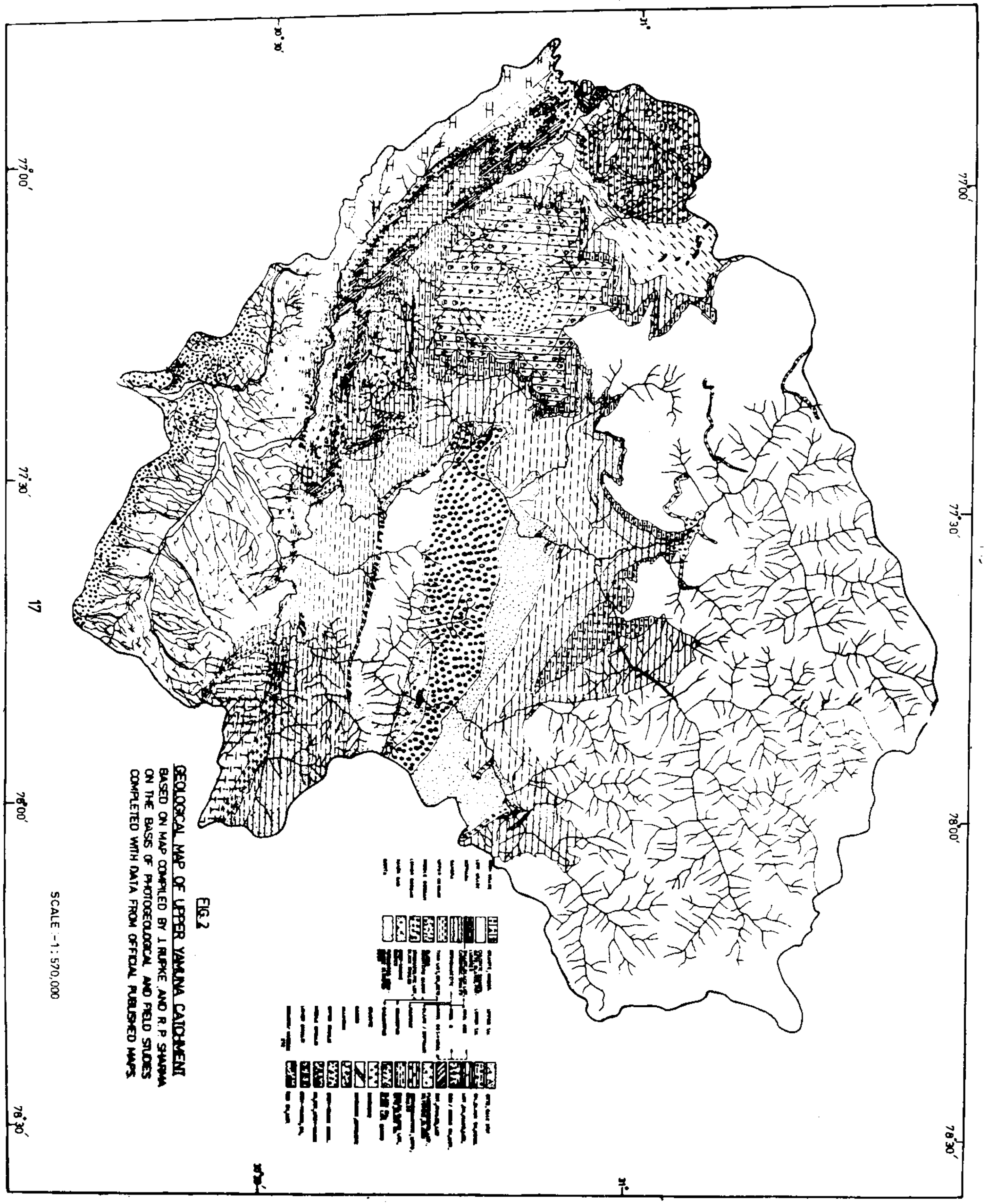




Fig.2 Geological map

## 5.0 AVAILABILITY OF DATA

Landsat data:

The study area is covered under four frames of Landsat images (Fig.3). The imagery which were used for the study are given herein. (Table 2).

Table 3 : Availability of Landsat data

| S.No. | Path and row number-world reference system | Date | Satellite | Senor | Bands | FCC | CCT |
|---|---|---|---|---|---|---|---|
| 1 | 157-039 | 14 Nov.72 | L-1 | MSS | - | FCC | - |
| | | 12 Feb.73 | L-1 | MSS | 5&7 | - | - |
| | | 5 Nov.79 | L-2 | MSS | 4,5&7 | FCC | - |
| 2 | 157-038 | 02 Dec.72 | L-1 | MSS | 5&7 | FCC | - |
| | | 12 Feb.73 | L-1 | MSS | 5&7 | - | CCT |
| 3 | 158-039 (147-039) for L-4& L-5 | 26 Apr.84 | L-4 | MSS | 5 | - | - |
| 4 | 158-038 | 15 Nov.72 | L-1 | MSS | - | FCC | - |

Base Map:

A base map of the Upper Yamuna Catchment area was prepared using survey of India topographic maps at 1:250,000 scale (Fig.4). The following are the Toposheets used

53 E

53 F

53 I

53 J

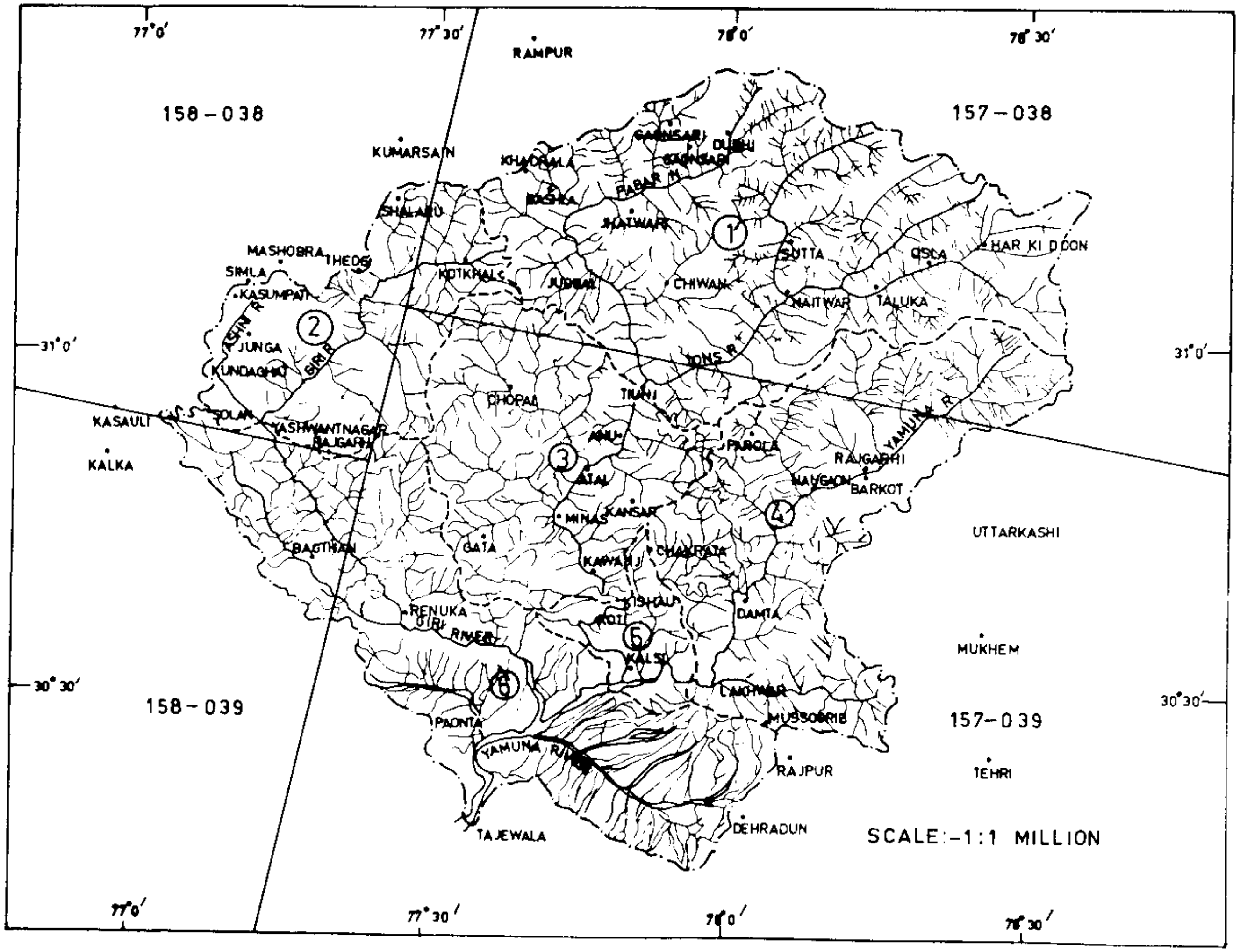


Fig. 3 Landsat coverage of the study area

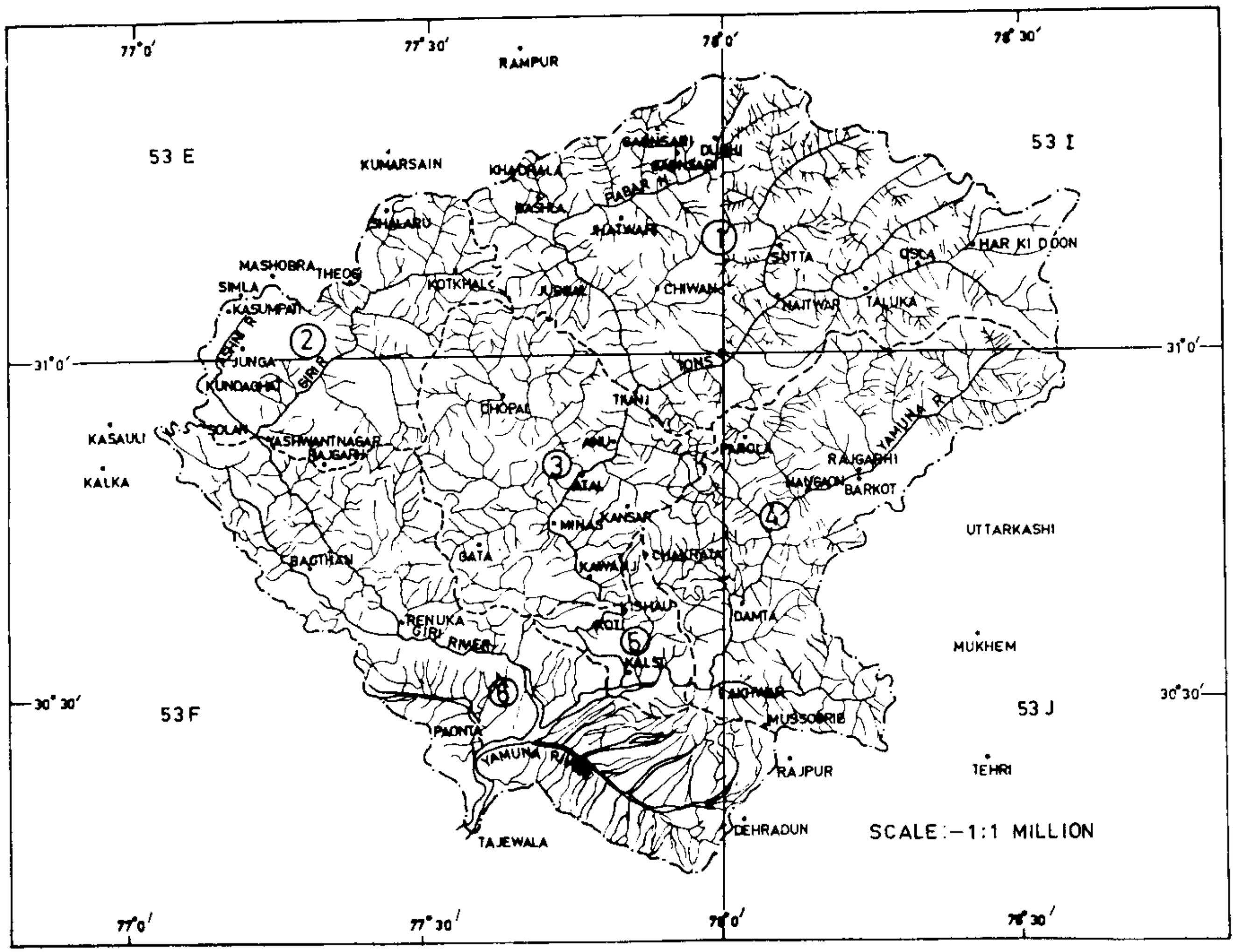


FIG. 4 Toposheet coverage of the study area

## 6.0 METHODOLOGY

Remotely sensed data can be analysed visually when these are available in the form of image. Digital analysis of the data could be undertaken when the data is contained in Computer Compatible Tapes (CCT) with required software.

For the present study, visual interpretation has been done for the area using the data available with the aid of equipment like (i) Large Format optical Enlarger ii) Diazo Printer iii) Magnaseope (iv) Light Table. Ground information are collected from the literature already available from various central and State Governments and academic institutions.

Digital analyses of two test sites of the area have been done with the image processing software based on maximum likelihood classifier which is operational in Institute's VAX-11/780 computer system.

## 7.0 ANALYSIS AND RESULTS

Land use mapping has been found to be very advantageous using Landsat imagery because of synoptic, repetitive and multispectral coverages of the data. The most appropriate band or combination of bands of Landsat imagery should be selected for each interpretive use. Bands 4(green) and 5(red) are usually best for detecting cultural features such as urban areas, roads, gravel pits, and quarries. In such areas band 5 is generally preferable because the better atmospheric penetration of red wavelengths provides a higher contrast image. Band 5 is also excellent for showing silty water flowing into clear water.

Band 6 and 7 (reflected infrared) are best for delineating water bodies. Since near infrared penetrates only a short distance into water, where it is absorbed with very little reflection, surface water features have a very dark tone in bands, 6 and 7. Wet lands with standing water or wet organic soil where little vegetation has yet emerged also have a dark tone in band 6 and 7, as do asphalt-surfaced pavements and wet bare soil areas. Forested area appear dark tones in bands 4 and 5 and light toned in band 7.

For the present study, bands 5 and 7 and FCC of MSS were found to be most suitable for mapping the land cover of Upper Yamuna Catchment. Standard False Colour Composites (FCC), are of great help in visual interpretation and mapping of landuse features as the grey tone of 3 bands (band 4,5 &7) is colour coded and presented so that information of the 3 bands can be compared and assessed in one glance.

## 7.1 Visual Image Interpretation for Upper Yamuna Catchment

The catchment of Upper Yamuna was demarcated on the basis of ridges shown by contour on toposheets. A base map of the area was then prepared in 1:250,000 scale using survey of India toposheets of 1:250,000 scale.

The Landsat image negatives of the area were enlarged from 1:1 m scale to 1:250,000 scale using Image enlarger and black and white prints were prepared. Also, False Colour Composite (FCC) using overlays made by exposing band 4,5 and 7 dia positives of images to diazo films of yellow, magenta and cyan respectively were prepared in Diazo Printer. The transparent FCC is viewed using large format optical enlarger with fixed magnification of 4.

Now using the elements of image interpretation, the various categories of land cover/land use were identified. The information from toposheets and other available map provided limited groundtruth. The characteristic features of the different land cover classes used as keys in interpretation are given in Table 3. The Land cover/Land use features information were then transferred to the base map to prepare the landuse/landcover map of Upper Yamuna Catchment upto Tajewala as presented in Fig.5.

### 7.1.1 Land cover distribution

Efforts have been made to select and delineate various hydrologically important land use categories.

The various categories recognised in the area are as follows:

1. Thick Forests
2. Thin Forests
3. Barren with sparse clusters of trees, agricultural fields

Fig. 5 Land use map of Upper Yamuna Catchment

Table 4: SIGNATURE OF VARIOUS LAND USE CATEGORIES ON LANDSAT IMAGES

| Sl.No. | Category | Tone in band 5 | Tone in band 7 | Colour in F.C.C. |
|---|---|---|---|---|
| 1. | Thick Forests | Dark | Light Grey | Deep red |
| 2. | Thin Forests | Dark to medium grey | Light grey | Red with mottling of yellow in some patches |
| 3. | Cultivated Area | Grey | Light grey | Red with dark blue patches in irrigated areas (rough texture) |
| 4. | Barren with sparse vegetation and built up area | Light grey | Dark grey | Yellow to light brown mottled with red and blue. |
| 5. | a.Sandy/gravelly river bed | Light Grey | Light grey | Light blueish |
| | b. River water | Grey | Dark grey | Blue |
| 6. | Snow | White | White | White |

and builtup area.

4. Cultivated area

5. Snow

6. Rivers

The area under cover of each land use category in the six sub-catchments is given in table 4.

The land use map of the catchment reveals the following general trend of land use distribution:

(a) The higher reaches of the catchment, above an altitude of 4,000 m are perpetually snow covered. The snowmelt area shows lack of vegetation and is barren.

(b) The ridges have a thick forest cover which gradually thins down towards the lower reaches.

(c) In the valleys, the slope towards the rivers/drainage are relatively steep. Land cover along these slopes are found to be forests/agricultural fields but are mostly barren with sparse vegetation and susceptible to erosion.

(d) Doon valley is predominantly cultivated land with built-up area for human settlement. The soil is sandy and gravelly and it is manifested in the bright tone in imagery of bands 5 as well as 7 wherever the land is lying fallow. There are also some protected thick forests whose regular shapes are prominent.

(e) The Siwaliks are covered by thick deciduous forests.

(f) The land use recognised as barren land from satellite imagery is not completely devoid of vegetation. Some of this land is under grasscover, cultivatation and also built-up area for habitation.

In between the forest area too, land is being used for cultivation and farming after clearing the forest. This cultivation is done in small patches and is either not resolved in satellite imagery or is too small an area to be delineated separately. Hence it is merged with forests or barren category inside which it occurs.

7.2 Digital Processing of CCT data for land use

Image processing software SACIPS developed by Space Application Centre, Ahmedabad was installed in National Institute of Hydrology VAX-11/780 system. Digital processing of CCT data (Frame 157-039 of 12.2.73) was done to classify the land use of 2 test areas of Upper Yamuna Catchment using maximum likelihood technique of supervised classification. In the attempt to classify, it was seen that the area which lies in the mountainous terrain of Himalayas, most of the landcover features are merged by shadow. Several land ratios were tried to eliminate the shadow affect.

Elimination of partial shadow in the Himalayan region of Upper Yamuna Catchment has been done using MSS $2^2$/MSS 4 band ratio. To classify the land cover of the area, only one image file i.e.ratio image of MSS $2^2$/MSS 4 has been used and the results were found to be much improved.

However, this effort could not eliminate the effect of shadow completely.

The test areas (Fig.6) that have been classified are:

1. Part of Asan River sub-basin lying between latitude 30.3 N to 30.6N and longitude 77.7 E to 78.1 E(Fig.7).
2. Part of Giri River sub-basin lying between latitude 20.2N to 30.7N and longitude 77.35 E to 77.80 E(Fig.8).

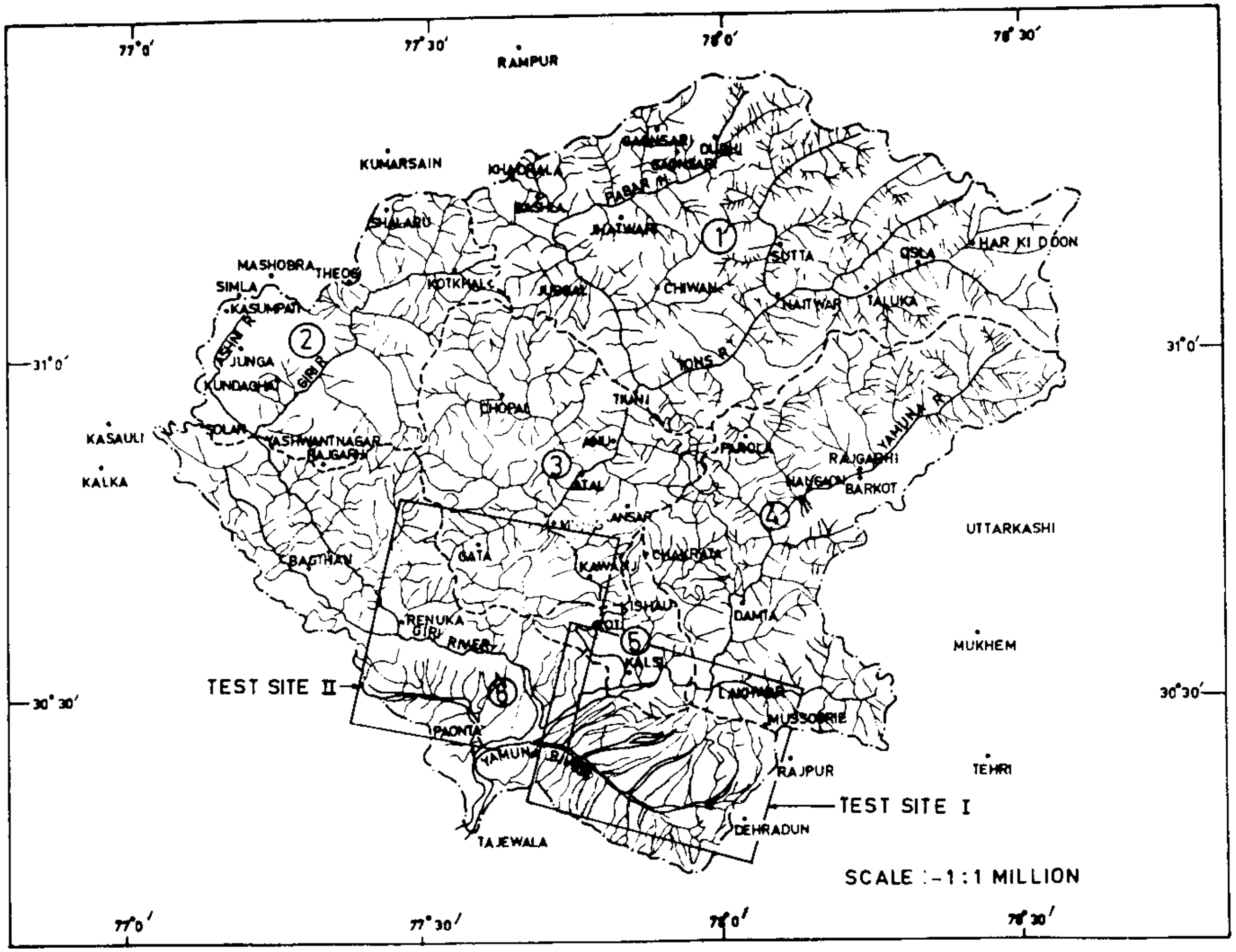


Fig. 6 Map showing the test areas

Fig.7 Computer classified land use map of part of Asan river sub-basin-test site-I

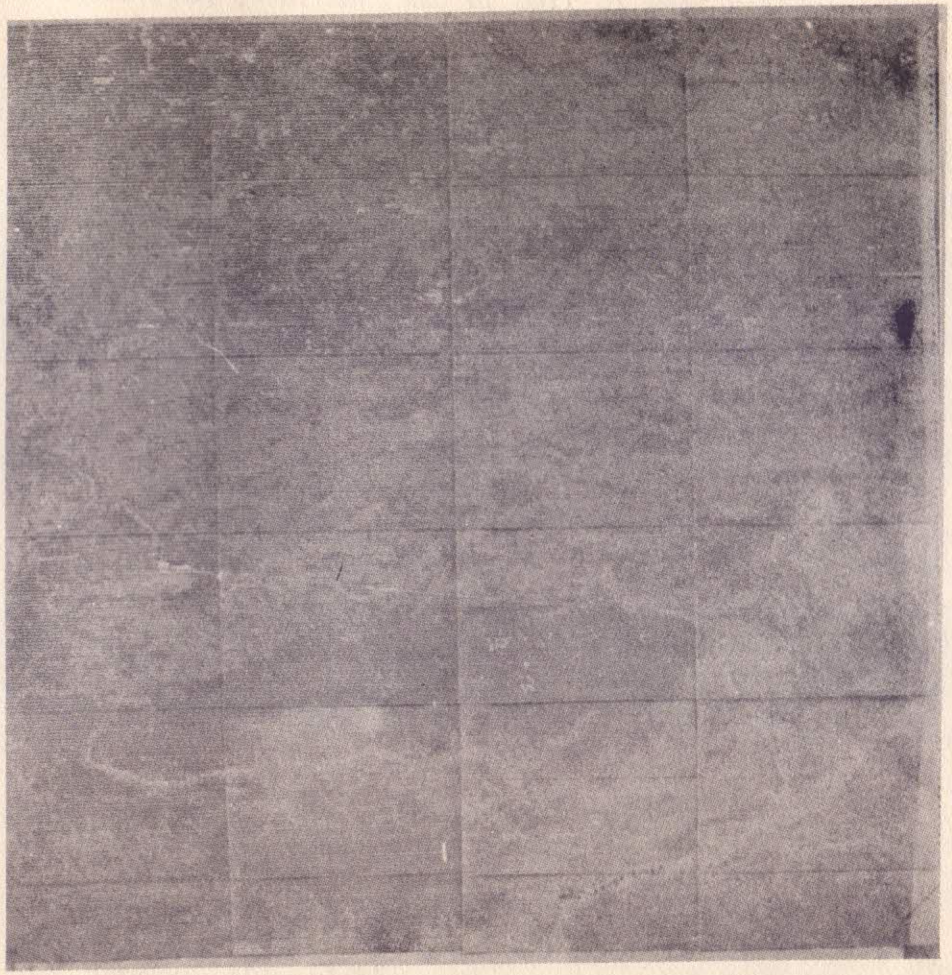

Fig.8 Computer classified land use map of part of Giri river sub basin-test-site-II

Four land cover/use classes have been categorised using training sets.

1. Forests
2. Agricultural area/thin forests
3. Barren area
4. Sandy/bouldery river beds.

The agricultural area and thin Forest could not be distinguished separately and have been merged into one.

Table 5 gives the comparison of percentage of area for different land use got by visual interpretation and digital processing for two test areas.

The disparity in results given by visual interpretation of satellite imagery and digital processing of CCT data is due to the fact that the small areas which were not classified have been classified pixel by pixel. There may be other reasons like temporal change in land use or misclassification due to registration problem.

## 7.3 Morphometric Analysis

Morphometric analysis and study of drainage characteristics is necessary to understand the hydrology of the basin as it gives a good indication of the underlying geological formations and their permeability, the run-off, water yield and storage capacity of the catchment.

Morphometric analysis or drainage basin analysis involves preparation of a drainage map, designation of stream order, measurement of channel length and catchment area etc. and thereafter computing various parameters like the bifurcation ratio, drainage density, form factor, cirocularity ratio etc.

The drainage map of Upper Yamuna has been prepared from 1:250,000 imagery of the study area with support from toposheets(Fig.9). It was not possible to delineate the smallest and first order streams at this scale. On making a limited check from available toposheets at scale 1:50,000, it was found that the streams designated as first order at 1:250,000 scale are second order or even third order streams on 1:50,000 scale. Variability of stream order with respect to scale of the imagery and toposheets often poses problem for subjective analysis. Although not free from inconsistencies, the plan of morphometric analysis is useful operationally and gives first hand idea about the various physical characteristics of the catchment. The evaluation of number of streams of various orders($N_u$) and subsequently determining the bifurcation ratio ($R_b$) have been attempted with to get an idea about the basin's response and the degree of geologic control on the runoff pattern.

Stream Order

If a sufficiently large sample is treated, the order number is directly proportional to size of the contributing watershed, to channel dimensions and to stream discharge. Dimensionless property of the order number makes it possible to compare two drainage networks differing substantially in linear scale with respect to the corresponding points in geometry. After assigning the drainage network elements their order numbers and the segments of each order are counted to yield the number $N_u$ of segments of given order u. Stream order is a measure of the position of a stream in the hierarchy of tributaries. It is natural that the number of stream segments of any given order will be fewer than the next lower order but more numerous than for the next higher order.

Bifurcation Ratio ($R_b$)

This ratio means that on an average these are $R_b$ times as many channel segments of any given order as the next higher order. The ratio of number of segments of a given order $N_u$ to the number of segments of the next higher order $N_{u+1}$ is termed as the Bifurcation Ratio ($R_b$).

$$R_b = \frac{N_u}{N_{u+1}}$$

Variation of watershed geometry in the catchment makes the bifurcation ratio vary from one order to the next to some extent. But it will tend to be same throughout the series.

The number of streams of different order in various sub catchments and the bifurcation ratios for the study area is given in Table 6.

When logarithm of number of streams are plotted against order, most drainage networks exhibit a linear relationship with small deviation from a straight line. Such plotting has been made for the upper Yamuna catchment using the figures from table 6. This is shown in Fig.10. The average value $R_b$ for a given channel network can be made by determining the slope of the fitted regression of logarithm of numbers on order. The regression Coefficient i.e.slope of the straight line is identical to logarithm of $R_b$. From fig.10, the bifurcation is estimated to be 4.68. This indicates that in the Upper Yamuna Catchment the geologic structures does not distort the drainage pattern. Because of the dimensionless character of $R_b$ and because of the drainage system in the homogeneous material tend to display geometric similarity, it is quite natural that the ratio shows minor variation from one portion of the catchment to the other. Hydrograph expected from this catchment or from any of the subcatchment will neither have the sharp peak nor expended peak and will tend to follow between these two extremes.

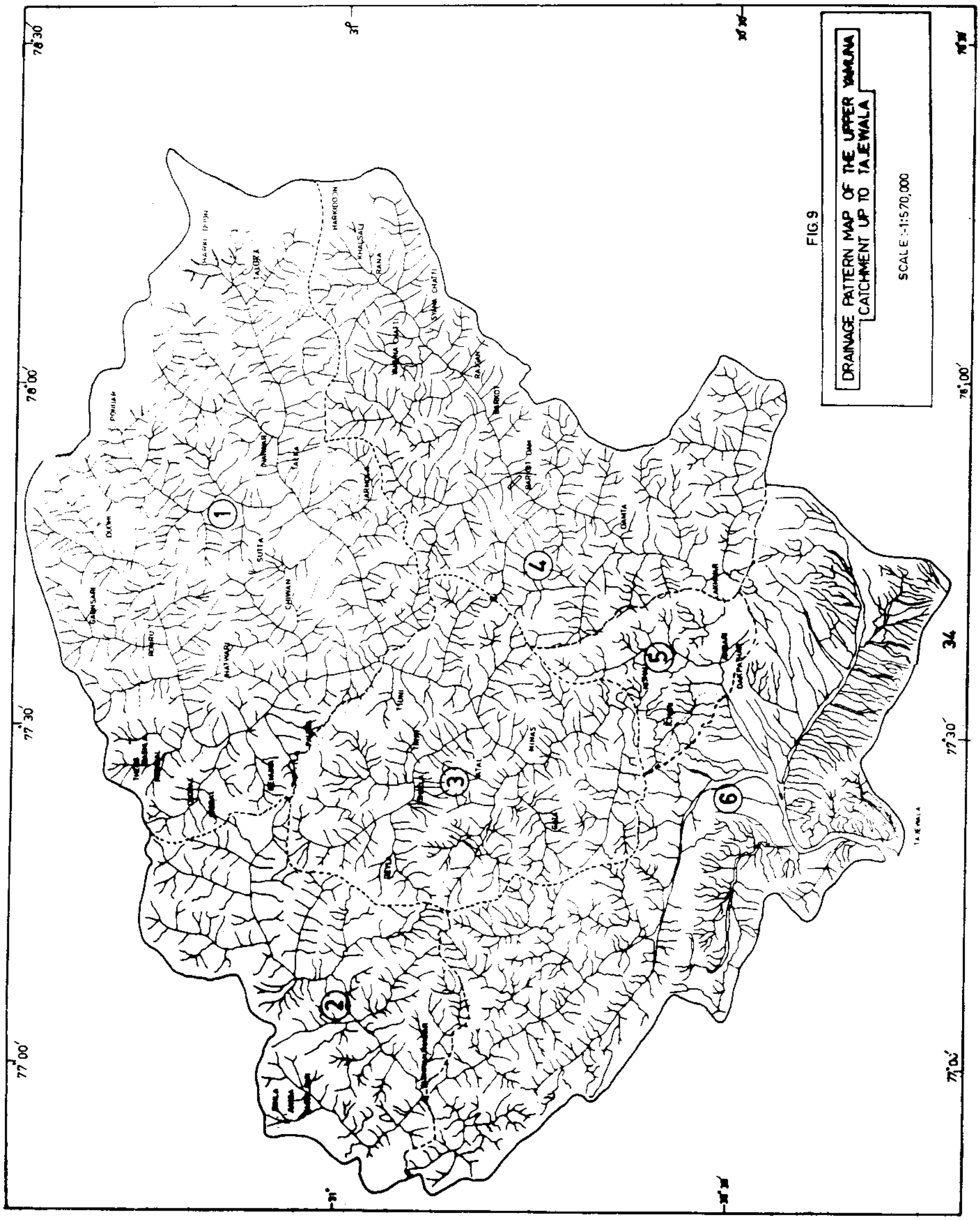


Fig.9 Drainage density map of Upper Yamuna Catchment

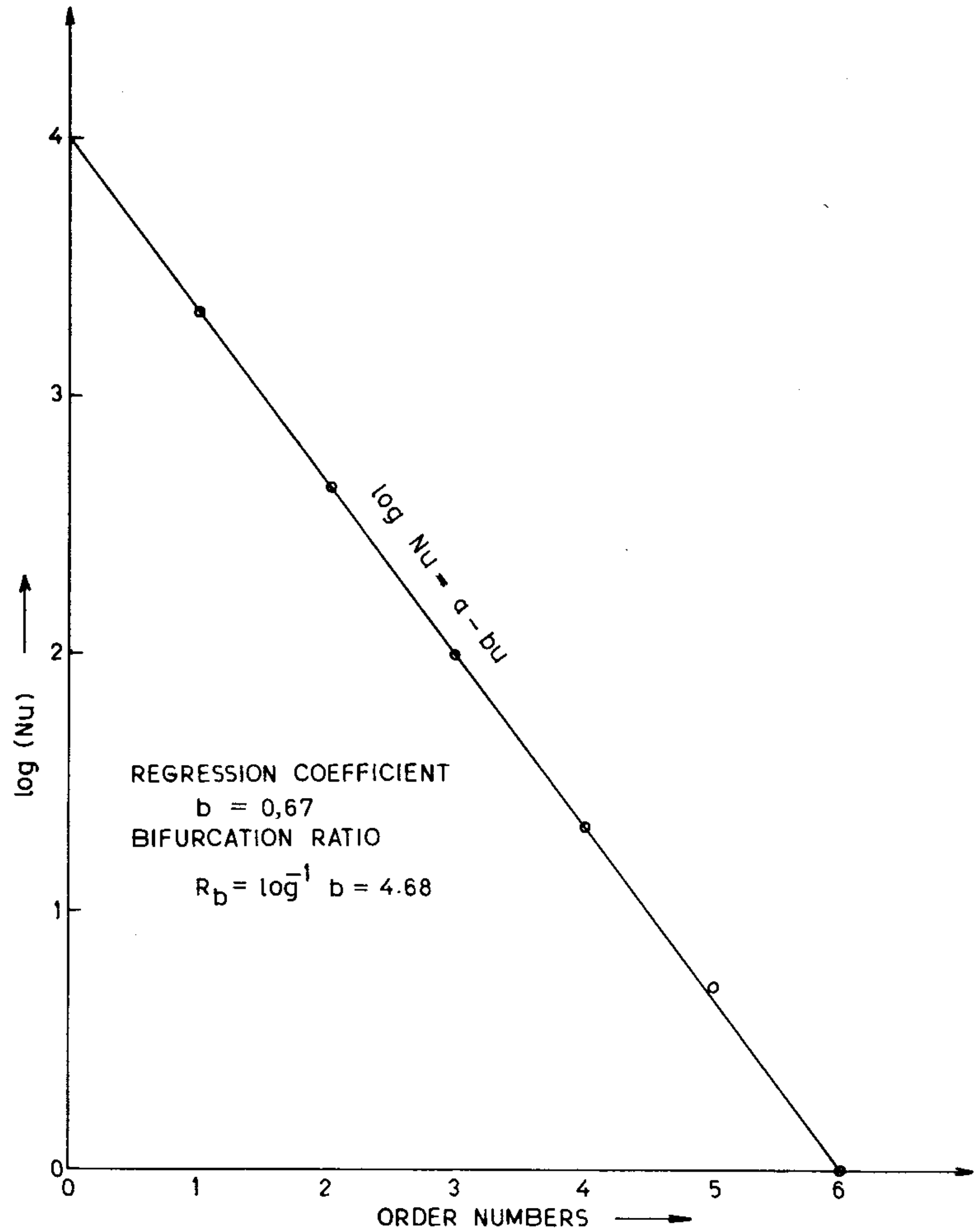


Fig.10. Plot of Logarithm of stream Numbers and order Numbers for Upper Yamuna Catchment.

Table 5 : LAND AREA UNDER DIFFERENT LAND USE CATEGORIES IN THE SIX SUBCATCHMENTS OF UPPER YAMUNA CATCHMENT UPTO TAJEWALA

| | Snow | Thick Forest | Thin Forest | Barren with sparse vegetation | Agricultural Area | River channel | Total Area of Sub-catchment |
|---|---|---|---|---|---|---|---|
| 1. Tons upto Tiuni | 912.5<br>27.1% | 1074.75<br>31.92% | 634.5<br>18.85% | 745.25<br>22.13% | - | - | 3367 |
| 2. Giri upto Yashwant Nagar | - | 209.375<br>14.82% | 496.875<br>35.18% | 706.25<br>50% | - | - | 1412.5 |
| 3. Tons from Tiuni upto Kishau | - | 415.625<br>26.2% | 411.875<br>26% | 757.5<br>47.8% | - | - | 1585 |
| 4. Yamuna upto Lakhwar | 155.625<br>6.89% | 621.25<br>27.49% | 653.125<br>28.9% | 830<br>36.72% | | | 2260 |
| 5. Yamuna from Lakhwar and Tons from Kishau upto Dakpathar | - | 31.25<br>8.74% | 111.25<br>31.12% | 185<br>51.75% | 21.25<br>5.94% | 8.75<br>2.45% | 357.5 |
| 6. Yamuna from Dakpathar and Giri from Yashwant Nagar upto Tajewala | - | 755<br>29.43% | 930.5<br>36.3% | 372.5<br>14.5% | 397.5<br>15.5% | 109.5<br>4.27% | 2565 |
| Total | 1068.125<br>9.25% | 3107.25<br>26.91% | 3238.125<br>28.04% | 3596.5<br>31.15% | 418.75<br>3.63% | 118.25<br>1.02% | 11547 |

Area in $Km^2$

Table 6 : COMPARISON OF PERCENTAGE OF AREA FOR DIFFERENT LAND USE FROM VISUAL INTERPRETATION AND DIGITAL PROCESSING FOR 2 TEST AREAS

Test Area 1

| Land use Category | Forest | Agricultural Area & Thin forests | Barren | Sandy/bouldery river channels | Unclassified |
|---|---|---|---|---|---|
| % area from digital processing | 32.3% | 40.2% | 19.8% | 3.2% | 4.5% |
| % area from visual interpretation | 28.05% | 49.45% | 18.5% | 4% | 0% |

Test Area 2

| Land use category | Forest | Agricultural Area & Thin forests | Barren | Sandy/bouldery river channels | Unclassified |
|---|---|---|---|---|---|
| % area from digital processing | 38.1% | 43.9% | 13.9% | 3.3% | 0.8% |
| % area from visual interpretation | 12.6% | 61.3% | 23 0% | 3.1% | 0.0% |

Table: 7 NUMBER OF DIFFERENT ORDER STREAMS AND BIFURCATION RATIO FOR SUB-CATCHMENTS OF UPPER YAMUNA CATCHMENT

| S.No. | Sub-Catchment | Sub-Catchment | No. of Streams ($N_u$) / Bifurcation Ratio($R_b$) | Order Number Ist | 2nd | 3rd | 4th | 5th | 6th |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 1 | Tons upto Tiuni | $N_u$ | 565 | 122 | 28 | 5 | 2 | 1 |
| | | | $R_b$ | - | 4.63 | 4.36 | 5.6 | 2.5 | 2 |
| 2. | 2 | Giri upto Yashwant nagar | $N_u$ | 445 | 51 | 9 | 1 | - | - |
| | | | $R_b$ | - | 4.8 | 5.6 | 9 | - | - |
| 3. | 1 and 3 | Tons upto Kishau | $N_u$ | 916 | 198 | 41 | 9 | 3 | 1 |
| | | | $R_b$ | - | 4.62 | 4.83 | 4.56 | 3 | 3 |
| + | | Yamuna upto Lakhwar | $N_u$ | 438 | 82 | 21 | 6 | 1 | - |
| | | | $R_b$ | - | 5.34 | 3.9 | 3.5 | 6 | - |
| | 2 and 6a | Giri upto confluence with Yamuna | $N_u$ | 468 | 105 | 24 | 4 | 1 | - |
| | | | $R_b$ | - | 4.46 | 4.38 | 6 | 4 | - |
| 6 | 6b | Bata N.upto Confluence with Yamuna | $N_u$ | 68 | 15 | 3 | 1 | - | - |
| | | | $R_b$ | - | 4.5 | 5 | 3 | - | - |
| 7. | 6c | Assan upto confluence with Yamuna | $N_u$ | 98 | 27 | 6 | 1 | - | -- |
| | | | $R_b$ | - | 3.6 | 4.5 | 6 | - | - |
| 8. | 5 and 6 d | upto Tajewala | $N_u$ | 82 | 18 | 4 | - | - | - |
| | | | $R_b$ | - | - | - | - | - | - |
| | Total | Upper Yamuna Catchment | $N_u$ | 2070 | 445 | 99 | 21 | 5 | 1 |
| | | | $R_b$ | - | 4.7 | 4.5 | 4.7 | 4.2 | 5 |

8.0 CONCLUSION

It is already well established that a reasonable accurate land cover map of an area could be prepared from the Landsat data. The Land use map of the Upper Yamuna Catchment upto Tajewala using Landsat imagery has been prepared. Qualitative ideas that emerge out will act as a base input for further studies.

Six land use categories of hydrologic importance could be deciphered from the imagery. About 10 percent of the catchment is snow bounded and about 55 percent of the area has forest cover both dense and thin . These information will be useful for runoff estimation. Agricultural activities are not prominent and constitute only about 4 percent of area. The percentage of barren land with very limited vegetation is to the tune of 30 percent and is an indicator of denundation of forest cover in the area though further detailed and specific studies will be required to establish these for quantified estimation of any parameter.

In order to minimise the effect of sun-shadow in digital processing, the $MSS2^2/MSS4$ band ratio image file found to be workable though could not eliminate the same completely. This created problem during the digital analysis of the test site of Giri river sub-catchment. Also, chances of some misclassification and mixing up of pixels are not ruled out due to registration problem while using printer output for training set purpose in absence of colour display console.

From the morphometric analysis, the average bifurcation ratio for the catchment has been estimated to be 4.68. This indicates that there is no effect of geologic formation on the drainage pattern and hydrograph expected from the sub-catchments and the catchment as a whole will not have extended or sharp peaks and will follow between these two extremes.

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