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HYDROLOGICAL LAND USE MAPPING OF NARMADA BASIN

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PREFACE

The estimation of runoff from a catchment is one of the important tasks of hydrologists. Study of several hydrological processes and modelling is completed by them to achieve this objective. This is accomplished using data/ information from catchments. Information e.g. land cover, management practices, surface roughness etc. are needed. These affect infiltration, interception, evaporation and other hydrological processes. These data are used in several hydrological models. A simple rainfall runoff model uses land use, land cover, soil and hydrological conditions in a catchment. This model is developed by Soil Conservation Services of United Stated Department of Agriculture. It is based on several infiltration data collected in United States.

Remotely sensed data in particular satellite borne sensor's data have great utility in deriving information from catchments. These data are available in digital form and they can be easily analysed in image processing software. Digital classification is a useful technique for extracting information e.g. land use and cover on the earth's surface. Remotely sensed data may be combined with collateral data on soils to obtain curve number for application in runoff estimation.

The upper Narmada basin has been selected in this study. This area is 17060 sq. km in extent. IRS-LISS-I sensor's digital data are used here. A land use map is obtained from remotely sensed and collateral data. For land use classes, curve numbers are assigned using standard curve number tables and averaging values there in. These may be used for estimating design discharge and in hydrological estimations/ modelling.

The report, entitled 'Hydrological land use mapping in Narmada basin', is a part of the work programme of the Remote Sensing Applications Division, National Institute of Hydrology for the year 1995-96. The study was carried out by Mr D. S. Rathore, Scientist 'C' of the Division.

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ABSTRACT

Among environment sciences, remote sensing is a science in which electromagnetic radiation sensors record images of the earth. Images are digitally analysed to get information. The incident radiation interacts with objects. Radiation is absorbed, reflected or transmitted. Leaf, soil and water has characteristic spectral reflectances, e.g., little visible light is absorbed and reflected and almost all infra red energy is absorbed by water. Image signature forms a basis for digital analysis of satellite digital data.

Here, a land use map is prepared for upper Narmada basin up to Jabalpur town. The areal extent of the basin is 17060 sq. km. It lies in Madhya Pradesh, India. The climate is tropical humid wet and dry. The sequential clustering digital technique is used on ERDAS software on IRS LISS I digital data. Spectral classes are assigned ground classes based on ground truth and spectral signature of objects. Collateral data in form of reports, data collected from ground truth and laboratory analysis are used to assign soil for land use classes. CN for these classes are assigned from standard tables.

CHAPTER 1 INTRODUCTION

Remote sensing technique directly gives information about earth's surface e.g. land cover. Land use is deducted from these data. Since hydrological processes are influenced by land use and cover in a watershed, these information are used in hydrological estimation and modelling. Thus, land use and cover map prepared from remotely sensed data may be useful in hydrological studies. Here, a land use cover map is derived for large basin and curve numbers are estimated for several land use cover classes.

For mapping, both digital and visual analysis techniques are available. Data are also available in both forms. They can be changed to one another with ease. Visual techniques relies on an human interpreter solely. Human eye has limitations in discriminating the objects/ tone/ color as compared to a digital computer. Digital techniques have advantages of using many channels of data, discriminating many numbers, repeatability etc. There are mainly two approaches in digital classification namely supervised and unsupervised.

In a supervised approach, first ground truth data/ collateral data are collected. Computer is provided typical spectral signatures from images and image is later classified using these. In unsupervised technique, inherent property of digital numbers to form clusters in spectral channel- digital number space is utilised. Thus typical signatures are automatically estimated by the computer. These are used to classify an image. The result is compared to ground truth/ collateral information and thematic classes are assigned to clusters. There are several clustering/ unsupervised techniques available namely:

1. Sequential clustering: In sequential clustering, a part of an image or complete image is used. First pixel is put in cluster one. Second pixel is compared with this pixel in terms of its distance from first. It is put to the cluster or to a new cluster based on this distance value and a limiting distance. When number of pixel in a cluster is incremented, its mean is recalculated. This mean is input in distance calculation for next pixel. The procedure is controlled by many parameters.

2. Iso data clustering: In this technique clustering is completed in many iterations through the data set. Initial cluster centres are either user defined or automatically generated. These are changed using same procedure as specified above. Thus, clusters are modified till a reasonable number of iterations are completed or specified percent unchanged-pixel are achieved.

1.1 LAND USE CLASSIFICATION SYSTEMS

Several land use and land cover classification schemes are developed by many organisations. These scheme's developments have been prompted by many reasons e.g. need of the hour, availability of new type of data, need to mitigate natural hazards/ disasters etc. In spite of availability of many such schemes, maps may be classified by individual schemes by individuals or organisations. This is caused due to inadequate information, coarseness and type of input data, experience and knowledge of interpreter etc. There are many land use classification schemes available. Many of these are widely used and acclaimed. These schemes are described here.

Revised USGS land use and land cover classification system

This classification system is a revision over an earlier similar classification system. It is developed for use with remotely sensed data and is a national classification system for USA. It is left open ended at 3rd and 4th level to provide flexibility to different users. Detailed definitions of each category at level one and two are provided. This system has been devised as a national frame work for land use and cover mapping using aerial photographs (Anderson and others 1976). Level-one categories are described here.

1. Urban or built up: Land with intensive use and structures built over it is urban land. These include cities, towns, villages, strip developments along highways, transportation, power and communication lines, industrial and commercial complexes, institutional areas etc. Other land uses within urban areas are classified as urban areas. On an urban fringe, agriculture and wetlands are classified under respective categories. In case of multiple uses of land, e.g., residential areas and dense forest cover, urban land use gets precedence in land use classification.

2. Agriculture: Land producing food and fibre is classified as agricultural land. Agriculture land differs from urban areas in density of road network and number of buildings. Pasture areas

may appear different from crop areas due to absence of road network and pattern of plots, farm machineries etc. Areas that restrict agriculture due to factors, e.g., wetness, are not classified as agriculture. Similarly, within wetland, wild crop and forest produce areas are classified in appropriate categories. Parks and cemeteries at an urban periphery may be confused with agriculture areas in remotely sensed data. Other areas, e.g., Wetland drained for agricultural activities, flooded rice field are classified as agriculture.

3. Rangeland: Rangelands are natural grass, grass like plant and shrub areas.

4. Forest: Forests possess 10% or more tree-crown areal density. They are stocked with trees which produce timber and other forest produces. Forests influence the climate and a water regime. Land that has less than 10% crown closure and not put to any other land use is classified as forest, e.g., land under cyclic tree-felling and block planting for timber. This has a cycle of two to three decades. Other forest activities are wilderness reservation, water conservation, property ownership etc. These activities may not be visible on remotely sensed data. These information are obtained from collateral data and are used at 3rd and 4th level of classification.

5. Water: Water is classified by US Bureau of Census (USBC) as land persistently under water provided, if linear it is at least 200m wide and if extensive it is at least 16 ha in area. For many purposes, water bodies smaller than as specified by USBC may be needed.

6. Wetland: Wetlands possess ground water near, at or above ground for significant part in most years. Alluvial and tidal areas are classified in this category. Examples of wetlands are mud flats, marshes, lakes, ponds, reservoirs. Mud flats and marshes are found near bays. In mountainous valleys also wetland develops on perched areas and in bogs. Hydrophytes and aquatic vegetation develop in wetland. They may be absent occasionally, e.g., on mud flats. Upper and lower boundaries may exist in wetland. Above upper boundaries any other land uses may exist. The lower boundary corresponds to water limit.

7. Barren land: Barren land possesses limited capability to support life and has cover in less than one third of its area. If vegetation is present, it is sparse and scrubby. Shrubs and bushes do not develop on such land. Soil is thin, absent leaving only rock cover. Areas for which no past or future use are evident, are classified in this category. Other classes e.g. clear-felled forests, fallow agricultural areas, land reserves for industrial dumping etc. are classified in appropriate categories. When occasionally heavy rainfall occurs in barren areas, short lived and luxurious plants may grow.

8. Tundra: Tundras are barren areas beyond the limit of forests in mountains.

9. Perennial ice and snow: These are ice and snow covered areas that survive summer melting seasons due to existing environmental conditions.

Wasteland classification system

Wasteland classification system is developed for use with satellite data to classify wasteland of India. It is developed for use with coarse resolution satellite data, e.g., Landsat MSS (Gautam and others 1991).

SCS land use classification system for runoff curve number (RCN) method

SCS runoff curve number method is used to estimate direct runoff volume in a watershed. This is most widely used in hydrology. It has been initially developed for small agricultural watersheds. Later, it has been modified to incorporate urban and semi-urban watersheds. Land use and land cover, soil and rainfall data are used. Land use and land cover data may be derived from satellite data. After estimating runoff volume, many equations, figures and tables are used to obtain runoff hydrograph (Ogrosky and Mockus 1964, Rawls and others 1993).

Land cover is vegetative or impervious cover. Both, vegetation and built-up land have controlling effect on runoff. Complex variables, e.g., plant sizes, root depth, plant density etc., are seldom known. Thus, general characteristics, e.g., type or crop, farming operations etc., are used in this classification (Ogrosky and Mockus 1964).

1. Agriculture: Good crop cover reduces impact of rain. This in turn increases infiltration and reduces runoff. Crop-rotations with at least single good cover crop reduce runoff. Effect of good crop cover is retained for at least two to three years. Crop rotation having combination of row, small grain crops and fallow land produce more runoff. Ploughing, planting, cultivation and farm operations carried out without regard to a land slope are straight row farming operations. They produce more runoff from an area. The contour farming creates furrows parallel to contours. Farrows detain water that infiltrates in the ground. Capacities of furrows depend on type of crops and slopes. For row-crops large sized furrows are created whereas for small grained and leguminous crops small sized furrows are created. Capacities of furrows reduce with an increase in the slope of the land. Terraces reduce runoff. For terracing in pasture and rangeland, plants and grasses are removed from them. They are classified as terraced agricultural land till plants reestablish themselves. Agriculture areas are further divided in to row, small grain and legumes (Troeh and others 1980). These classes are described here.

<u>Row crops:</u> These crops are grown in rows to facilitate cultivation operations e.g. tillage, weed removal, spraying of insecticides etc. Soil remain unprotected and is compacted by rain

drop's impact. Slopes also allow easy movement of water. Example of these crops are corn, soybean, sorghum, sugarcane, sugar beat etc.

Small grain crops or cereals: These crops are closely growing crops. They are sown with at least 15 centimetres spacing or are broadcasted. Examples of these crops are rice, wheat, oat, barley, Rye, peanuts etc.

Legumes: These are nitrogen fixing crops. They provide better crop cover than small grain crops.

2. Pasture and rangeland: Hydrological conditions are dependent on amount of grazing, percentage cover and amount of the dry matter of plants. Good hydrological conditions result due to less grazing with presence of more dry matter and higher percentage cover in land. For intermediate hydrologic conditions, Curve Numbers (CN) are interpolated from CN tables.

3. Meadows: Meadows are permanent grass land.

4. Wooded land: From coarse resolution data, e.g., Landsat MSS, it may not be possible to obtain detailed land use and land cover as given in RCN method. Alternate land use and land cover classification is given by Ragan and Jackson (1980). Alternately, when many crop types are identified from satellite data using digital classification they may also be assigned suitable curve numbers (CN).

Land utilization classification

Land utilization classification is a modified classification developed in 1952 from an earlier such classification. This is used in agricultural planning (Bansil 1984).

1. Forest: Government and private forest land, areas under forest cover or potential forest areas are forests. Agricultural areas within forests, grazing areas etc. are classified under appropriate classes.

2. Area not available for cultivation: This includes barren and uncultivable areas and other land use. Barren and uncultivable areas are land that require high cost for converting them for agricultural use, e.g., sandy areas and mountains.

3. Other uncultivated excluding current fallow: These include permanent pastures, grazing land, uncultivable waste and plants, e.g., Bamboo not included in net sown areas. Pasture and grazing land are permanent pasture, meadows and village grazing land. Cultivable wastes are land not under cultivation in current year and last five years or more.

4. Fallows: These include current and other than current-fallows. Current-fallows are lands that are not under cultivation in the current year. Other than current-fallows are lands that are not under cultivation in last two to four years. These are lands that go temporary out of cultivation due to reasons, e.g., poor status of farmers, scarcity of water etc.

5. Net sown areas: These are areas under crops. Cropped areas that have double cropping are counted only once.

1.2 SOIL CLASSIFICATION SYSTEMS

Taxonomical classification

Earliest classification system for soil has been developed by Russian scientist Dokuchaev (1870, vide Foth 1984). Soil forming factors were the basis of the classification. This was used in United States of America (USA) till 1960. In 1960, a classification system has been adopted in USA based on soil morphology. Modern classification system (Soil Taxonomical Classification) is modification on this. This is adopted in the year 1975 for USA. This is a hierarchical classification system. Soils are classified as order, suborder, great groups, subgroups, family and series (Foth 1984).

Soil Texture designations

Soil texture is fineness and coarseness of the soil. Specifically it is relative proportion of sand, silt and clay. Sand, silt and clay are particles smaller than gravel (2.00 mm). A texture triangle is developed by United States Department of Agriculture (USDA). This system uses percentages of sand, silt and clay separates in soils to designate their textures. Indian Standards Institute has tabulated soil textures designations for percentages of soil separates (Foth 1984, Annonymus 1983).

Hydrological soil classification

In SCS runoff curve number model, soils are classified according to hydrological properties of soils. In this system soils are classified in groups designated as 'A' to 'D'. These are known for most of the soil series in the USA. Group-A soils possess high transmission rate on throughly wetting. This includes deep sandy and gravelly soils. Group B soils are soils with a moderate transmission rate when they are throughly wetted. Group-C soils possess slow transmission rates. These soils possess fine texture. They normally have an impeding layer. Other soil group is 'D'. These soils possess very slow transmission rates when they are throughly wetted. These are, e.g., clayey soils, shallow soils over an impervious layer and soils with a water table near surface (Ogrosky and Mockus 1964).

1.3 CROPPING SYSTEMS

Crops are grown in several seasons. These are monsoon, winter and summer. Monsoon and winter crops are respectively called Kharif and Rabi crops in India. Crops are also defined as annual, biennial, and perennials. Annual crops are sown after every harvesting. Other crops can be harvested many times after single sowing. Cropping practices for few crops are described here (Thakur 1980).

1. Koda millet or Kodo or Paspalum scrobiculatum: They attain maximum height of 45-60 centimetres. They are long duration annual crops. They require at least one interculturing.

2. Rape or Rai: It has 10-180 centimetre height. It is grown 30-45 centimetre apart in rows. Thinning is completed for maintaining 15 centimetres plant to plant distance.

3. Red gram or Arhar: They attain height of 180 to 375 centimetres. They are sown at 120 centimetres row spacing and 20 centimetres plant spacing.

Above information can be obtained from several data sources e.g. satellite remotely sensed data, collateral data etc. Curve numbers can be assigned to land use and cover. These are useful in estimation of design descharge from a basin.

CHAPTER 2 LITERATURE SURVEY

2.1 LAND USE MAPPING

Land use and land cover, in the Faizabad district, Uttar Pradesh, has been mapped using IRS data at 1:250000 scale. Digital data are also used. Land use and land cover is mapped using multitemporal data, i.e., of October and February. Rice crop area is mapped applying digital classification of low rainfall year data of October. Depth of water is determined using data of the high rainfall year and those of low rainfall year for October and September. Flooded area is mapped using data acquired 15 days after flood occurrence in August (Singh and Singh 1996).

A watershed of 39.1 sq. km areal extent is studied in Sikkim for land use and cover. Data used are SPOT MLA and PLA at 1:50000 scale of November and October respectively. Visual interpretation technique is used (Krishna 1996).

Prasad and others (1996) have mapped land use and land cover in a canal command in the Mehendragarh district in Harayana. Study area is 196 sq. km. in extent. Area receives 446 mm annual average rainfall. Data used are IRS LISS II FCC at 1:50000 scale of October and March. CCT of data acquired in December, is also used. Major kharif crops are Bajra and Guar. Major rabi crops are wheat and mustard. Crop area is compared with Bureau of Economics and Statistics (BES) yearly crop acreage statistics for minors. Percentage differences vary from 0.6 to 21.6.

Land use and land cover, in a part of the Bhatinda district, Punjab, is mapped using multidate data. Area receives mean annual rainfall of 470 mm. Dunes are of two to nine metres high. Extent of study area is 950.5 sq. km. Data used are IRS FCC of 1989, 1992 and 1993. Main land use is agriculture. It is shown that area under settlement is increasing through land use changes in agricultural land. Wasteland has increased due to canal induced water logging and salinity in part of the area. Levelling of sand dunes has also occurred (Chaurasia and others 1996).

Land use and land cover in the Saharanpur city is mapped using sequential aerial photographs, satellite and ancillary data. Saharanpur has an area of 25 sq. km. Panchromatic aerial photographs at 1:10000 and 1:4000 scale,, IRS LISS II geocoded FCC at 1:50000 scale are used. IRS data are used to map only built up area in an urban growth region. A detailed land use and land cover map is prepared using aerial photographs. The minimum mapping unit has been 0.16 ha (Bisht and others 1995).

A land-use map, of 572 sq. km. watershed in Midnapur district, West Bengal, is prepared by Kumar and others (1991). The watershed receives mean annual rainfall of 1400 mm. Soils in the watershed are mainly alluvial. Other soils are lateritic and red soils. Data used are IRS LISS II CCT of October and FCC of 1:125000 scale. Study area from CCT is extracted. Mainly digital classification with maximum likelihood technique is used. Classified subscenes are merged manually. Software used is VIPS-32.

Das and others (1992) have mapped land use and land cover in a watershed in Bihar. Extent of the watershed is 1000 sq. km. It receives mean annual rainfall of 1157 mm. Geology of the area is complex. Mainly gniesses and schists are present. Hills, plateau, valleys and plains are physiography. Data used are Landsat MSS CCT and FCC. FCC is generated at 1:63000 scale. FCC is interpreted to map broad land use and land cover classes. Detailed categories are obtained from existing maps. Normalized Difference Vegetation Index (NDVI) is used to map vegetated and non vegetated areas.

Sudhakar and others (1994) have mapped a land-use map of Jalpaiguri, West Bengal. Area of the district is 6227 sq. km. It receives 2000 mm mean annual rainfall. Soils are coarse gravelly, sandy clay and loam. Data used are IRS LISS II CCT of November. Data are geometrically rectified to 1:50000 scale using topographic maps. Maximum-likelihood technique is used in classifying both reserve and non reserve forests. Classified maps are merged later. District area is extracted using the district mask. Software used is VIPS-32 on VAX 11/780. Forest cover is 22.82%. NDVI and FCC are also generated. Training data are tested for their separability using confusion matrix and ellipsoidal plots. To test accuracy of classification, confusion matrix using ground truth points, aerial photographs, and additional check points is generated. Accuracy of classification is 85 and 90% for land use and land cover other than forest and forest land cover respectively.

Land use and land cover mapping is carried out in a Tehsil in the district, Kheda, Gujrat. Area is 577 sq km. in extent. Data used is IRS LISS II CCT of March. Data is digitally classified on VAX 11/780 system. FCC is also generated for the area. Data are geometrically rectified using SOI topographic maps of scale 1:50000. A mask for study area is prepared. Maximum likelihood technique is used in classification. Salt affected soils are sodic in nature. Moderate to slight salt-affected soils are observed in waterlogged areas. Water logging is due to canal irrigation. Pasture/ grazing, water logged and slight salt affected area are respectively 9, 8 and 10% of the total geographical area (Sugumaran and others 1994).

Land use and land cover is mapped in Bargi left bank canal command area. Command-area is 137 sq. km. in extent. The slope varies form zero to 3%. Average annual rainfall is 1246 mm. It lies in Jabalpur and Narsinghpur district, Madhya Pradesh. Data used are IRS LISS II FCC of October, November and March. Agriculture land use is 97%. Forest area is 3%. Forest is delineated on both pre and post monsoon data. Ground truth information is obtained from topographic maps (Rathore 1995).

2.2 SOIL MAPPING

Salt affected soils are mapped in Punjab. Data used are Landsat MSS FCC and imageries at 1:250000 scale for years 1972 and 1984. Available maps of 1972 are used. Salt affected area of all categories have decreased due to reclamation technology adopted by farmers. Farmers have used gypsum. Soil is leached and open drains, embankments and bund are constructed. In many areas, due to canals, water logging and salinity have increased. Salt affected soils are mainly found in low lying areas (Sidhu and others 1991).

Salt-affected soils, in many pockets in district Kanpur, Uttar Pradesh, are mapped. Area is 53 sq. km. in extent. Data used are aerial photographs and Landsat TM FCC of scale 1:40000 and 1:50000 respectively. FCC for month of March with bands 1, 2 and 4, aerial photographs for 1972 and soil survey maps for 1956 are used. Cultivation increases from -0.4% (a decrease) to 44% during period 1956 to 1986. There is decline, during period 1972 to 1986, of 6 to 13%. Reduction is due to abandoning of cultivation in later period. In areas with high EC and pH there is a lower increase in cultivation as compared to areas with low EC and pH. There is a marginal increase of 3% in salt affected area in areas beyond gross reclamation sites. (Singh 1994).

Rathore and Jain (1995) have mapped soils in Bargi left bank canal command area. A clear boundary is not seen between yellow (Alluvial) and black clays in post monsoon data.

CHAPTER 3 DESCRIPTION OF STUDY AREA

For the present study, the Narmada basin up to the Jabalpur city is selected (Fig. 3.1). Area lies between latitudes 21°42'N and 23°18'N and longitudes 79°40'E and 81°49'E. Area is covered by Mandla, Jabalpur, Seoni, Balaghat, Durg, Bilaspur and Shahdol districts in Madhya Pradesh, India. Major tributaries to Narmada are Burhner, Banjar and Gaur. Minor tributaries are Seoni, Chakrar, Machhrar, Kharmer, Kanai, Silgi, Dandana, Balai, Hingna and Temur. Tributaries of Burhner are Phen, Halon and Kukra. Tributaries of Banjar are Jamunia, Tanner, Kanhar, Sarpan and Matiyari (Fig. 3.2). The total area is 17060 sq. km.

Climate: Area is covered by tropical humid wet and dry type of climate. The area has three distinct seasons, namely, wet (June to October), winter (November to February) and summer (March to May) (Critchfield 1983, Battan 1984).

Rainfall: Rainfall occurs mainly between July and October. Annual rainfall is between 1397.0 mm (Ghansore) and 1741.5 mm (Paraswada). Based on 20 year data annual rainfall at Niwas is 1369.2 mm. In June to September nearly 84 to 90% of annual rainfall occurs. Large monthly rainfall occurs during July and August months. In these months, 57 to 64% of annual rainfall occurs. July receives highest monthly rainfall. Months of January and February receive 46 to 67 mm rainfall. Ghansore receives 67 mm rainfall in January and February. There are high yearly fluctuations in rainfall, e.g., at Niwas, annual rainfall is between -48 and 54% of normal rainfall (Rahangdale and Dixit 1984).

Temperature: The basin falls in an average annual temperature zone of 22.5° to 25°C. Small southern part of Banjar basin falls in temperature zone of 25° to 27.5°C. Minimum temperature reaches 1°C (December 1977). Maximum temperature recorded is 45°C (May 1969). Temperature records at Mandla between 1966 and 1981 excluding year 1975 are available. Highest minimum temperature is 28.6°C (September 1967). Lowest maximum temperature is 23.2°C (January 1981). In winter, frost occurs. December and January are coolest months (Kundu 1989, Rahangdale and Dixit 1984, Mishra and Choudhary 1979).

Humidity: Humidity is low in April and May. Humidity increases with an onset of Monsoon in June and decreases from September. There is high humidity in December and January. Minimum and maximum humidity at Mandla is 40 (February 1977) and 70% (February 1978) respectively. Minimum and maximum humidity in summer is 19 (May 1975) and 38% (April 1978) respectively. During monsoon minimum and maximum humidity is 71 (July 1979) and 89% (July 1977) respectively (Rahangdale and Choudhary 1985).

Physiography: Study area lies in North Deccan physiographic division of India. Satpura is the physiographic region. There is Maikala range in north and east. Plateaus are Lakhnadon, Paraswara, Baihar and Raigarh. Prominent hills are Dindori hills in Maikala range.

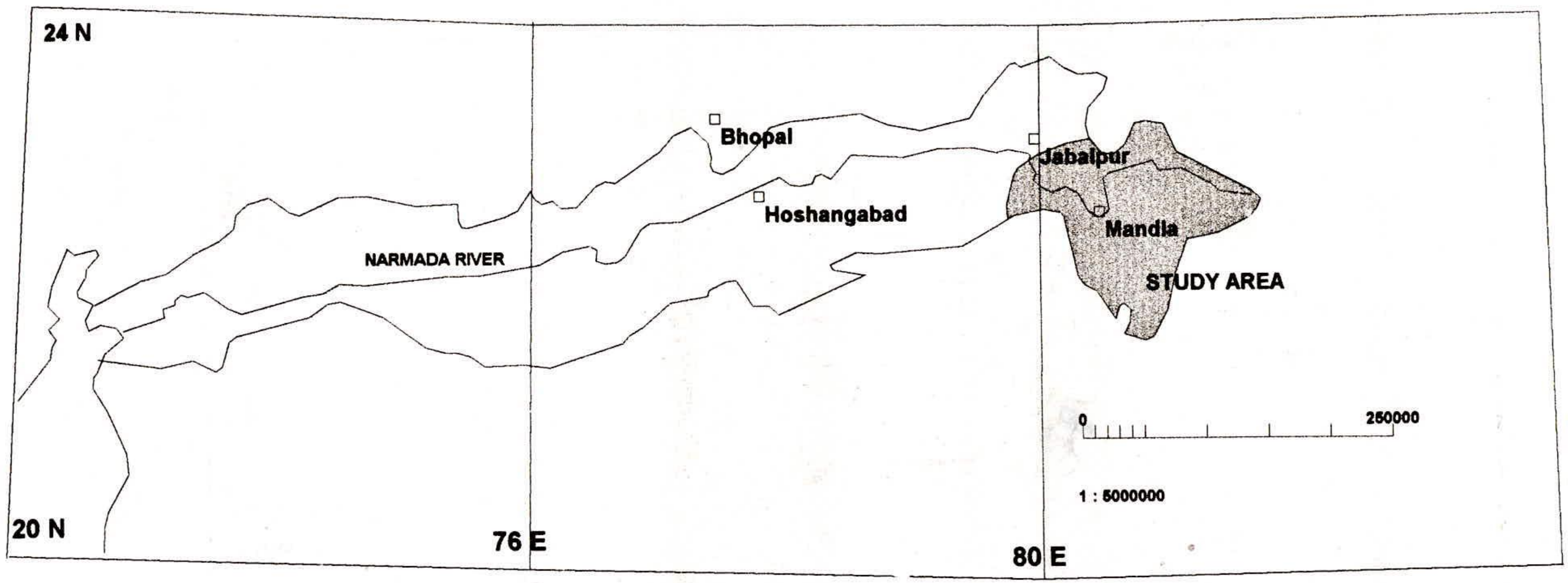

FIG. 3.1 LOCATION MAP

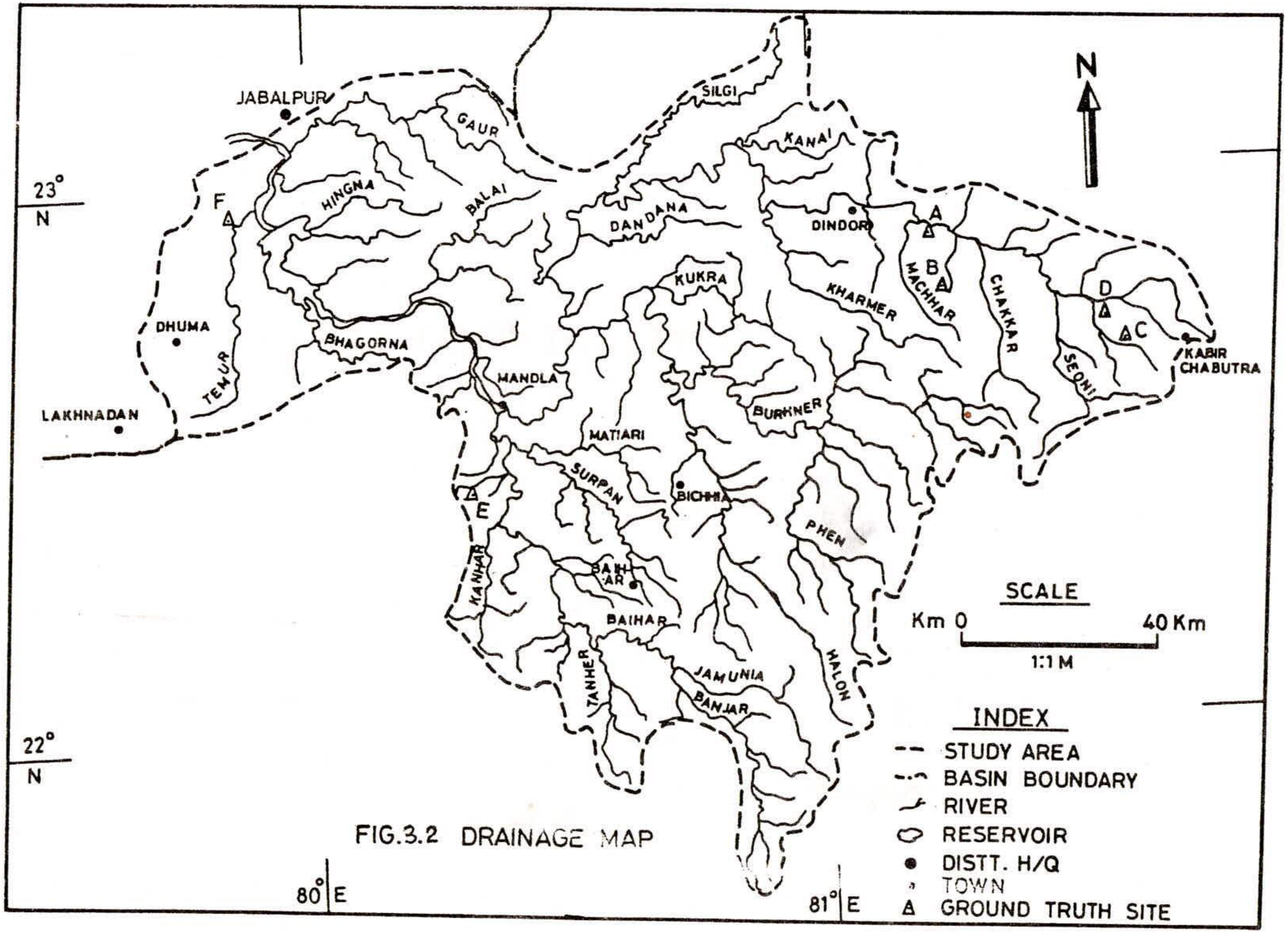

FIG.3.2 DRAINAGE MAP

CHAPTER 4 STATEMENT OF PROBLEM

Remotely sensed data have been used in past to obtain catchment information. Images, e.g., aerial photographs, CCT, imageries etc. are continuous or discrete. They are two dimensional views of environment. Digital images can be handled quantitatively. It is a basic requirement of image processing that images may be transformed from one form to another. A discrete image consists of picture elements or pixels. Pixels possess digital number (DN) and location on a two dimensional image space. DN depends on electromagnetic radiation received by sensor and number of bits, e.g., 6, 7 or 8 bit used to store data. Coordinates are 1, 1 at the top-left corner. In digital image processing three basic operations namely input, manipulations and display, are carried out on them. These operations are carried out on mainframe, mini, micro and work stations. There are many ways in which digital image processing is completed. Very important in environment sciences are image restoration and correction, enhancement, compression, colour display, classification and development of Geographic Information System (GIS).

Aim of many computational hydrological procedures is to estimate design discharge in a river. Discharge may be determined using many catchment variables, directly from measurement's time series etc. Often availability of discharge data is limited in a catchment. This has prompted development of many rainfall-runoff models. SCS has developed a Runoff Curve Number (RCN) procedure for runoff estimation. Method is applicable for small agricultural watersheds. It accounts for land use and treatment, soils and antecedent moisture condition. Thus, infiltration computation is embodied in the model. CN are given in tabular form. Numbers are based on runoff measurements for many catchments.

Hydrological land use and land cover mapping has not been completed in past for upper Narmada catchment. A land use and land cover map will be prepared for Upper Narmada catchment. The CN will be assigned to land use and land cover classes.

CHAPTER 5 DATA AVAILABILITY AND METHODOLOGY

5.1 DATA AVAILABILITY

IRS data

IRS LISS-I CCT with path row numbers 24-52, dated 11.04.89 and 17.11.89, 24-53, dated 11.04.89 and 25-52, dated 12.04.89 and 05.10.89 are available.

Soil survey

Detailed soil-surveys have been completed for five minor irrigation schemes (MIS) by Detailed Soil Survey Scheme, Department of Agriculture, Government of Madhya Pradesh, Adhartal, Jabalpur. Methodology for soil survey includes close traversing up to 50 to 100 metres, demarcation of soil units based on soil texture, colour, structure, effective depth, stoniness, percent rock content, slope, erosion etc., collection of surface soil samples for every 30 ha. or even as close as 5-10 ha. and profiles for every 80-100 ha. or up to 50-60 ha. for smaller MIS. Soil units are marked on 1" to 16 miles (approximately 1:3960) cadastral maps. Gullies, forests are also marked on maps. Soil profiles are dug up to depths of 183 cm or more or up to the bed rock level whichever is met earlier. Physical and morphological characteristics e.g. horizons depths, pH, CaCO3, EC, hydraulic conductivity, bulk density, organic carbon, soil infiltration rates etc. are determined. Minor irrigation schemes Sangwa, Mukash, Matiyari, Sursatola and Gwara have gross command areas are respectively 1470, 187, 11231, 150 and 257 ha. These MIS are described here.

Sangwa MIS: Sangwa MIS is in block and district Mandla. The proposed dam on river Basaha is located 15 km south west of Mandla and 9-km west of the Mandla-Nainpur road. The water-table of the area rises upto October due to storage of water in paddy fields. However, the water-table goes down after October and is low in summer. Gross command area is 14.7 sq.km in extent. Command-area possesses mixed geology. There are two basaltic flows in the area with intertrappian of shale and cherty lime stone. Granites are also found in the area. Crops, e.g., paddies, wheat, pulses, grams, peas are grown. Soils are developed from basaltic parent material (Rahangdale and Choudhary 1982).

Matiyari MIS: Matiyari MIS is in the Mandla district. The dam is located on river Matiyari at village Bukra Bahra. It is 9 km north- east of Anjania village. Anjania is 29 km from Mandla-Nainpur road. Command-area is bounded by Narmada on north, Matiyari on south, Banjar on west and forests on east. Narmada enters the command from village Padaria and flow up to village Purva. Two basaltic flows with shale and cherty limestone as intertrappian and granitic gneisses form the geology. Soils are derived from both types of parent material (Mishra and Choudhary 1979).

Mukash MIS: Mukash MIS is in Tehsil Niwas, district Mandla. The dam is built on a local ephemeral stream. It is located near village Mukash. It is 22 km from Niwas-Mandla road. Area is underlain by basaltic rocks. Soils are derived from basalt (Rahangdale and Dixit 1986).

Sursatola MIS: Sursatola MIS is in block Bajag, Tehsil Dindori, district Mandla. The dam is proposed near village Sursatola. It is 29 km from Dindori on the Dindori-Amarkantak road. Area is underlain by basalt, granite and sandstone. Soils are classified as very deep black soils with patches of yellow and shallow red soil (Rahangdale and Choudhary 1985).

Gwara MIS: Gwara MIS is located in Karanjia block, Dindori Tehsil, Mandla district. The dam is located 2 Kilometres on right of Jabalpur-Amarkantak road (214 Kilometres stone). The nearest village from the dam is Nari Gwara. Main geology is formed with basalts. Other rocks are granites and sand stones (Rahangdale and Choudhary 1986).

5.2 METHODOLOGY

Geometric correction

Well defined objects, both on the images and the base map, are used as ground control points (GCPs). There are four basic steps involved in geometric correction.

1. GCPs are selected. GCPs are objects, e.g., centre of water bodies, road intersections etc.
2. A geometrically corrected grid in latitudes and longitudes is prepared.

3. Latitudes and longitudes in the geometrically corrected grid are transformed to image x and y coordinates. These points become new locations in the image.

4. At locations, as computed above, DN are resampled. Nearest neighbour, bilinear and cubic convolution resampling techniques are used. In nearest neighbour technique, DN remains unchanged. This technique computes a geometrically-abrupt image. In bilinear and cubic convolution techniques smooth images are formed.

A base map is prepared at a scale of 1:50000 from topographic maps. Major drainage lines, rivers, ponds (approximately >0.25 sq. km.), reservoirs, embankments, the basin boundary etc. are digitized. Coordinate system with coordinates expressed in metres is selected for base map. It is an arbitrary system and is north oriented at longitude of 81°E. This map is used to rectify digital satellite images.

Data are geocorrected applying first/ third order transformation and nearest neighbour resampling. Resampling is completed at square pixel size of 82 metres. Details of GCP's are provided in Table 5.1. GCP selected are namely stream-bends, confluences, centres of ponds, centre of embankments, watershed boundaries etc.

There are dropout/ purged lines in image 25-52: post monsoon date. Thus, two sub-images are taken for this image and are separately rectified and mosaiced subsequently.

Table 5.1 GCP

Image Path row	Date w.r.t. monsoon	GCP Total	used	Order	rms
25-52 lines 1156 onwards	post	43	30	3	1.21
25-52 lines 1-1155	post	18	18	3	0.83
24-52	post	77	55	3	1.26
25-52	pre	70	51	3	1.18
24-53	pre	10	7	1	0.92

Sequential clustering classification

Four rectified satellite images (with three bands: 1, 3, 4 for post monsoon image and all four bands for other images) are classified. Only three bands in post monsoon images are due to non availability of one band data during this study. Software used is PC ERDAS- 7.5. Sequential clustering technique is used. Digitized segments for ground truth sites are displayed over a classified image. Spectral classes corresponding to ground classes are noted from the display. Classes are also identified using GIS display. Color on GIS display corresponds to signature on clusters. 'Location' interpretation-element is also considered for assigning classes. In case a cluster is assigning two conflicting ground truth classes, it is assigned to an unknown class. 'unknown' classes are described below:

1. Areal extent of this class is very small (1.1 sq. km.). This is located in image 25-52 Pre monsoon date. The class has yellow color on GIS.

2. Areal extent of this class is 6.3 sq. km. This class has cyan color on GIS display. It is located in image 24-53: pre monsoon date.

3. Areal extent of the class is 5.5 sq. km. This has pink color. This class is located in image 24-53: pre-monsoon date. It is located in open area with scattered trees (SOI topographic maps 64 C/13, 14).

4. Areal extent of this class is 715.8 sq. km. This is located in upland (ground truth site- A) and agriculture land (ground truth site- B) in image 24-52: post monsoon date.

5. Areal extent of this class is 1200.5 sq. km. Agricultural land (ground truth site- F) and village (ground truth site:E) are located in this class. It is located in image 25-52: post monsoon date.

6. Areal extent of the class is 0.3 sq. km. It has forests and horticulture land (Batel garden). It is identified in image 25-52: Post monsoon date.

7. Areal extent of this class is 15.6 sq. km. It has two classes namely forests and scrubs. It is identified in image 25-52: post-monsoon date.

Default parameters except 'x' and 'y' skip parameter are selected for this classification. 'x' and 'y' skip parameter values are selected as 5 each . A value of '1' requires more processing time.

There are many classes obtained for each land use class at level-1. It is observed that a large 'maximum classes' parameter should be selected for this classification. Some classes of small areal extent are created, thus. It may be difficult to identify these and it may require more post classification analysis/ ground truth. For small 'maximum classes' parameter, there is misclassification in classes at ground truth site.

CHAPTER 6 RESULTS

6.1 RESULTS

Ground truth

Villages Kauria, Girwarpur, Bavli, Merhakhar, Murgatola and Tinsa are visited. These are located at latitudes and longitudes respectively 81°14′30″E, 22°53′20″N, 81°16′00″E, 22°48′10″N, 81°36′40″E, 22°40′40″N, 81°34′50″E, 22°44′10″N, 80°19′00″E, 22°27′15″N, 79°50′10″E and 22°58′15″N. They are in SOI topographic maps 64F/1, 5, 10 and 10, 64B/7 and 55N/13 respectively. They are assigned location names 'A', 'B', 'C', 'D', 'E' and 'F' respectively (Fig 3.2).

Soil: Soils at ground truth sites are in general mixed black and gravelly brown/red soils. Soils in the valleys are in general black soils. In upland areas, soils are gravelly brown/ red (Fig. 6.4). There are other soils namely red/ brown soil in north and east of Girwarpur (Fig. 6.1), red sandy soil in south-west and south of Merhakhar (Fig. 6.2), black-brown soil of small areal extent towards south of Tinsa (Fig. 6.3).

Groundwater: High groundwater levels are observed in wells located in agricultural land. Near skeletal soils/ hills groundwater level observed is low in wells. Dug wells are both lined and unlined. Wells and hand pumps at several locations except a few e.g. Tinsa, go dry in May. Water is augmented in this period from perennial river or nallas.

Crops: Different cropping systems exist at Tinsa and other five sites. These are described here.

<u>Tinsa:</u> Kharif crops are Kodo, Jwar (sorghum) and soybean. Soybean is not successful here. Kodo is the main crop. Rabi crops are gram, wheat, Masoor (lentil), Arhar. Gram is the main Rabi crop.

<u>Other sites:</u> Kharif crops grown are rice, Jagani, Kutki (panicum miliare), Kodo, soybean, maize, Rai and Arhar. Rice is main Kharif crop. Maize is grown only in small plots near houses. After maize, Rai is grown. At Murgatola, soybean and Lakhodi are also grown. Rabi crops grown are wheat, gram, Masoor, Urad (black gram), Alsi (linseed), Batari, Ramtila (niger) and mustard. Wheat, gram and Masoor are main Rabi crops.

Use of chemical fertilisers: Use of chemical fertilisers is limited due to economical reasons. Only at Murgatola single use of fertilisers is reported for rice crops.

Land use and land cover map

Land use and land cover map is shown in the Fig. 6.5. Percentages of the areal extent of culturable land, forests, waste land -upland, waste land- rock, water and Villages are respectively 31.3, 39.6, 14.2, 0.2, 1.0 and 2.2. The remaining area (11.5%) is unclassified. Curve numbers can be assigned based on this map. For any watershed, average curve number may be estimated based on available numbers.

Hydrological soil classification

For soil survey repórt, soil profiles are also mainly in group 'D' of hydrological soil classification. Soil series 'Kunda' and 'Anjania' both in Matiyari MIS, and some soil patches of shallow gravelly soils in Sursatola MIS are in group 'C'. Soil series 'Khunajhir-Kala, Mukash MIS is in group 'B' Thus, areas in culturable land are of group 'D'. Soil group for upland is assumed to be 'C' based on soil profile data at MIS.

Curve number estimation

For estimating curve numbers few assumptions are made for culturable area, rocks and upland areas. The relative proportions of rice crops, other crops and fallow within culturable area are 0.45: 0.15: 0.4. These are arrived from MIS data. Curve numbers are given in Table 6.1. The table gives both standard values for curve numbers for SCS land use and cover, soil classes and proposed curve number values for the basin. Following assumptions are made for these curve numbers. A lower CN is assumed for Temur catchment due to different cropping pattern observed during ground truth.

1. Crops are contoured row crops.
2. Rocks are assumed to be impervious areas.
3. Upland areas are assumed to be bare.
4. Village land is assumed to be mixture of developeing urban areas and woods with poor hydrological condition.

6.2 DISCUSSIONS

1. *Forest areas:* Forest areas are mainly in hills. Since this method is devised for small agricultural areas, other method may be used to derive/ modify design runoff resulting from forests/ forest dominated watersheds.

2. *Unknown classes:* For watershed, where unknown classes cover large areal extent, curve number may be used with caution. Preferable, classes may be identified using additional satellite data/ collateral data reclassifying/ analysing them.

3. *GIS accuracy:* Basin boundaries are generalized in land use and land cover map as compared to a 1:50000 SOI topographic map. This may require GIS manipulations to correct boundary.

4. *Thematic Accuracy:* Accuracy of this classification is not estimated. Thus, while using land use map, it should be inspected using collateral data, satellite data etc.

5. *SCS method:* SCS method is an empirical method. These results are needed to be validated for Indian catchments. Other method may also be used to estimate design storms for comparing results from this.

Table 6.1 Curve numbers

Land use	AMC condition I	II	III	Hydrological Soil group
Paddy	100	100[1]	100	-
Row crops: contoured				
Hydrological condition:				
Poor[2]	75	88	95	D
Good[2]	72	86	94	D
Bare soil[2]	85	94	98	D
	80	91	97	C
Impervious[2]	98	98	98	-
Developing urban area: newly graded area (pervious areas only, no vegetation)[2]	80	91	97	C
Woods: hydrological conditions- poor	59	77	90	C
Proposed values				
Culturable				
Temur catchment	80	91	97	
Other catchments	89	96	99	
Upland	80	91	97	
Rock	98	98	98	
Water	100	100	100	
Villages	70	85	94	

[1] Assumed.

[2] (Rawls and others, 1993, Ogrosky and Mockus, 1964)

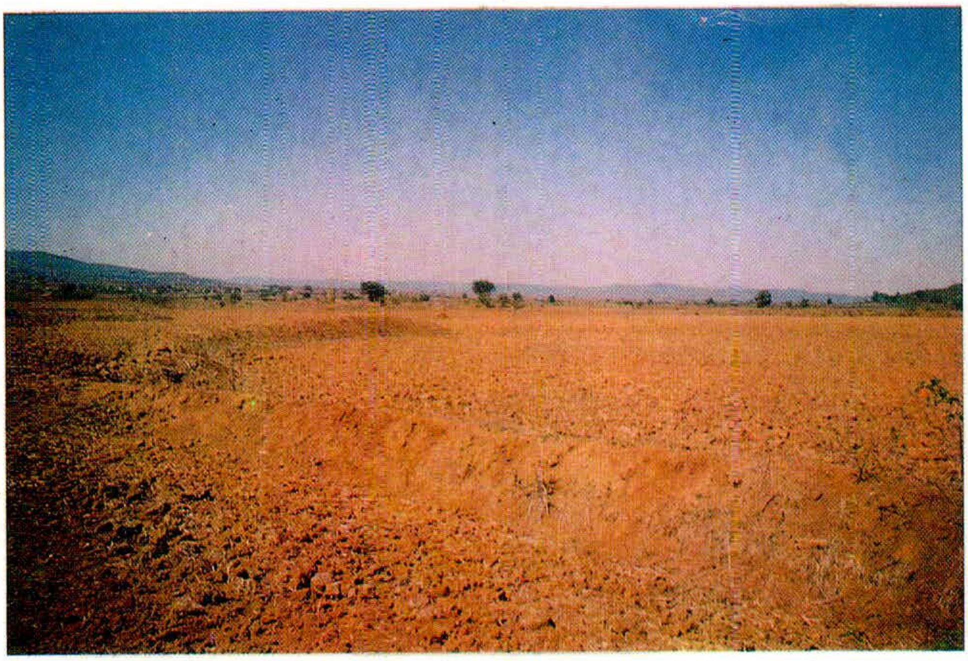

Fig. 6.1 Brown soil in agricultural land at Girwarpur

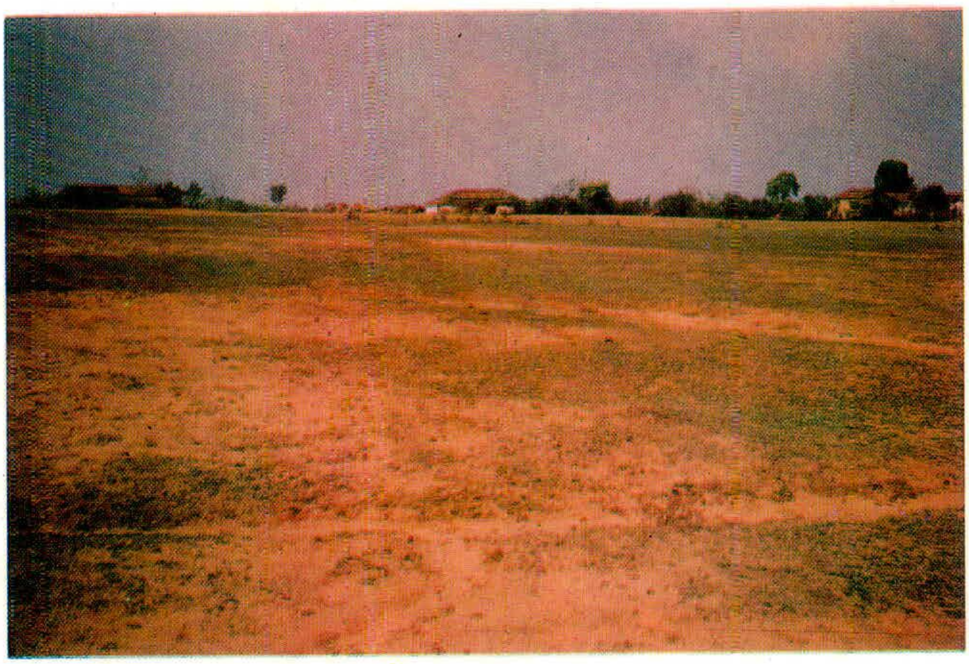

Fig. 6.2 Red soil in bare land at Merhakhar

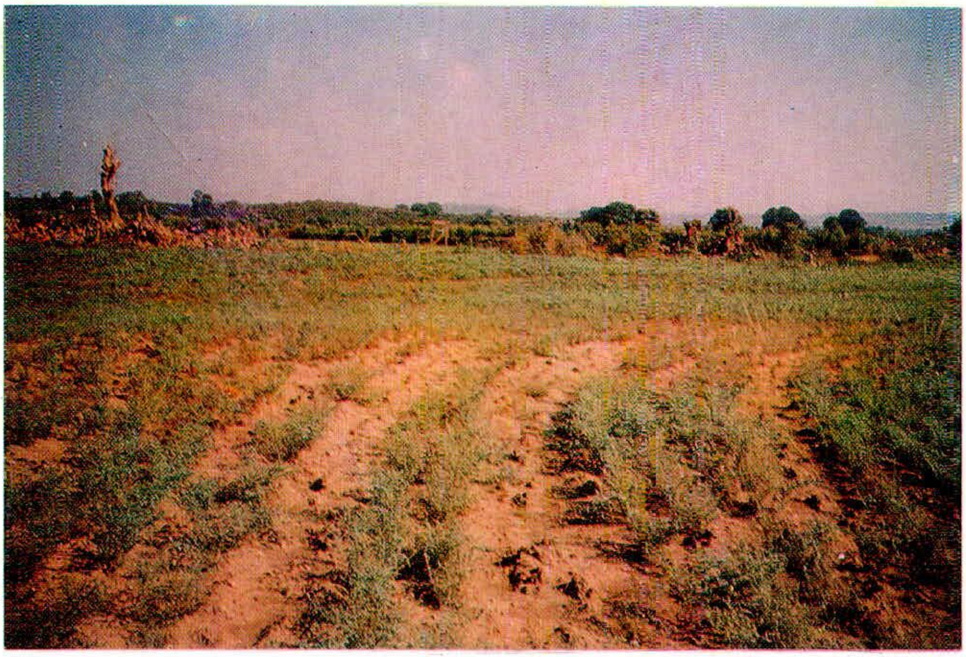

Fig. 6.3 contour cropping at Tinsa

Fig. 6.4 Crop on upland at Kauria

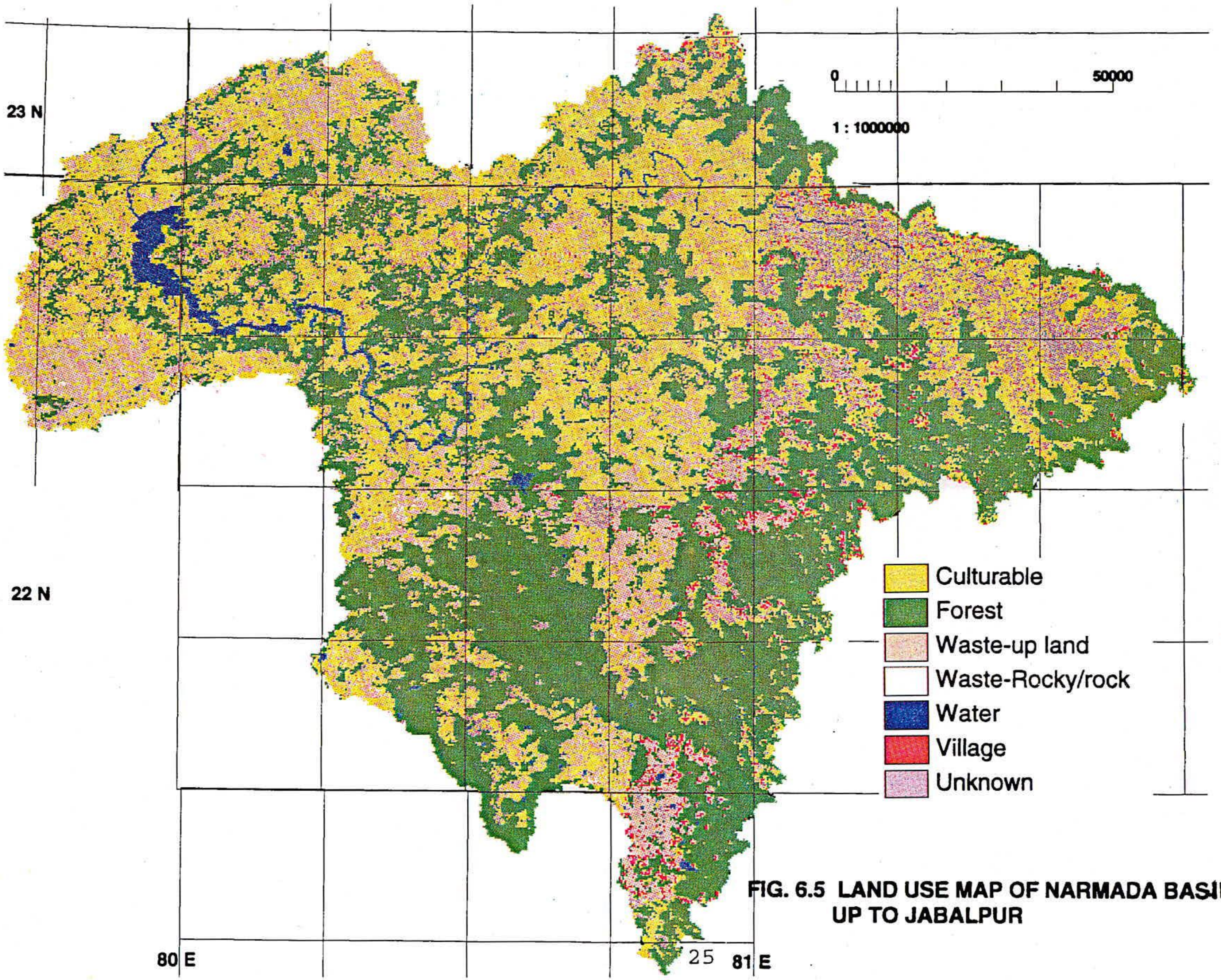

FIG. 6.5 LAND USE MAP OF NARMADA BASIN UP TO JABALPUR

CHAPTER 7 CONCLUSIONS

1. For higher rainfall, runoff is nearly 1.5 times for AMC III than that for AMC II. For small rainfall these values are nearly 2 (for culturable: other than Temur catchment) to 8 (for other areas except villages) times. Approximate effective rainfall for this basin is 0 to 90%. For AMC III this is of the order of 70- 90% at 50 mm rainfall. For small rainfall, it varies from 20 to 80%. At AMC II, small rainfall results in effective rainfall of 1 to 30%. At AMC I, there is no effective rainfall from small rainfall. For a 50 mm rainfall, effective rainfall is 10 to 60%.

2. Broad classes at level-I are easily delineated using satellite data of IRS LISS-1 and sequential clustering technique.

3. Hydrological conditions e.g. contour cropping, litter etc. can not be identified in satellite data at this resolution. This information has to be supplemented from collateral data and ground truth.

4. There are unknown classes obtained in this classification. These can be identified through additional data/ ground truth etc. Thus, the map is need to updated for use.

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