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HYDROLOGICAL LAND USE MAPPING IN NARMADA BASIN FROM JABALPUR TO HOSHANGABAD

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Many methods e.g. empirical formulae, SCS curve number method etc. are used in design discharge computations/ continuous runoff modelling. Using the SCS curve number method, certain empirical relationship of catchment hydrological variables and dimensional unit hydrograph, design hydrograph/ continuous runoff modelling is done. The computations are done for a watershed in Narmada basin for 25, 50 and 100 years return period and the 1- day design storm. The 1- day duration rainfall depths are, respectively, for the above return period are 143, 161 and 181 mm.

Land use mapping is done for a part of Narmada basin from Jabalpur to Hoshangabad. The catchment area is 27900 sq km. The mapping is done using satellite data of sensors WIFS and LISS-3 onboard IRS. WIFS data for September 1997 and February 1997 are used. The LISS-3 data for September 1997 is used.

GIS softwares namely ILWIS and ERDAS are used here. ERDAS (ver. 7.5) is used for the digital image processing. Sequential clustering technique is used. ILWIS is used for computing of watershed physical properties namely length, area and slope.

Curve numbers are assigned to land use cover classes using land use cover map and collateral data on soils. Average curve number is computed for a watershed for design runoff hydrograph computations. The watershed lies in Umar catchment. The areal extent of the watershed is 17.2 sq km. Peak discharge computed for 25, 50 and 100 year return periods using land use map prepared from WIFS and LISS-3 data are respectively 52, 59 and 67; 58, 66 and75 cumec. The design discharge is useful for irrigation/ water resources structures in the watershed.

INTRODUCTION

Stream gauging and discharge measurements are done in many catchments to establish historic stage and discharge records. The data are useful in water resources planning and design of hydraulic structures etc. There are often a limited number of such measurement station set up in basins. This has prompted hydrologists to establish many flood formulae and methods for flood estimation for catchments. Flood formulae are simple to use, but they are applicable to particular geographic regions only. Runoff curve number method of Soil Conservation Services (SCS), United States Department of Agriculture (USDA) is useful for estimation of flood volume, peak discharge and discharge hydrographs for design storms. The method uses physical characteristics of catchments e.g. land use/ cover and soils etc. The method is described here.

1.1 RUNOFF CURVE NUMBER METHOD

This method is developed for small agricultural watersheds in the United States. The method is based on experimental data on runoff and infiltration. Based on the data an initial abstraction value is fixed for storms. The initial abstraction is defined as losses till the direct runoff begins. These include infiltration, interception, evaporation losses. For the given rainfall thus, excess rainfall is estimated. The excess rainfall can be converted to peak discharge and discharge hydrographs.

Input required in the method are land use/ cover, soil and catchment wetness prior to the rainfall event. A single parameter is defined for these variables. This is arrived at by simple weighted averaging of the parameter of uniform characteristics units.There are three catchment wetness conditions defined namely wet, normal and dry.

Direct runoff hydrograph is computed in the method utilising SCS dimensionless unit hydrograph, design rainfall data at interval of unit duration and empirical relationships. The empirical relationships used are for 'lag time' (Eq. 1.1) and 'time of concentration' (Eq. 1.2). The SCS unit hydrograph is computed for large number of measurements on watersheds in the United States. There are two forms of the unit hydrographs (UH) available namely curvilinear and triangular (TUH). In both UH the volume up to peak discharge in 3/8th of the total volume of runoff. For mountainous and swampy catchments the values are different. For the mountainous catchment the peak is achieved faster and thus, the area of the direct runoff hydrograph upto the time-to-peak is less than 3/8th of the total area. In former UH, the time base is 5 times the time-to-peak and in the TUH it is 8/3 only. The values are for normal catchments. The inflection point is located at approximately 1.7 times time-to-peak. The direct runoff hydrograph for the design storm is determined by convolution of hydrographs of the unit duration (McCuen 1982).

$$L=0.342\ l^{0.8}(0.0394S+1)^{0.7}/Y^{0.5} \quad (1.1)$$

$$Tc=1.67L \quad (1.2)$$

$$qp=0.2085AQ/Tc \quad (1.3)$$

$$Tp=0.67Tc \quad (1.4)$$

$$Tb=1.78Tc \quad (1.5)$$

Where,

L is basin lag expressed in hours

l is catchment length expressed in km

S is maximum retention in mm

Y is percent slope

Tc is time of concentration expressed in hours

qp is peak discharge for unit duration hydrograph in cumec

A is catchment area in sq km

Q is excess direct runoff volume in unit duration in mm

Tp is time to peak (UH) in hours

Tb is time base in (UH) hours

1.2 EMPIRICAL FORMULAE

Conventionally, empirical formulae are in use for finding peak discharge. In the formulae, the peak discharge is related to the catchment area only. One such formula was given by Dicken in 1865 (Varshney 1974, Subramanya 1994) (Eq. 1.7).

$$Q=C\ A^{3/4}$$

Where

Q peak discharge in cumec

C coefficient (value ranges from 11 to 42 for annual rainfall of 600 to 1250 mm)

A catchment are in sq. km.

For the Narmada basin the value specified in 28. The formula is applicable to moderate size catchments in north and central India.

1.3 LAND USE

One of the input in the runoff curve number technique is land use and cover map. This map may be obtained from ancillary data or through remotely sensed data. The ancillary data are also used as ground truth information. The remotely sensed data when used in digital form provide digital maps that are easy to manipulate in a GIS for area extraction, statistics etc. The use of remote sensing technique is described here.

Remote sensing technique

A remote sensing technique is defined as a technique in which electromagnetic radiation sensors are used to collect information about the earth's surface. The electromagnetic energy reflected/ emitted from earth are recorded by these sensors. Thus the data represent the surface of the earth. The data are digitally processed or visually interpreted to get useful information. Since, the computers have better capability in differentiating color/ tone on the remotely sensed data than human eye, digital processing is more useful in application of remotely sensed data. The techniques are described here.

Digital classification

A digital image is made of values/ numbers stored in computer. These values represents a small area of the earth called picture element or pixel. The values of digital numbers (DN) depend on the electromagnetic response of objects and the quantization level of the data. For example a surface will have different DN at 7 and 8 bit quantization.

The DNs are processed to obtain thematic information from the remotely sensed data. The process is called image classification. Two main approaches are used in image classification namely supervised and unsupervised. In supervised approach a computer is given specimen signatures for objects and it then assigns the themes to pixels based on some similarity to the signatures supplied. In the unsupervised technique the inherent grouping of the data in feature space is utilised. A feature space is a n-dimensional plot of measurements. The measurements may be DNs of other measures. The resultant clusters or groups in this classification are assigned themes based on ancillary data. The supervised technique requires detailed ground truth information.

Here, unsupervised technique is used on digital data to obtain land use and cover map. The map is useful for estimation of design discharge. Curve numbers are also assigned to the land use and cover classes.

1.4 NARMADA BASIN

Land use

Narmada basin from Jabalpur to Hoshangabad is selected for hydrological landuse mapping. Information on land use and cover for the basin is available from collateral data e.g. reports. The information for Betul district and Bargi command area (Jabalpur and Hoshangabad districts) are available. The information is briefly presented here.

Betul district land use

Main kharif crop in the district is Sorghum (Jowar). It covers approximately 17% area. Other kharif crops are rice (6%),, Maize (3%), kodo, Tur (8%), Soybean, and groundnut (4%). Rabi crops are wheat (15%), Kutki, gram (9%), Sugar cane(0.1%), potato and Alsi (1%).

Rice is grown from June to October. Sorghum is grown from June to October- January. Tur is grown from July to march. Wheat is grown from October-December to February- April. Gram is grown from October to February.

Forest areas and barren areas are respectively 41% and 3%. Net sown area is 40%. Kharif crop area is 40%.

Contour bunding, field bunding, gully plugging, tree planting, pasture development, strip cropping etc are practised in the district. Simple stone terracing is also done.

Bargi canal command area

Cropping in Jabalpur is mainly monocropping. This is due to high clay content in the soil. Large area is left fallow in Kharif season for conserving moisture for Rabi cultivation. This practice is followed since difficulty is faced by farmers in working with soils during rainy seasons. The water is released for lower fields after allowing infiltration. For this system 0.3 to 1 m bund height in used. Other than this system tanks, tubewell, open well etc. are also used for the irrigation. In this system 6 and 9% area is irrigated in respectively Jabalpur and Narsinghpur districts.

Main kharif crops are paddy, sorghum and Arhar. Other crops in the kharif seasons are Bajra, millets, maize, green gram, black gram, Niger, sesamum and soybean. Sesamum and soybean are grown only in Narsanghpur district. Area under kharif crop in the Jabalpur and Narsinghpur districts are respectively 18 and 27%. In some tank irrigation projects up to 200% cropping intensity is obtained. In the rabi seasons respectively 50 and 55% area is cultivated. This is the cropping pattern observed in the year 1982- 83. The area under paddy and other crop in the Jabalpur and Narsinghpur districts are given below (Anonymous 1986):

Crop types	Area in thousand ha	
	Narsinghpur	Jabalpur
Paddy	4.24	2.52
Non- paddy	21.70	8.791
Total	25.94	11.31

Soil

Information about soils in the Betul district, Bargi canal command area and in the basin (broad Indian soil classification) is available this information is given here and is useful for obtaining SCS curve numbers to agricultural watersheds.

Broad Indian soil classification

Three types of the soil namely black; mixed red and black; and skeletal soils are found in the basin as per the broad Indian soil classification. Black soils are found in three sub types namely deep, medium and shallow. The differences in the classes in terms of texture, depth etc. are described below. Predominant soil type in the basin is deep black soil. The soil types are briefly described here.

Deep black soils have depth of more than 100 cm and clay content ranging from 40 to 60%. Medium black soils have depth 30 to 100 cm and clay content 20 to 40%. The shallow soils have depth less than 30 cm and clay content 15 to 30%. Shallow soils have clay loam texture. This soil is found in Betul district. Deep black soil is found in Narsinghpur, Hoshangabad and western part of the Jabalpur district. Eastern part of the Jabalpur district has medium black soil. This soil is slightly coarse.

Mixed red and black soils have alternate red and black soils. Red soils are coarse texture soils. This soil is found in northern part of the Betul district and in a part of Chhindwara district.

Skeletal soils are gravelly soils. Patches of black soils are found in the soil type. Raisen,Sehore and Damoh district has this soil type (Sinha and Gupta 1985).

Betul district soils

Soils in the Tawa valley are sandy loam. Other soils are poor soils (Anonymous 1982).

Bargi canal command area soils

The catchment has soil series namely Sarol, Songuriya, Kunda, Baloda, Gopalpur, Amgaon and Bachaiya. Nearly 80 to 90% area is occupied by clay and clay loam soils. Coarse texture soils has clay content of 7 to 26%. Soils in the command area are in general very deep and imperfectly to moderately drained. Limited area has also sandy loam texture (Anonymous

1990).

Using land use and cover map obtained from remotely sensed data and soil information from collateral data; SCS curve number are assigned to watershed. The curve numbers are useful in design discharge computations.

Probable maximum precipitation (PMP)

1-day design storm iso- hyetals are available over the basin. Pachmari receives highest rainfall in the basin. The design rainfall is 646 mm here. Betul receives low rainfall. The design rainfall at Betul is 400 mm. In the Narmada valley between Jabalpur to Hoshangabad the design rainfall varies from 400 to 480 mm (Anonymous 1988).

Synthetic storm

Synthetic storms are developed from given point rainfall or areal rainfall. The synthetic storm is developed by SCS for 1 day precipitation depth. The storms are developed for two different regions in United States. Type I storm is developed for Hawaii, Alaska, coastal region in Sierra Nevada and Cascade mountains in california, Oregon, Washington. Type II storm is developed for reminder of USA, Puerto Rico and Virgin Islands. The storms are developed for areas less than 1000 sq. km. and frequencies 1 to 100 years. The distributions are based on generalised rainfall depth- duration- frequency relationship for durations in intervals of .5 hours. The incremental depths for 0.5 hours periods are determined. The highest depth is arranged at the centre of design storm period. Subsequent high depths are placed on either side of this depth.

Time distributions of rainfall is also given for catchments upto Narsighpur in the Narmada. The distributions are based on rainfall records at 11 stations in the Narmada basin. Two distributions of respectively 48 and 82 hours are given.

Depth- duration- frequency relationship

Depth- duration- frequency relationship is developed for India by Ram Babu (1979) (vide Tripathi and Singh 1993) from self recording raingauges (42) records. The general form of the relationship is given in the Eq. 1.6. Coefficients for Jabalpur and Central zone are also given. For Jabalpur constants K, a, b, n are respectively 11.379, 0.1746, 1.25 and 1.1206. For central zone the values are respectively 7.4645, 0.1712, 0.75 and 0.9599.

$$i = K\,T^{a}/(t+b)^{n} \qquad (1.6)$$

Where

i rainfall intensity in cm $hour^{-1}$

T return period in years

t duration in hours

K, a, b, n constants

Area- depth relationship

The point rainfall depth for a duration and frequency is larger than depth over an area in catchments for same frequency- duration. From United States Weather Bureau area depth relationship (Gilman 1964) the areal rainfall is expressed as percentage of the point rainfall. For a catchment of 26 sq km, the percentages for 24, 6, 3, 1 and 1/2 hour duration storms are respectively 98, 97, 97, 92 and 87. For larger catchments, the values are further reduced.

2. LITERATURE SURVEY

Four case studies in land use cover mapping are presented here. The studies are completed in various countries and use variety of data and special classification systems. Classification techniques used is supervised technique in most case studies. The reason for use of this technique is availability of detailed ground truth data/ ancillary data including orthophotos. The studies are described below:

A case study in USA

May and others (1995) have classified using supervised technique the land use and cover areas for the Lassen Volcanic National Park (LUNP) in northern California, USA. The area is 430 sq. km. Data used are TM and SPOT (the SPOT data covers only part of the study area). An earlier classification for conifer forest was available and this area is masked out from the data. The accuracy of this earlier classification is 2, 6% for respectively commission and omission. The classification is completed on both raw and principal component transform images. Two classifications namely for vegetation types and subtypes are done. The accuracies are evaluated for all classifications. The classes are shrubs, meadows (two subtypes for each) and low density vegetation. The last class has sparse mixed vegetation of small conifers, shrubs, grasses and forbs on pervious volcanic soils for dry summer months. The training sets are selected based on interpretation of color aerial photographs (at 1:20000 scale) and field visits. 120 sites are selected in all. Each site has at least 0.5 ha homogeneous area. A lower accuracy level is obtained with SPOT data than TM data due to absence of additional IR band in this data. Vegetation class error in omission and commission is <=10% for TM data. For subtypes most omission errors are >20% and most commission errors are >30%. There is confusion between meadow subtypes (commission error >50%).

With SPOT data, vegetation type error is >20% is omission and commission. Shrubs and meadows are less separable. There is greater confusion of these classes with low density vegetation. The similar result is obtained with TM bands 2, 3 and 4.

Shrub subtypes occurs in burned and logged areas that include evergreens (subtype 1) and seeps, streams and lakes (subtype 2). Meadow subtypes are located on wet, alluvial soils and contains narrow leave grasses (subtype 1) and on drier sites and of broad leaved varieties (subtype 2). Data are rectified in UTM with r.m.s. of 1 pixel. The month of the data acquisition is August.

A case study in Phillipines

Apan (1995) has done land use and cover classification for an area (848 sq.km.) in

Phillipines. The area is mountainous and had elevation from 0 to 1709 m above MSL. Main land use and cover classes are forests including mangroves on lowlands and grasses. Main seasons are dry (Nov. to April) and wet (May to October). The monthly temperature very from 27° to 32°C. The reforestation schemes/ programmes are operational. Softwares used are microBRIAN 3.1, ARC/INFO 7.0 and IDRISI for Windows. TM data (except thermal band) are used for Feb. 1992. Visual and digital classification techniques are used. In digital classification supervised classification with TM bands 3, 4 and 5 and unsupervised classification with NDVI are used.

For supervised classification, forest types, crown density, crown successional stages and non-forest area classification are done. Forest types are closed canopy forest in advanced successional stage of certain type; mixed dense grasses; dried grasses; mature mangroves; mature, dense tree plantation; mature dense coconut; and mixed agricrops (e.g. corn, rice, green leafy vegetation and bananas etc.) The color of all mature tree varieties is dark green on composite of TM bands 3, 4 and 5 (Blue, Green and Red or BGR). The color of mixed dense grasses, dried grasses and mixed agricrops are respectively yellow- green, whitish to light magenta/ pink and less dark green on FCC. For low, medium and high crown density classes the color in the FCC are respectively whitish to magenta; light, yellowish green and dark green. Similar spectral signature are observed for successional stages of respectively initial, intermediate and advanced. The non- vegetation classes are bare soil-1 (includes dry agricultural area), bare soil- 2 (includes bare upland and highly eroded land), built-up including road, buildings, tracts, parks etc., water and shadow. There signature on the FCC are respectively magenta/ pink, dark magenta/ pink to violet, bluish and magenta, black and black. Accuracy checking is done by visual, statistics comparison etc.

Ellipse plot are compared for various classifications/ classes for TM bands 3 and 4. All mature forest types have overlapping ellipses. The mixed dense and dried grass classes have non overlapping ellipses. Crown cover and successional stage classes are separable as seen on ellipse plots. In non- vegetation classes, upland bare/ highly eroded class has moderately overlapping ellipse with built-up class. Shadows and water classes have non overlapping ellipses. Shadow has lower DN in band 3 and a higher DN in band 4.Dry agriculture land class has higher DN in both bands 3 and 4. Water bodies are not mapped with adequate accuracy. They are confused with shadows. Cultural features are not classified properly.

An unsupervised classification of NDVI data is done. The maximum classes selected are 100. Classes are assigned/ merged by visual comparison with the ancillary data. The classes are not as vigorous as the supervised classification. Here, bare land, low-, medium and high- crown cover density classes are identified. Water and cloud area are delineated from visual interpretation. These areas are masked out prior to the classification. Water pixels are identified based on bluish to blank color and patterns and location of pixels. Mountain shadow class is confused with deep water class. The accuracy of the map is 94%. The omission accuracy ranges fro 81% to 96%. The commission accuracy ranges from 86% to 95%. Lower limit belongs to low crown cover class. Confusion in all classes occurs with spectrally adjoining classes e.g. low crown cover class is confused with bare as well as medium density class. The accuracy of the unsupervised map from NDVI is checked by selecting random points (287). The reference points are checked in field, on ancillary data and based on the knowledge of the foresters.

Visual interpretation technique is also used. Subtypes of mature forests are not identified in this. Crown cover density and successional stage classes are mapped by the relative greenness in the FCC (TM bands 3, 4 and 5 as blue, green and red respectively). Only high and low crown cover density classes are delineated. The color of the classes are respectively green to dark green and light green to yellow-green. Roads are mapped on FCC of TM bands 1, 2 and 3. The roads are not visible below thick forests and in the built-up areas.

A case study in Columbia

Langford and Bell (1995) have studied land use and cover in a hill side environment in Columbia. The data used are from TM sensor and supervised classification technique is applied. Training sets are generated pixel-by-pixel with at least 50 pixels per class and each pixel at sufficient distance from each other. There locations are generated from orthophoto maps and adjusted slightly at the time of sampling on digital data. Data are rectified at 10 m and 30 m pixel size and respectively cubic convolution and nearest neighbour resampling methods are applied. Software used is ERDAS Imagine on SUN workstation. The classes are waste land (two classes), scant pasture, dense pasture, bush scrub, young woodland, mature woodland, Bamboo stand, coffee plantation and cropped land. Accuracy of the classifications is assessed using three schemes namely 'blind', pure-pixel' and 'confirm'. In the first technique, stratified random samples are drawn. Ground classes are decided by photo interpretation independently from the classification results. Classes for the mixed pixels are determined by the interpreter by judgement. In second approach, pure pixels are taken manually on the orthophoto for accuracy checking. In the third method, points are selected keeping both the orthophoto and the classified maps side-by-side. The number of points selected in each approach are respectively 750, 1108 and 750. The results of 'blind' accuracy checking are only presented in the literature.

Dense pasture class is confused with scant pasture, bush fallow and cropped land. The bush fallow is confused with dense pasture, young woodland, cropped land and bamboo stand. Young woodland is confused with bush fallow, mature woodland and coffee plantation. Mature woodland is confused with coffee plantation. Bamboo stand is confused with young woodland and bush fallow. Coffee plantation is confused with woodland and Bamboo stand. Cropping land is confused with bush fallow and bamboo stand. The reason for above may be the gradual change between classes e.g. from waste land to scant pasture to dense pasture.

The study area is 15 km X 20 km is size. TM data are used for August 1989 (single date). Data are rectified and georeferenced to the transverse Mercator projection. RMS error of rectification is 0.46 pixels. The GCPs are used from 1:25000 scale topographic maps. Ground truth is obtained from panchromatic aerial photographs of July 1989 at a scale of 1:36000. There are 80% population those occupy 20% land holding. Farm sizes are < 5 ha. This together with many crop varieties grown results in intricate arrangement of fields with the same crop areas. The crops are grown on slope as high as 30°.

A case study in U.K.

A land use and cover mapping is completed in approximately 10 km X 10 km area is northeast Scotland, U.K. The classes are undifferentiated woods, moorland, bogs (2 classes) improved pasture (3 classes) and natural grassland. Undifferentiated woods includes conifers (dominant), deciduous and scrubs. Improved pasture land are selectively managed or fertilized and often reseeded. The subtypes are good, moderate and poor quality improved pasture. Natural grassland also includes very good quality improved pasture.

Data used are TM (May 1990) and Panchromatic aerial photograph of 1:24000 scale (May 1988). The aerial photographs are stereoscopically interpreted. The photographs are scanned and rectified at 2.91 m r.m.s. error. The pixels size is 5 m. Based on the maps prepared from the stereoscopic interpretation and ancillary data on soils, further maps are prepared on broad plant community from digital aerial photographs (contrast stretched). Based on this, the number of the classes to be used in classification are decided. TM data are rectified at 20 m pixel size with 1.25 pixel r.m.s. error and cubic convolution resampling. Atmospheric correction by dark pixel subtraction method is done. The data are clustered using K- mean clustering. On the resulting map a 9 X 9 majority filter is applied. The resultant map is compared with 1988 land use and cover map pixel-by-pixel. Land use and cover classes in later map are all woodland, dry heather moor, wet heather moor, bog, improved pasture and natural grassland. NDVI values for the TM classes and their dispersion measures are also given.

3. STUDY AREA

For this study, Narmada basin from Jabalpur to Hoshangabad is selected. The basin lies between latitudes 21°45'N and 24°00'N and longitudes 77°45'E and 80°30'E approximately. The area is covered by districts Betul, Hoshangabad, Sehore, Raisen, Narsinghpur, Chhindwara, Damoh, Jabalpur and Seoni. Major left bank tributaries are Sonar, Sher, Shakkar, Dudhi, and Tawa. Major right bank tributaries are Hiran, Sindhori, Tendoni and Barna. Tanks and reservoirs are Pariat tank, Baharband, Barna and Tawa. Total area of the basin is 27893 sq. Km. Description on rainfall, temperature and the physiography of the area follows:

Rainfall: In western part of the study area e.g. at Betul, Sohagpur etc., the mean annual rainfall varies from 100 to 120 cm. In the central and eastern part, the mean annual rainfall is 120 cm. In pachmari and surrounding hilly area in the Satpura hills, mean annual rainfall varies from 140 to 200 cm.

Temperature: Most of the catchment falls in the mean annual temperature zone of 22.5° to 25°C. Areas around Hoshangabad and Betul falls under mean annual temperature zone of 25°- 27.5°C.

Physiography: Physiographic subdivision are Vindhyan range in the north, Narmada valley in the middle and Satpura range in the south. Maximum elevation is 1350 m at Pachmari in west-central part of the study area. Mahadeva Hills are found in Satpura range. Plateaus are Lakhnadon, Dudhi and Horand plateaus. Sher river flows in the Lakhnadon plateau. Dudhi river flows in the Dudhi plateau. Tawa river flows from Horand plateau and Mahadeva Hills (Kundu 1989).

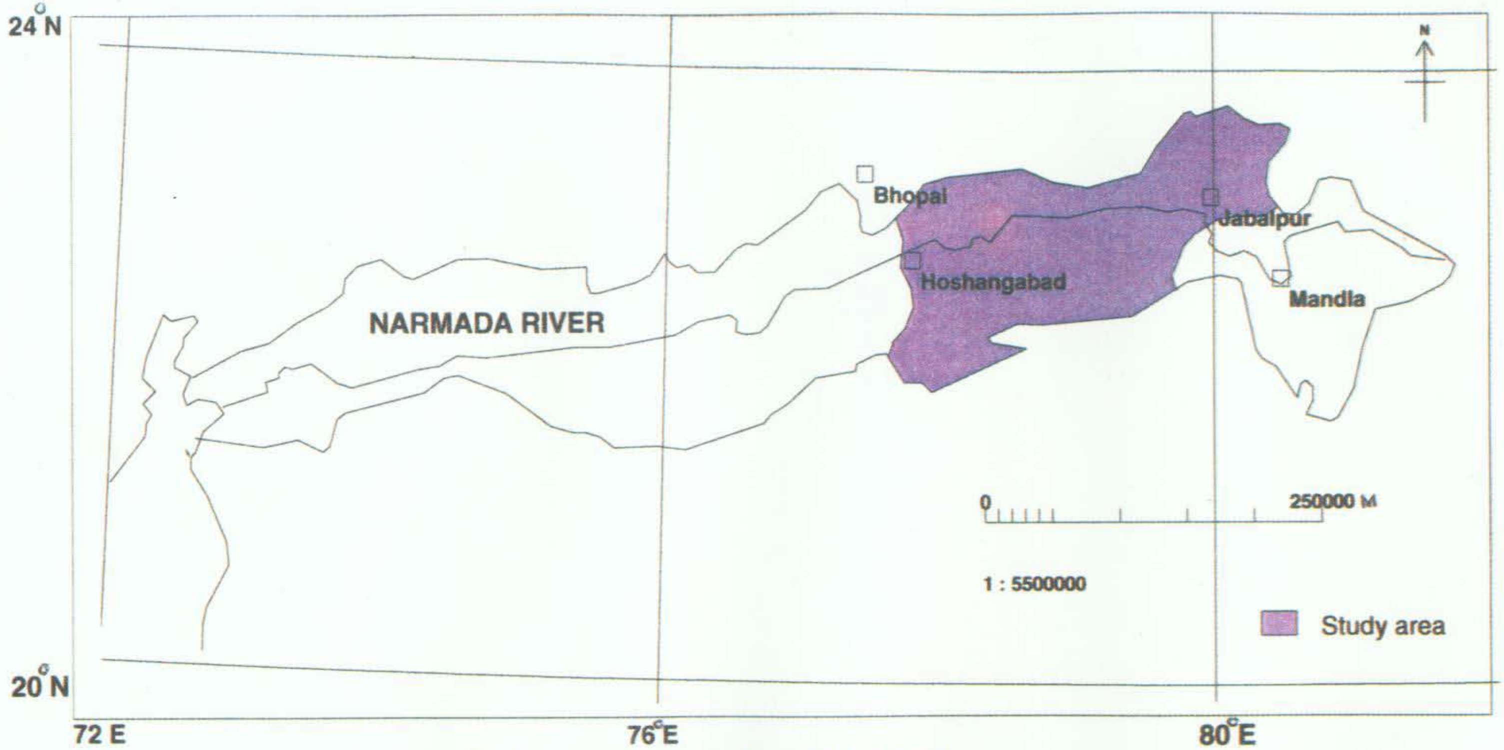


FIG 3.1 LOCATION MAP

4. STATEMENT OF THE PROBLEM

Discharge or runoff data from catchments are measured by gauges, velocity- area method etc. The data are not available at many sites for small catchments. The data are useful for finding design discharge values. In the absence of the historic data, the design discharge is estimated using flood formulae and other methods/ models etc. One of the method is Soil Conservation Services (SCS), United Stated Department of Agriculture (USDA) curve number method. An important assumption in the method is that there is no attenuation of the flood in the channel in the catchment. This will produce larger design discharge values.

There are not many gauge- discharge sites located within the study area on the main river and the tributaries. One to two gauges and one discharge site are available in few major tributaries. Small catchment data are not available in the study area. The simple method such as the curve number technique is useful in this case. This method will use data such as land use, cover and soil and other physical characteristics e.g. catchment length etc. The land use and cover map can be easily obtained from remotely sensed data.

Although land use map at 1:250000 scale is available for a part of the study area in hard copy format prepared from visual interpretation of remotely sensed data, no map is available in digital format. A digital map is easy to manipulate within a GIS for estimating curve numbers. Thus, a hydrological land use map is prepared from digital analysis of remotely sensed data here.

The extent of the area of study is 27893 sq. km.. The fine resolution data e.g. LISS-III (pixel size 0.06 ha) requires nearly 200 MB for storing 4- bands data. Whereas, coarse resolution data with 2- band e.g. WIFS (pixel size 3.2 ha) requires nearly 2 MB storage space. Required processing time for LISS-III data is also more, since more number of pixels are required to be processed. For runoff estimation using curve number technique, level-1 land use maps have been used. These curve numbers were derived by averaging curve numbers for level-2 or more classes. Thus, WIFS data will be useful in this study.

5. DATA USED AND METHODOLOGY

5.1 DATA USED

The study area is covered by SOI topographic maps 55 E, F, G, I, J, K, M, N and 64 A. At the scale of 1:50000, the topographic maps are 55 E/16, 55F/ 13 to 16, 55 G/13, 55I/ 4,7,8, 11,12,15,16, 55J/ 1 to 11, 13 to 15, 55 M/ 4,8,12,15,16, 55 N/ 1 to 3, 5 to 7, 9 to 11, 55 A/ 1 to 3, 5 to 7. Many topographic maps are used for ground truth purpose in the satellite data classification for land use and cover mapping. The satellite data used are given below:

Satellite	Scene	Sensor	Date
IRS 1C	99-56	L3	30.9.97
IRS P3	99-56	WIFS (1 Visible and 1 IR band)	23.9.96
IRS P3	99-56	WIFS (1 Visible and 1 IR band)	14.2.97

5.2 METHODOLOGY

In this study, average runoff curve number table is produced for the study area based on standard curve number values. Design discharge is estimated for a small agricultural watershed Using the curve number table produced here. Similar estimation may be done in small agricultural watersheds in the basin. The methodology for the preparation of landuse and cover map and design discharge estimation is presented here.

5.2.1 LAND USE

Multi date and multi sensor satellite digital data are used for land use and cover mapping in the basin. Satellite data are rectified using SOI topographic maps as reference maps. The digital data for the basin is extracted from the rectified data. The map reference selected is given here.

Geoid	Everest India 1956
Map projection	Polyconic
Central meridian	79°E
Northing	0 m
Easting	500000 m

Rectification

There are two scenes of IRS WIFS data and one scene of IRS L-3 data those are used here. One WIFS scene is rectified in ILWIS Window version software using SOI topographic map at 1:250000 scale as reference map. The data is resampled at 180 m pixel resolution using nearest neighbour resampling technique. Other WIFS scene is rectified and georeferenced using rectified and georeferenced digital data of WIFS. The rms error in GCPs is less than 1 pixel for WIFS scenes.

L3 sensor data is rectified in ILWIS software. Band 3 (IR) image is used for selecting GCPs in the image. SOI topographic maps at the scale of 1:250000 is used as reference maps. Although band 4 (middle IR) has different resolution, this band is rectified using same set of GCPs. There are 49 GCPs selected. The rms error is 3.906 pixels. The pixels size selected of resampling of the data is 24 m. The nearest neighbour resampling technique is used.

Basin boundary

The basin boundary is digitized in ILWIS from SOI topographic maps at the scale of 1:250000. This map is used to extract image data for the basin area from the rectified digital data.

Classification

Two date WIFS data are digitally classified on PC ERDAS Ver. 7.5 software using sequential clustering technique. Default parameters except X and Y skip factors are used. The X and Y skip factors have value of 5 each. The clustering technique used and the thematic classes identified are briefly discussed here.

Thematic classes

Thematic classes identified through sequential clustering are agricultures area, area under Kharif fallow, forests, open land, scrub/ gully land (also includes hill/ forests and open land), river sand and water. Some area is unclassified.

Thematic map from WIFS (September)

Number of clusters in thematic classes, respectively agricultural land, Kharif fallow land, forest, open land, scrub/ gully and water are 3, 2, 6, 2, 2 and 4. There are 8 clusters that remained unclassified. These include unresolved agricultural land- scrub (1 cluster), urban- water- valley land (1 cluster), cloud (1 cluster), cloud- river sand (2 clusters) and cloud shadow- water (2 clusters).

Thematic map from WIFS (February)

Number of clusters in thematic classes, respectively agricultural land, Forest, open land, scrub/ gully, river sand and water are 8, 5, 1, 5, 2 and 2. 4 clusters remained unclassified namely unresolved mixed water- sand or unresolved urban- valley land, forest- open land, forest- dense scrub and water boundary pixels- forest. Each unresolved class has one cluster.

Overlay analysis

Two landuse maps obtained above are overlaid. Unclassified area in the September WIFS thematic map is replaced with thematic classes from Rabi WIFS data.

5.2.2 CURVE NUMBER

For preparing curve number table for a basin, a land use and soil information in the basin are needed. The land use and cover map is obtained from remotely sensed data. Soil information are obtained from existing reports (Anonymous 1986, Anonymous 1982). The information on land use and soil for computation of curve number are presented here.

Hydrological Soil classification

In the Bargi canal command area, the soil type is mainly deep clay. This soil is imperfectly to moderately drained. The agricultural area is assumed to be of deep clay and hydrological soil group 'D' is assumed in the command for the agricultural area. The area with sandy loam texture are assigned hydrological soil group 'A'. This are is of small extent and is thus neglected.

In Betul district, Tawa valley has sandy loam texture. Thus, the Tawa valley is assigned hydrological soil group 'A'. Other area as per broad Indian soil classification has clay loam texture. These areas are assigned hydrological group 'D'.

In the skeletal soil region (broad Indian soil classification), black soil areas are assigned hydrological soil group 'D'. Skeletal soil areas are assigned hydrological soil group 'C'. The typical soil profile is assumed to be 0- 15 cm gravelly sandy clay loam and 15- 30 cm weathered parent material (Khunajhir- kala soil series in the Upper Narmada).

SCS land use classification

In the Bargi command area, there are different cropping patterns in Jabalpur and Narsinghpur districts. A level 1 land use classification is done here. The crops are assumed to be in same proportion in the watersheds as that in the districts. The proportions of paddy to row crops in Jabalpur and Narsinghpur districts are respectively 1:3 and 1:5. Kharif fallow agriculture fields are bunded and rain water is left to stagnate in the field. Thus, the class is assumed to be similar to paddy class for hydrological classification.

In Betul district, proportion of row, legume and rice crops is 0.75:0.10:0.15.

The standard curve numbers and computed curve numbers are given in the Table 5.1. The curve numbers for agricultural area in the Bargi command and Betul districts are computed as follows:

Agricultural area in the Bargi command (Jabalpur district)

(Paddy * 1 + Row_D * 3)/ 4

Agricultural area in the Bargi command (Narsinghpur district)

(Paddy * 1 + Row_D * 5)/ 6

Agricultural area in Tawa valley, Betul district

(Row_A * 0.75 + Legume_A * 0.10 + Rice * 0.15)

Agricultural area, Betul district

(Row_D * 0.75 + Legume_D * 0.10 + Rice * 0.15)

Where

Row_D is row crop on hydrological soil group 'D' etc.

5.2.3 A CASE STUDY WATERSHED

Design discharge estimation is done in a small agricultural watershed. Land use classification is done with the LISS III data and WIFS data. Watershed physical and hydrological characteristics are described here.

The watershed lies in Umar catchment. It is located in the SOI topographic map 55 N/5. The geographical coordinates are 22°52′ and 22°58′ latitudes and 79°22′30″ and 79°25′30″ longitudes.

Physical characteristics

The watershed boundary is delineated in the topographic map of the scale 1:50000. The boundary is digitized in ILWIS ver. 2.2 software. The physical characteristics of the watershed are given here.

Area	17.2 sq km
Perimeter	19.3 km
Average slope	0.4%
Length	8.5 km

The average slope is determined from a DEM. The DEM is created in ILWIS from the contours (20 m) shown in the SOI topographic map. Length is measured as a distance from remotest point in the watershed to its outlet.

Land use

Land use classification of the watershed is done from LISS 3 and WIFS data. The LISS-3 image for the watershed is extracted from the rectified LISS-3 data. The image is classified using the sequential clustering technique in PC ERDAS ver. 7.5 software. The default parameters except X and Y skip factor and number of classes are selected. The above, other than default, parameters are respectively 5, 5 and 10. Percentage area under the classes, namely agriculture, Kharif fallow, forest, open land are 52, 11, 1 and 27 respectively. Unclassified area is 9%. This area lies in valley. More area is classified under open land class as compared to the classification by WIFS data.

The classified WIFS data is extracted for the watershed. Percentage area under the classes, namely agriculture, Kharif fallow, forest, open land are 41, 13, 32 and 13 respectively. In the open land, 8% area of the gully/ scrub class is also included. Unclassified area is 1%.

Curve numbers

Curve numbers are derived from the percentage area of the land use. A weighted average from the curve numbers of the land use classes is determined. The soil under open land, forests are assumed to be the skeletal soils and are assigned hydrological soil group 'C'. The agricultural soils and Kharif fallow land soils are assigned hydrological soil group 'D'. Curve numbers varies between 90- 98, 77- 98 and 59- 98 for the AMC-3, -2 and -1 respectively. Average curve numbers are 94 and 96 for the AMC-3; 86 and 90 for the AMC- 2; and 74 and 80 for the AMC-1. Lower values are determined from WIFS land use data. This is due to higher wood class percentage in the WIFS data.

Discharge hydrograph

The direct runoff hydrograph is computed for the AMC- 3 and 25, 50 and 100 years synthetic storms. The synthetic storms are generated using the depth- duration- frequency relationship (Ram Babu 1979) (vide Tripathi and Singh 1993). The 1- day design rainfall distribution are used. The 1- day rainfall depths for 25, 50 and 100 years frequencies are 143, 161 and 181 mm respectively.

Table 5.1 Curve numbers

Land use	Hydrological soil	Curve number		
		AMC-1	AMC-2	AMC-3
Paddy	Standing water	98	98	98
Fallow	Standing water	98	98	98
Row crop: contoured and hydrological good condition	A	45	65	82
-do-	D	72	86	94
Bare	C	80	91	97
-do-	D	85	94	98
Wood: hydrological poor condition	A	26	45	65
-do-	C	59	77	90
-do-	D	67	83	93
Legume: contoured and hydrological good condition	A	35	55	74
-do-	D	67	83	93
Agriculture: Jabalpur district	Composite	79	89	95
Agriculture: Narsinghpur district	-do-	76	88	95
Agriculture: Tawa valley, Betul district	-do-	52	69	84
Agriculture: Betul district	-do-	79	92	99

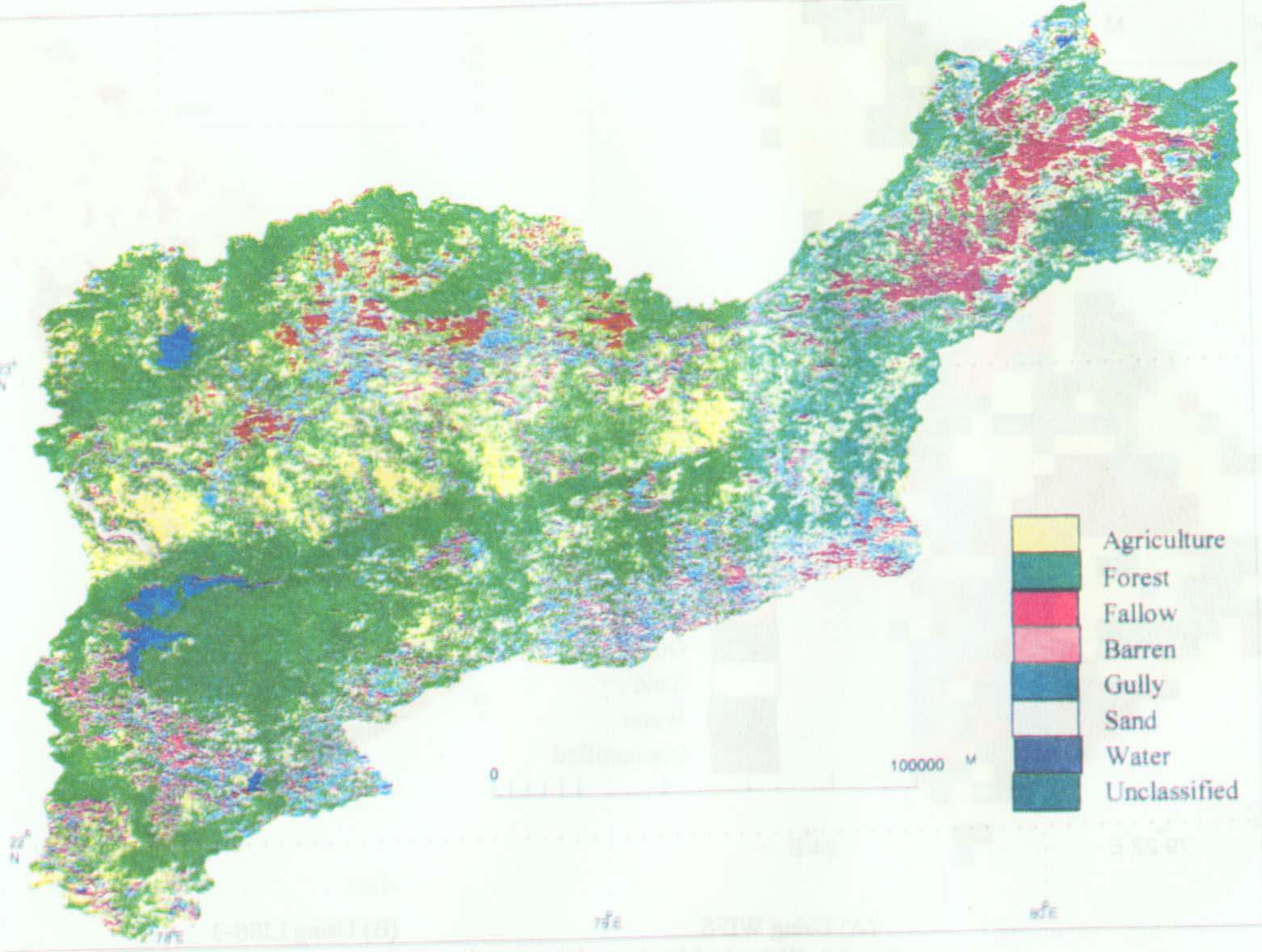
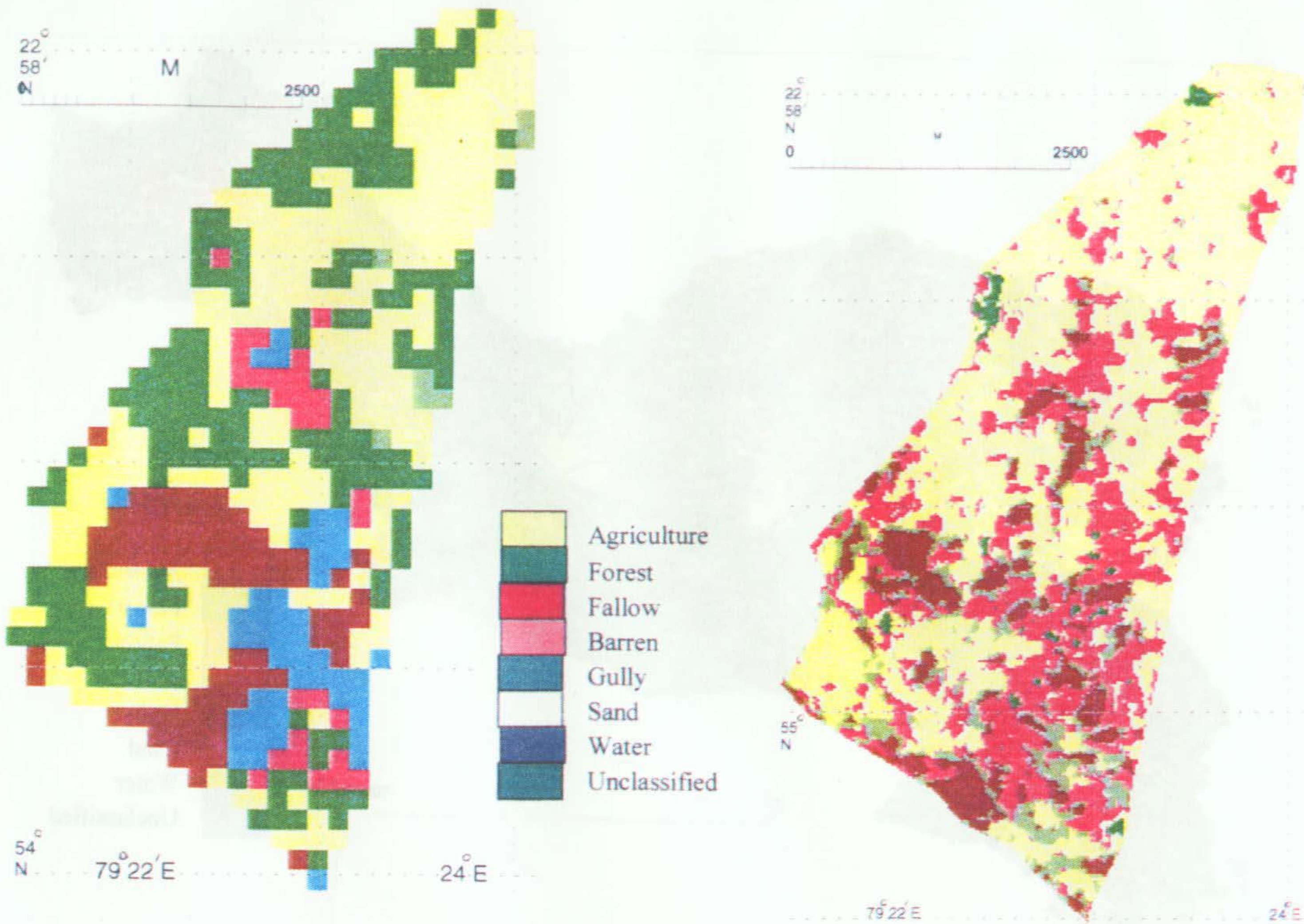


Fig 5.1 Land use map



(A) Using WIFS (B) Using LISS-3

Fig. 5.2 Watershed land use, Umar catchment

RESULTS

A curve number table is obtained for a part of the Narmada basin from Jabalpur to Hoshangabad. The land use map derived from remotely sensed data and collateral data e.g. soil survey reports, project reports etc. are used. The remotely sensed data used are of the WIFS and LISS-3 sensors onboard IRS. A design direct runoff hydrograph is obtained for both the data types for 25, 50 and 100 year return period synthetic storms. The land use and cover map and direct runoff hydrographs are described here.

Hydrological land use

Land use map is prepared for the Narmada basin from Jabalpur to Hoshangabad. The catchment area is 27900 sq km. Percent area under land use classes, namely agriculture, Kharif fallow, forest, open land/ scrub, river sand and water are 22.8, 8.8, 52, 13.3, 0.2 and 0.9. Unclassified area is 2%. In part of the area in the basin, large area is left fallow in the Kharif season. In the practice, the rain water is stored in the bunded agriculture fields and infiltration is allowed to take place. This moisture is used for the Rabi cultivation. Largely, Kharif fallow is located in Jabalpur and Narsinghpur districts. Hydrologically the fields will act as paddy fields. For the design runoff hydrographs most of the rainfall will be converted to runoff from this area.

Curve numbers derived from LISS-3 and WIFS data have nearly equal values for a watershed in Umar catchment. The area of the selected watershed is 17.2 sq km. There are differences in the classifications in terms of unclassified areas and forest class. From the WIFS data more area in classified in the forest class. The LISS-3 derived map has more unclassified area.

Design discharge

Design storm is determined from depth- duration- frequency relationship. The relationship is available for India. From this synthetic storm is generated. The SCS triangular unit hydrograph and SCS method has resulted in design direct runoff hydrograph. The 1- day design rainfall 143, 161 and 181 mm for return periods of 25, 50 and 100 years. For the return periods the peak discharges computed are 52, 59 and 67; 58, 66 and 75 cumec respectively for the WIFS and LISS-3 data. Higher value is useful for design purpose in the watershed.

CONCLUSIONS

1. Design discharge computations are done for a watershed in Umar catchment. The watershed is an agriculture watershed with areal extent of 17.2 sq km. The 1- day design storm depths for return period of 25, 50 and 100 years are respectively 143, 161 and 181 mm. The peak discharge computed from the synthetic storm for the above return periods are respectively 58, 66 and 75 cumec for the LISS-3 data. The values are useful for design in the small water resources and irrigation structures, bridges etc.

2. Nearly 9% area is left fallow in Kharif for conserving moisture in the clayey soil for Rabi cultivation in Jabalpur, Narsinghpur districts and other areas. The practice results in lower cropping intensity. The system is required to be replaced with other means of irrigation for increasing the cropping intensity.

3. WIFS data have provided land use map for the entire basin. This map is useful for computing curve number for agricultural watershed in the basin.

4. WIFS data have been found easier to handle due to less storage space and less processing time required in the data as compared to higher resolution data e.g. from the sensors LISS-2 and -3. The data provide useful information of the land use.

5. Comparable land use maps are obtained form LISS-3 and WIFS data.

6. 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.

7. 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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