CASE STUDY CS(AR) - 190

ESTABLISHMENT OF SCS RUNOFF CURVE NUMBER FOR BATANE SUB-BASIN OF PUNPUN BASIN USING IRS-1A LISS II DATA BASE

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PREFACE

The impact of landuse changes on the basin wide runoff is of the interest to many water resources planners and managers. Mathematical models are commonly used to estimate runoff values. The hydrological model developed by the soil conservation service (SCS) have been widely used internationally for water resources management and planning. These methods can be successfully applied in urban and suburban area as well as on agricultural land.

The river Punpun is one of the right bank tributary of the river Ganga. It joins the Ganga near Fatwa about 25 Km downstream of Patna covering a total distance of 232 Km. The Punpun basin has been selected for delineating the landuse and hydrological soil cover classification. Further a sub basin of punpun basin up to the Santhua gauging site has been selected to establish the runoff curve number. The remote sensing imageries of IRS-1A, LISS II have been used for land use classification.

The results obtained show that remote sensing data has immense potential for land use interpretation and also permit the selection of image data at periods of the year when land use cover and surface conditions are critical to hydrological studies.

The Soil Survey and Land Use Planning Centre, Sabour, Bhagalpur, Govt. of Bihar desire our thanks for supplying necessary soil information of the study area. The report has been prepared by Shri A.K.Lohani, Scientist `B', Shri M.Arora, SRA and Shri R.K.Jaiswal, SRA under the guidance of Dr. K.K.S.Bhatia, Head and Scientist `F', Ganga Plains Regional Centre, Patna. The services of Shri Sivadas A.K. are also acknowledged.

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ABSTRACT

Much hydrologic research has been directed at understanding the hydrologic processes involved with a gauged watershed and applying this knowledge to predict the runoff values needed for efficient water resources development and management. Mathematical models are commonly used to estimate runoff values. A widely used hydrological model for calculating storm runoff, developed by the USDA Soil Conservation Service (SCS) uses storm rainfall and curve number. The Soil Conservation Service runoff curve number (CN) is a quantitative descriptor of the land use/ land cover/soil complex characteristics of a watershed and is commonly assigned based on information acquired from field surveys and/or interpretations of aerial photographs. For the establishment of the curve number of a basin the information on hydrologic soil group, hydrologic condition, treatment or practices, and land use/ cover are utilized.

The conventional techniques used in the land use mapping are expensive and time consuming particularly for large watersheds. The relatively new technique of satellite remote sensing provides a real time and reasonably accurate information at a faster and less tedious way. In the present study various land use classes has been interpreted in the Punpun basin and estimate runoff by establishing the SCS runoff curve number, using IRS-1A, LISS II, FCC prints.

1.0 INTRODUCTION

The scarcity of available land and water resources, which is outcome of growing population, has necessitated its proper planning and management. The management of water resources is also imperative due to regional imbalance in available water. To overcome the problem created by the temporal and spatial variations in water availability, hydrologists and engineers attempt to make predictions of water availability. Estimate of hydrologic quantities particularly runoff is very much required as input to engineering design, which represent the engineers attempt to solve the problem.

The impact of land use changes on the basin wide runoff is of interest to many water resources planners and managers. Mathematical models commonly used to estimate runoff values such as the soil conservation service (SCS) runoff curve number system, are based on physical descriptors of the watershed (e.g. catchment/drainage area, land cover and soil type) and measured climatological parameters such as rainfall and streamflow. The method is used to estimate the peak discharge for a drainage basin. It takes into account an important parameter called runoff curve number which is a function of the soil type, the land use condition, and the antecedent soil moisture. The prime variable in the basin wide runoff curve number estimation is land use changes with the time.

The information related to land use and land cover have historically been gathered by ground surveys or low altitude photography. These survey methods are very expensive and time consuming. Hydrologists and planners are interested in data that are quickly gathered, to eliminate temporal difference, and are repetitive. A repetitive data source is helpful in determining change as they occur over time. A potential method for collecting the requisite information on land cover and soil type of broad areas is through the utilization of satellite data. Translation of the timely available land use/cover and soil type information to runoff index is a very important task.

2.0 REVIEW OF LITERATURE

2.1 Introduction

Rapid development of space technology and earth observation systems, which started with simple television cameras, has now led to the development of many sophisticated sensors operating in different parts of electromagnetic spectrum. Satellite observations and the use of satellite imagery and photography by many nations for various applications, have made us all aware of the promise and potential of satellite remote sensing techniques.

Remote sensing techniques had been widely used by various investigators for the effective management of available resources. This chapter deals with the work carried out in the past in areas related to land and water resources management using remotely sensed data.

2.2 Remote sensing for resources survey and mapping

An attempt has been made by Hamza et. al. (1981) to generate useful land use/ cover classification maps of central Tunisia from Landsat imagery. An important consideration included the use of multitemporal data for monitoring changes over time. After geometric correction to a Lumbext Conformal Map projection and spectral contrast enhancement, a false colour image was produced for both data sets at the scale 1:2,00,000 Two manual interpretation maps were obtained with forty different land use/cover classes.

Sahai et. al. (1983) selected Panchamahals district in Gujrat for making an up-to-date resources survey using remote sensing techniques. Multiband and multitude landsat data and multiband aircraft data were used for these studies. The detailed land use and hydromorphological maps were prepared in 1: 12,500 and 1:15,000 scale respectively. Colour infrared imagery was also used for mapping forests.

Subudhi et. al. (1989) used Landsat Thematic Mapper for urban land use/cover mapping. Visual interpretation techniques were employed to extract information about Lucknow city and its environs had been studied to evaluate the usefulness and

potentiality of satellite data for urban area studies.

Remote sensing techniques have been widely used for land use/land cover mapping. In India, land use/land cover of Chakrata in Western Himalayas (Porwal and Pant, 1989), a part of Midnapore district, West Bengal (Lohani, 1989, Lohani and Tiwari, 1995) etc. are some more examples.

2.3 Remote sensing applications in land use change monitoring

Remote sensing techniques were used by Nagaraja et.

al. (1985) for monitoring land use changes for planning and environmental conservation. They studied the capability of remotely sensed data to delineate and understand the present land use/land cover and pattern of change over a large area of Belgaum district in Karnataka. The spatial distribution of various land use/ cover categories and their percentage area coverage for the periods 1980 and 1982 were calculated to understand the pattern of changes in land use.

2.4 Remote sensing for hydrologic modelling

Land use and vegetal cover information for upper Yamuna basin were derived by Chandra et. al. (1984) and then they obtained morphometric and relief characteristics of the basin, with the help of Landsat imagery and aerial photographs. These characteristics were used to derive runoff coefficients for various land uses for use in simulation of runoff employing rational formula.

Jackson and Rawls (1981) evaluated the potential of using a Landsat data base to make the curve number estimation process more cost effective and less tedious. In the Washington. D.C., ten watersheds were evaluated using a Landsat land cover data base developed by the U.S. Geological Survey. They concluded that these data can be effectively used.

The Little river watershed near Tiffon, Georgia was studied by Slack and Welch (1980) using Landsat digital data to determine SCS curve number and hydrological soil groups. They concluded that Landsat can permit hydrologists to derive curve number on a percent basis for large watersheds by correlating generalized land cover with hydrologic soil groups and data derived from SCS table. They reported that to determine curve numbers for large coastal plain watersheds, it is feasible to use Landsat data which perhaps, eliminate or minimise costly field surveys.

2.5 Application of Remote Sensing in Water Resources

Still and Shih (1985) used remote sensing data in the form of Landsat computer compatible tapes (CCT) to determine land use and land cover as an aid in hydrologic studies that were used to estimate a basinwide runoff index. With the use of the general electric image 100 multispectral image processing system in conjunction with the Earth Resource Laboratory Application Software (ELAS). CCT's on Feb.9, 1976, were analyzed by spectral difference to determine unique land use condition within the Econlockhatches (Econ) River basin, Florida. Landsat Band 5 (0.6-0.7 um) and band 7 (0.8-1.1 um) in the multispectral scanner system in conjunction with the supervised techniques of ELSA were successfully used to classify the land use into 22 classes. The result showed that the landsat data can be further successfully used to monitor the USGS land use level 1. An advantage of using the Landsat data for **land** use classification is that new data are periodically available for updating the landuse information. The soil conservation services curve member was used to establish a basin wide runoff index which includes a prime variable of land use changes with the time. The basin wide runoff index in 1977 (with SAS 1972 Land use maps) was similar to the one in 1976 (with landsat data dated February 9,1976). This implies that the runoff from the entire Econ Basin was not noticeably changed during the period of 1972 and 1976.

3.0 DATA REQUIREMENT AND METHODOLOGY

In the present study, Batane sub basin of the Punpun basin in the Ganga River System has been selected for the establishment of SCS runoff curve number. Pre and post-monsoon false colour composite (FCC) prints of IRS-1A, LISS II along with available soil information were used to delineate different land use classes and hydrological soil group classes in the Punpun basin. In this chapter, location, extent and physiography of the study area together with the data used for analysis have been discussed. An explanation of the concepts and methods that have been employed for the present study is also presented.

3.1 Location and extent of study area

The Punpun river originates from Chottanagpur hills of Palamau district in Bihar at an elevation of 300 m and at north latitude of 24° 11' and east longitude of 84° 9'. It is one of the important right bank tributaries of river Ganga. The punpun river system lies approximately between longitude 84° 10 to 85° 20'E and latitude 24° 11' to 25° 25'N (Fig.3.1). After flowing for most of its portion in north east direction it joins the Ganga at Fatwah, about 25 km downstream of Patna. The river is rainfed and carries little discharge during non-monsoon period. It receives most of the discharge from the right bank

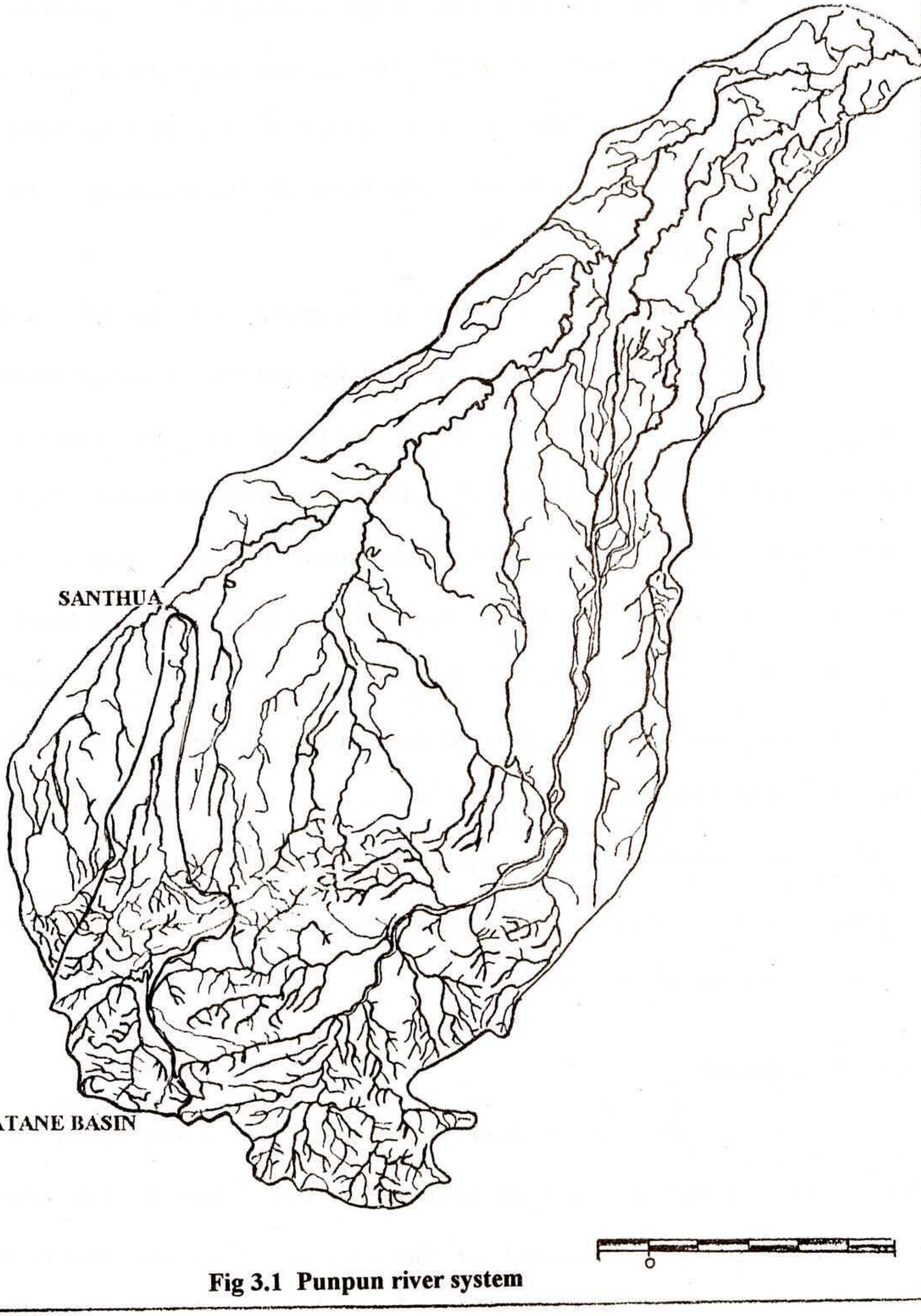

Fig 3.1 Punpun river system

tributaries. The length and the catchment area in respect of all the important tributaries have been worked out separately and shown in line diagram (Fig.3.2). The ground elevation varies from 300 m near origin of the river to about 50 m near out fall into the river Ganga. The general direction of the drainage is from south-west to north-west.

The Punpun river basin is roughly trapezoidal in shape. The length of the basin is about 180 Km and the average width in upper and lower reaches of the basin is 60 Km and 25 Km. respectively. The total area of Punpun basin is about 8530 Sq. Km. which is one percent of total area of Ganga basin in the country. The entire catchment lies within the state of Bihar and is spread over the districts of Patna, Gaya, Aurangabad, Hazaribagh and Palamau. Batane sub basin of the Punpun basin is selected for the development of SCS curve number. The Batane sub basin has catchment area about 640 sq. Km. and falls in the Aurangabad district. The Batane sub-basin is marked in the Punpun river system as shown in fig. 3.1.

3.2 Topography

The upper most portion of the basin lying in the districts of Palamau and Hazaribagh is hilly and mostly covered under forest. The lower part of the catchment in the districts of

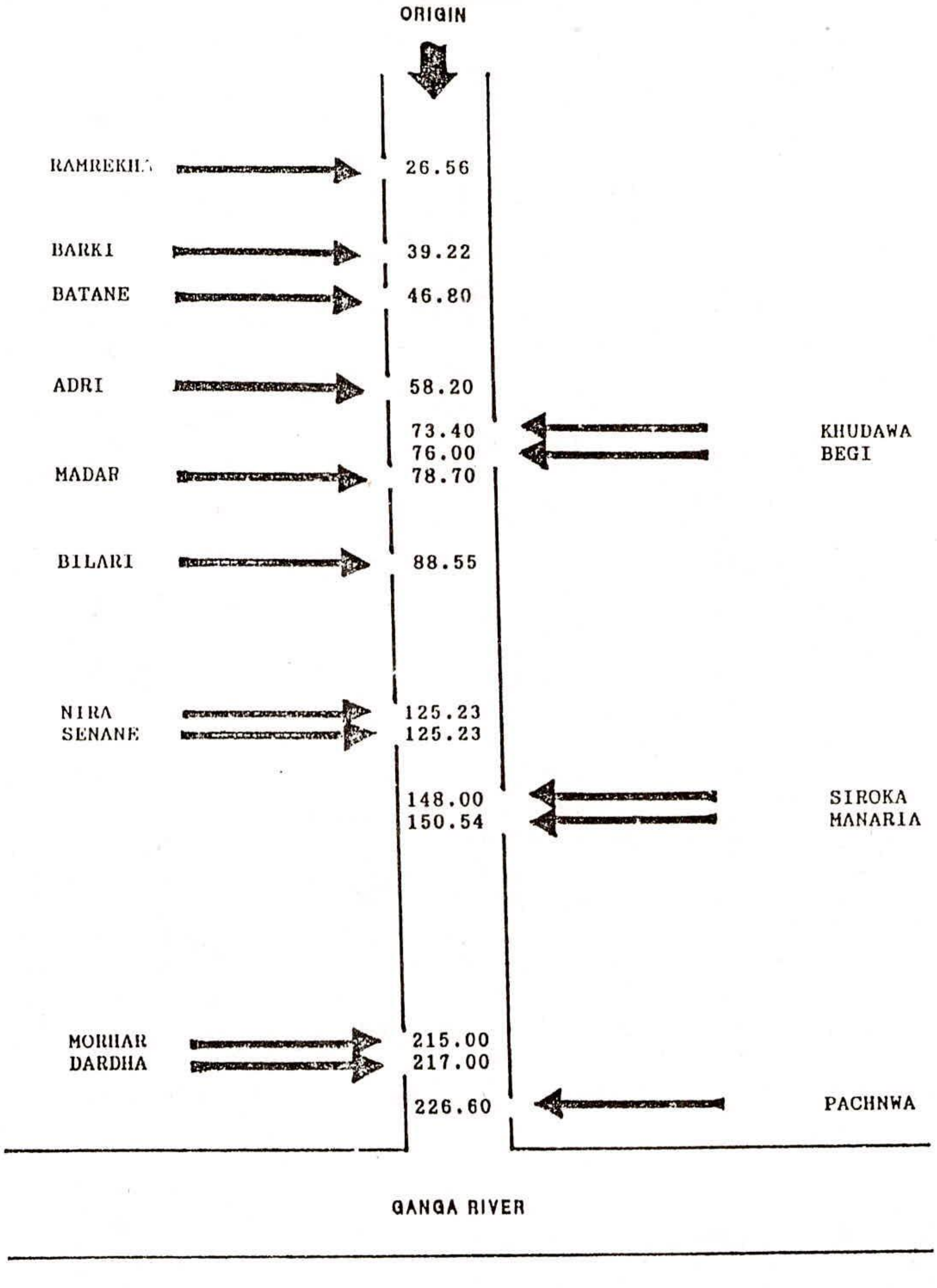

Fig 3.2 Line digram of Punpun river system

Aurangabad, Gaya, Patna is mostly plain or having some uniform mild slope.

3.3 Data used

Paper print product FCC of IRS-1A, LISS II were used for delineating the land use classes in the basin. Both pre-monsoon and post-monsoon data of following dates were used in the study.

Type of data	Path/Row	Scene	Date
Pre-Monsoon Data			
IRS-1A, LISS II	P22-R50	B 1	April 9, 1989
IRS-1A, LISS II	P22-R50	B 2	April 9, 1989
IRS-1A, LISS II	P21-R50	A 1	April 8, 1989
IRS-1A, LISS II	P21-R50	A 2	April 8, 1989
IRS-1A, LISS II	P21-R50	B 2	April 8, 1989
Post-Monsoon Data			
IRS-1A, LISS II	P21-R50	B 2	Nov. 14, 1989
IRS-1A, LISS II	P21-R50	A 1	Nov. 14, 1989
IRS-1A, LISS II	P21-R50	A 2	Nov. 14, 1989
IRS-1A, LISS II	P22-R50	B 1	Dec. 7, 1989
IRS-1A, LISS II	P22-R50	B 2	Dec. 7, 1989

The soil information of the study area was collected from the office of the Soil Survey and Land Use Planning Centre, Sabour, Bhagalpur.

3.4 Soil information

Six broad soil associations are found in Punpun basin which are given below :

1. Yellow-Reddish yellow-medium deep, light textured catenary soils.

2. Hill and Forest soils of steep slopes and highly dissected region

3. Old Alluvium yellowish Red - yellow soils of foot hills

4. Old Alluvium Reddish Yellow - yellow-gray catenary soils

5. Old Alluvium Gray-Grayish yellow, heavy textured cracking soils.

6. Tal land soils.

The entire area of Punpun basin have two groups of soils (i) Sedentary soils and (ii) Old alluvial soils. The first three soil associations are sedentary, whereas last three are old alluvial. Sedentary soils are classified under hydrological soil group B' while old alluvial soils under Group `C' (Fig. 3.3). A major portion of Batane subbasin lies in hydrological soil group C'

Sedentary soils are found in Partapur, Manatu, Chhatarpur, Dumaria etc. whereas alluvial soils occupy rest of the portion of Punpun basin. The tal land soils are found in extreme northern portion of the said basin.

Each soil association is described below :

3.4.1 Yellow-reddish yellow, medium deep, light textured catenary soils

Medium deep over morrum (both ferrugenous and quartizite) bed rock, reddish yellow on slopes. Yellow in central portion of broad level lands and lower slopes, grayish yellow to

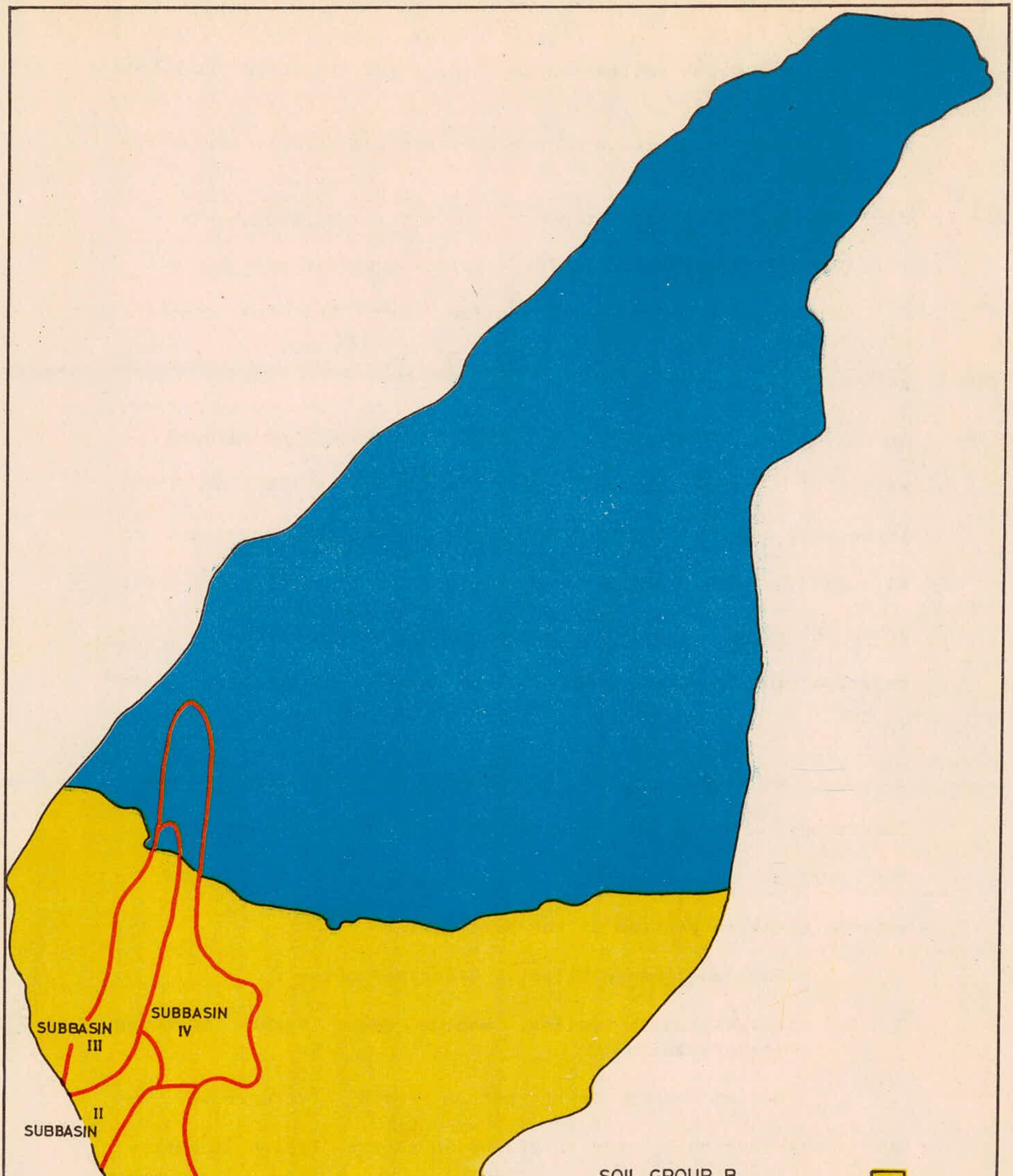

Fig. 3·3 Hydrologic soil map of Punpun basin light gray in low land, light to medium textured, moderately acidic to neutral, medium to low fertility status. These catenary soils have lighter texture, ferrugenous concretions, thick morrum beds below 75-150 cms some soils have ochric epipedon thin or moderately thick argillic horizon, strong brown to yellowish red colour. They are formed from acid rocks and freely drained, clay minerals distributed are Hydrous mica, Kaolinite, smectite, chlorite etc.

3.4.2 Hill and forest soils of steep slopes and highly dissected regions

Shallow to medium deep over rocks and regoliths, well drained to excessively well drained, very strongly to moderately acidic, light textured generally gravelly or stony, covered with forest of various kinds with few cultivated patches. Soils developed in Holocene deposits or on steep slopes over parent materials acid sedimentary or metamorphic rocks or acid sediments and alluvium are brownish in colour and do not have a fragipan, duripan and carbonate in the Cambic horizon. Some soils have ochric epipedon, a thin or moderately thick argillic horizon, but no fragipan and an abrupt change in texture at the top of the argillic horizon. They are strongly acidic, friable, mottled and containing granular structure.

Some of the soils have dark red to dusky red argillic horizons and a dark colour epipendon, formed form mainly basic rocks.

3.4.3 Old Alluvium yellowish red-yellow soils of foot hills

These soils have been developed on colluvial deposits in alluvial fans. Soils over bed rocks and pables are excessively drained to moderately well drained, shallow to medium deep, moderately acidic to neutral in reaction, poor to moderate in fertility, reddish to brownish in colour and lacking petrocalcic or nitric horizons or even duripan. The clay minerals found are hydrous mica, kaolinite, chlorite, smectite etc.

3.4.4 Old Alluvium Reddish Yellow-yellow-Gray catenary soils

The well drained reddish yellow soils are strongly to moderately acidic with well developed B horizon generally containing ferrugenous concretions. The poorly drained low land soils are grayish in colour, slightly acidic to slightly alkaline in reaction containing ferrugenous concretions in most of the cases showing a tendency to crack during dry months. Some of the soils have argillic horizons with ferrugenous concretions in the lower horizon and no duripan within 1 m. of soil surface and nitric horizon. Some soils have been formed in upland depressions, where fresh sediments do not accumulate. Clay minerals found are Kaolinite, Hydrous mica and chlorite.

3.4.5 Old Alluvium Gray-Grayish yellow, heavy textured cracking soils

Grayish yellow to gray in colour, medium heavy to heavy in texture, neutral to slightly alkaline in reaction, cracks having on drying (5-8 cms wide and 60 to 120 cms deep), very weakly developed profiles, mottles of low croma in the lower horizon. Clay minerals mainly observed is smectite followed by hydrous mica.

3.4.6. Tal Land Soils

Gray to dark gray in colour, medium heavy to heavy in texture slightly to moderately alkaline in reaction, cracks during summer (1 cm to more than 5 cm wide and more than 50 cm deep) and swells with the on set of monsoon, clay content nearly 40 to 50 percent through out the profile, slickensides along with the wedge shaped structural aggregates observed. Soils are found in level land or depressions. Soils become bone dry during summer and remain inundated during rain. The clay minerals mainly found are smectites followed by hydrous mica. The soils have good fertility status.

3.5 Ground Truth (GT) data

The Survey of India topographical sheets and the maps supplied by Hydrology Cell, Govt. of Bihar were used to prepare the base map and to finalise the different land use/ cover classes. Further, the ground truth information about the study area available with Hydrology Cell and Water and Land Management Institute, Patna were also used in the study.

3.6 Concepts and Methods

3.6.1 Preparation of land use map

The land use map of the Punpun basin was prepared using visual interpretation techniques. An initial tracing of the study area clearly indicating the boundaries and a few control points was prepared from Survey of India toposheets and the base map supplied by the Hydrology Cell, Govt. of Bihar. This initial tracing was superimposed on a satellite FCC which was illuminated using a light table. Boundaries of various land use/ land cover classes were demarcated. Keeping in view the fundamentals of visual interpretation, different features were classified. The interpretation was based on site, shape, shadow, tone, texture, pattern and association characteristics of the images.

After preliminary image interpretation, the results were compared with the limited ground truth data available and corrections and modifications were made wherever found necessary. After the modifications, details were transferred on to the base map. Graphical method was used to obtain the area under different land use and cover classes.

3.6.2 SCS Runoff Curve Number System

The hydrological methods and model developed by the Soil Conservation Service (SCS) and described in their National Engineering Hand Book (U.S.Soil Conservation Service, 1972) have been widely used internationally for water resources management and planning. Continuous development of the techniques has made it possible to apply the methods in urban and suburban areas as well as on agricultural lands. The major input parameters for the SCS techniques are land use and soil type.

The USDA Soil Conservation Service (SCS) runoff curve number (CN) computes direct runoff through an empirical equation that requires the rainfall and a watershed co-efficient as inputs. The watershed co-efficient is called the curve number, which represents the run off potential of the hydrologic soil-cover complexes. The SCS model involves relationships between land cover, hydrologic soil class and curve number. The SCS run off model for small watersheds is described thus:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8\,S} \qquad \ldots 3.1$$

$$\text{where } S = \frac{1000}{CN} - 10 \qquad \ldots 3.2$$

Vandersypen et. al. (1972) have given the following equation for the estimation of runoff for the Indian conditions :

For black soil region (Antecedent moisture condition I) and for all other regions :

$$Q = \frac{(P-0.3S)^2}{P+0.7S} \qquad \ldots 3.3$$

For Antecedent moisture conditions II & III in black soil region :

$$Q = \frac{(P-0.1S)^2}{P+0.9S} \qquad \ldots 3.4$$

where,

Q = actual direct run off, cm
P = total storm rainfall, cm
S = potential maximum retention, cm

This equation should be used with the assumption that the cracks which are typical of black soil when dry have been filled. Therefore, this equation is to be used where the antecedent moisture could fall into AMC group II and III. When AMC I needs to be analysed use equation no. (3.3).

The `S' value are transformed into the curve number of the watershed by the following equation :

$$CN = \frac{25400}{254 + S} \qquad \ldots 3.5$$

where,

CN = Curve number

= f(soil, land, vegetal cover, antecedent moisture etc.)

Values of initial abstraction to be used for Indian conditions are presented in table 3.1.

Table 3.1 Values of initial abstraction for Indian region

Condition or Region	Initial abstraction
Black soils region, AMC II & III	0.1S
Black soils region, AMC I	0.3S
All other regions	0.3S

3.6.3 Determination of curve number from IRS data

The land cover and soil information derived from the IRS data is far more general than that specified in Table 3.2 and it is necessary to establish a curve number classification system compatible with the IRS data. This can be accomplished with the aid of the standard SCS table of runoff curve numbers modified for Indian conditions.

Table 3.2: Runoff curve numbers for hydrologic soil cover complexes for Indian conditions (AMC II and Ia=0.3S)*

Cover			runoff CN for hydrologic soil group			
Land use	Treatment/ practice	Hydrol. condn.	A	B	C	D
Cultivated	straight row		76	86	90	93
	contoured	poor	70	79	84	88
		good	65	75	82	86
	contoured &	poor	66	74	80	82
	terraced	good	62	71	77	81
	bunded	poor	67	75	81	83
		good	59	69	76	79
	paddy		95	95	95	95
Orchards	(with under-story cover)		39	53	67	71
	(without under-story cover)		41	55	69	73
Forest		dense	26	40	58	61
		open	28	44	60	64
		shrub	33	47	64	67
Pasture		poor	68	79	86	89
		fair	49	69	79	84
		good	39	61	74	80
Wasteland			71	80	85	88
Hard surface areas			77	86	91	93

* source : Handbook of Hydrology, 1972

3.6.4 Weighted curve number

The weighted curve number for each sub-basin was calculated by using the following equation:

$$\text{Weighted CN} = \frac{CN1 \times A1 + CN2 \times A2 + \text{-----} + CNn \times An}{A1 + A2 + \text{------} + An} \quad \ldots 3.6$$

where, CN1, CN2, ----, CNn are the curve numbers for different land uses and treatment and hydrologic soil groups present in the sub-basins of the watershed and A1, A2, ----, An are its respective sub-basin areas.

The weighted curve number for the whole basin was calculated by using the equation,

$$\text{Weighted CN} = \frac{\text{CN of sub-basin} \times \text{Area of sub-basin}}{\text{Total area of watershed}} \quad \ldots 3.7$$

When the basin is divided into small grids with available landuse and soil information the calculation of SCS run-off curve number can be rapidly done using a computer software (Lohani and Bhatia, 1993).

4.0 RESULTS AND DISCUSSION

The present study aims to prepare land use and hydrological soil group classification map of Punpun basin and to establish SCS runoff curve number for the Batane sub basin. For this purpose satellite data of both pre and post monsoon period were used. These data includes the IRS-1A, LISS II, FCC prints. From these data land use of the basin was delineated and available soil information were interpolated for the whole basin.

4.1 Identification criterions used for land use classification of the basin :

The fundamentals of image interpretation have been discussed in chapter III. Keeping in view different land use categories were classified. Inference made for the classification are as follows.

Punpun river basin can be divided into two major groups: hilly and plain. Hilly area is mainly covered by forests, while the plain area is mostly irrigated crop land. After careful visual interpretation of IRS-1A satellite FCC prints, the Punpun basin has divided into six major classes (Fig4.1). These are: Agricultural land, forest land, water logged area, waste land, Built up area, river and tributary. Area falling under each category is presented in Table 4.1. Batane sub basin is further

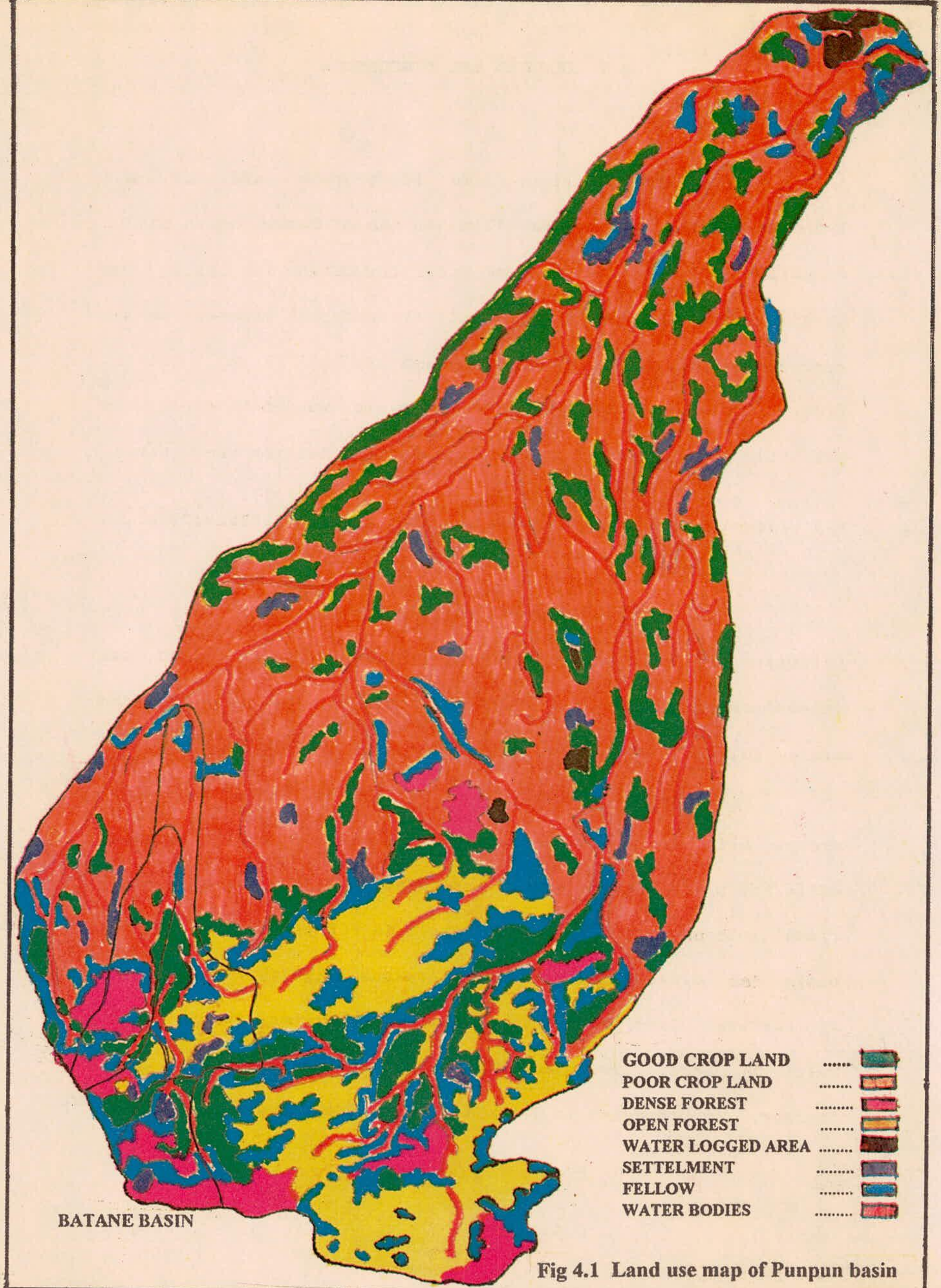

Fig 4.1 Land use map of Punpun basin

Table 4.1: Land use classification of Punpun basin obtained from IRS-1A data base.

Sl. No.	Land use	Hydrologic soil group	Area (sq.Km.)	% of total geographical area
1.	Agriculture land			
	(a) Good crop land	B	822.40	9.64
		C	455.83	5.34
	(b) Poor crop land	B	3953.41	46.35
		C	660.23	7.74
2.	Forest			
	(a) Dense	B	36.66	0.43
		C	242.66	2.84
	(b) Open	B	39.84	0.47
		C	711.23	8.35
3.	Waterlogged area		44.63	0.52
4.	Settlements	B	100.41	1.18
		C	103.20	1.21
5.	Fallow	B	213.96	2.51
		C	709.24	8.31
6.	Waterbodies (river/ponds)		436.30	5.11
			8530.00	100.00

divided into four sub basins and area falling under different land use and hydrological soil groups in each of the sub basin is presented in Table 4.2.

4.1.1 Agricultural Land

The agricultural land was generally found associated with canals and streams. Low land paddy was considered as good crop land or intensively cultivated i.e land put under cultivation in all seasons whereas upland paddy was considered as rainfed. The cultivated land was found in red to brown colour. Since the FCC were of for both pre and post monsoon-periods, the classification of poor and good crop land was based on different cropping season.

4.1.2 Forest Land

On FCC the classification of forest land is quite easy. It was found to be crimson red colour and of smooth texture. In comparison to open forest, dense forest was found to be more brighter in colour and smoother in texture. These inference were later verified from base map prepared from toposheets.

4.1.3 Water logged area/water bodies

Sky-blue to deep blue colour patches in imageries were identified as water bodies. At some points it was found tinted with black tone reflecting the sedimentation level. In general,

Table 4.2: Land use classification of Batane basin (divided into four sub basins) obtained from IRS-1A data base.

Sl. No.	Land use	Hydrologic soil group	Area (sq.Km.) I	II	III	IV
1.	Agriculture land					
	(a) Good crop land	B	20.52	22.21	45.28	18.55
	(b) Poor crop land	B	0.00	0.00	31.28	31.29
		C	0.00	0.00	11.37	48.37
2.	Forest					
	(a) Dense	B	55.32	18.24	53.91	3.20
	(b) Open	B	29.12	26.41	0.00	67.65
4.	Settlements	B	10.87	4.34	1.8	11.33
5.	Fallow	B	31.37	22.21	34.35	16.12
		C	0.00	0.00	0.00	8.89
Total area			147.20	93.41	177.99	205.40

water bodies were closely associated with agriculture land. Wet and marshy land were seen in bluish-white colour. Often it was found surrounded by agriculture land. Nature and pattern of the stream/canals were very distinct on FCC.

4.1.4 Built up area

Built up area were found in bluish black colour with scattered white spots. This classification was later verified from the base map of the study area.

4.1.5 Waste land

Waste land were seen in pale white colour with scattered reddish spots. Near total white spots were seen on the FCC, where ever land was bare or impervious.

4.2 Establishment of runoff curve number from IRS-1A Data

Land use and soil information of the basin serves as the basic input to the curve number technique. The curve number has been classified for different soil-cover complexes. Various land cover classes that can be derived from the IRS-1A, FCC data is far more generalised then that specified in standard Table 3.2 (Hand Book of Hydrology, 1972). Relatively coarse spatial resolution of satellite data limits the differentiation between various treatment practices. Jackson et. al. 1975 felt the necessity for establishing a curve number classification system compatible with the Landsat data. Further, they developed a curve number table suitable for landuse classes obtained from Landsat data. Similarly, in the present study runoff curve numbers compatible with IRS-1A, LISS II data have been developed (Table 4.3). This was accomplished with the aid of the standard SCS table of runoff curve numbers (Table 3.2). For example curve number for "poor cultivated land" is an arithmetic average of all curve number values under the heading "poor hydrologic condition Straight row were not included in this calculation since any straight row cultivated land would probably be either poor cultivated or good cultivated in the land use map prepared from IRS-1A data.

The interpreted classes were confirmed with the available data base and some ground checks. The land use classification map was superimposed on the soil map to find out area of different hydrologic soil groups under different land use/cover classes. These maps were prepared to a scale of 1:2,50,000. Runoff curve number for the area under each land use category in the sub basins of Batane river basin was computed from the CN multiplied by the corresponding percentage of land use as listed in Table 4.4 to 4.6. The basinwide runoff CN was summation of the weighted CN in each

Table 4.3 : Runoff curve numbers for hydrological soil cover complexes compatible with the IRS-1A data.

Landuse	Cover: Hydrologic condition	Antecedent moisture condition II: Ia = 0.3S A	B	Ia = 0.1S C	D
Cultivated	Poor	66	76	82	84
	Good	62	72	78	82
	Paddy	95	95	95	95
Orchards		40	54	68	72
Forest	Dense	26	40	58	61
	Open	28	44	60	64
Pasture/Fallow		68	79	86	89
Wasteland		71	80	85	88
Roads/Runway		73	83	88	90
Settlements/Hard surface area		77	86	91	93

Table 4.4: Weighted curve numbers of Batane sub basins obtained from IRS-1A data base (for AMC I).

Sl. No.	Land use	Hydrologic soil group	CN	Area (Sq.Km.) I	II	III	IV
1.	Agriculture land						
	(a) Good crop land	B	53	20.52	22.21	45.28	18.55
	(b) Poor crop land	B	58	0.00	0.00	31.28	31.29
		C	66	0.00	0.00	11.37	48.37
2.	Forest						
	(a) Dense	B	22	55.32	18.24	53.91	3.20
	(b) Open	B	26	29.12	26.41	0.00	67.65
3.	Settlements	B	72	10.87	4.34	1.8	11.33
4.	Fallow	B	62	31.37	22.21	34.35	16.12
		C	72	0.00	0.00	0.00	8.89
TOTAL AREA (Sq.Km.)				147.20	93.41	177.99	205.40
WEIGHTED CURVE NUMBER				39	42	47	50

Table 4.5: **Weighted curve numbers of Batane sub basins obtained from IRS-1A data base (for AMC II).**

Sl. No.	Land use	Hydrologic soil group	CN	Area (Sq.Km.) I	II	III	IV
1.	Agriculture land						
	(a) Good crop land	B	72	20.52	22.21	45.28	18.55
	(b) Poor crop land	B	76	0.00	0.00	31.28	31.29
		C	82	0.00	0.00	11.37	48.37
2.	Forest						
	(a) Dense	B	40	55.32	18.24	53.91	3.20
	(b) Open	B	44	29.12	26.41	0.00	67.65
3.	Settlements	B	86	10.87	4.34	1.8	11.33
4.	Fallow	B	79	31.37	22.21	34.35	16.12
		C	86	0.00	0.00	0.00	8.89
TOTAL AREA (Sq.Km.)				147.20	93.41	177.99	205.40
WEIGHTED CURVE NUMBER				57	60	65	67

Table 4.6: Weighted curve numbers of Batane sub basins obtained from IRS-1A data base (for AMC III).

Sl. Land use	Hydrologic soil group	CN	Area (Sq.Km.) I	II	III	IV
1. Agriculture land						
(a) Good crop land	B	86	20.52	22.21	45.28	18.55
(b) Poor crop land	B	89	0.00	0.00	31.28	31.29
	C	93	0.00	0.00	11.37	48.37
2. Forest						
(a) Dense	B	60	55.32	18.24	53.91	3.20
(b) Open	B	64	29.12	26.41	0.00	67.65
3. Settlements	B	94	10.87	4.34	1.8	11.33
4. Fallow	B	91	31.37	22.21	34.35	16.12
	C	94	0.00	0.00	0.00	8.89
TOTAL AREA (Sq.Km.)			147.20	93.41	177.99	205.40
WEIGHTED CURVE NUMBER			74	76	80	82

category.

4.3 Estimation of Runoff

The river Batane is rainfed and remain dry during non rainy season i.e. from November to June. For calculating the runoff daily rainfall data of the two raingauge stations is considered. These stations are Aurangabad and Hariharganj. Seventeen years rainfall data (fro 1974 to 1990) of these stations were used to calculate the runoff. The remote sensing data of the basin was used for the year 1989. The runoff curve numbers for the various hydrologic soil cover complexes, the antecedent moisture conditions I, II, III and hydrologic soil group, of the sub basins have been estimated. The weighted curve numbers for the subbasins I, II, III and IV of batane basin for AMC II have been calculated as 57, 60, 65 and 67 respectively. The curve numbers for AMC I and AMC III have also been calculated from the curve number table developed for IRS data. Based on the above information and equations, the daily runoff has been estimated using the daily rainfall data for 17 years by using equations 3.3 and 3.4. The total annual runoff from the basin is presented in table 4.7. The observed runoff data for the Batane basin was 29.28 M M^3 for the year 1989 and the calculated runoff for the same year is 31.89 M M^3. It shows that the calculated runoff is only about 9% more than the observed one.

Table 4.7 : Estimated annual runoff from the Batane basin

Year	Subbasin wise runoff (mm)				Total runoff from Batane basin M M^3
	I	II	III	IV	
1974	15.76	23.31	48.84	97.03	33.12025
1975	29.02	37.87	74.93	105.16	42.74584
1976	10.19	14.65	26.12	352.50	79.92102
1977	92.39	104.63	132.48	142.42	76.20648
1978	206.63	237.48	304.18	161.86	139.98600
1979	32.40	41.28	61.36	17.85	23.21310
1980	11.39	16.38	32.57	120.01	33.65385
1981	14.15	17.15	26.55	82.11	25.27589
1982	42.13	52.11	78.00	39.40	33.04511
1983	22.84	30.43	51.42	15.97	18.63700
1984	30.83	41.09	78.41	319.55	87.96816
1985	33.92	41.35	61.12	112.43	42.82740
1986	34.56	43.35	64.47	142.76	49.93447
1987	232.60	254.01	300.32	229.79	158.61860
1988	6.39	10.04	25.19	108.38	28.62326
1989	13.29	17.04	31.09	111.09	31.89959
1990	14.97	20.04	34.63	309.96	73.90510

5.0 CONCLUSION

Satellite sensors are capable of discerning of various landuse/ cover features rapidly in a large area. The visible and near infrared bands on the satellite multispectral sensors allow monitoring the vegetation. In the present study the remote sensing application to the landuse mapping and soil classification is utilised to determine runoff curve number of the basin.

The following conclusions are drawn from the study :

1. The land use/cover classes interpreted from satellite remote sensing data are more generalised in comparison to ground survey. Therefore, it is necessary to develop a more general land use classes suitable to remotely sensed data in curve number technique.
2. Although remote sensing is not a substitute for conventional methods, yet it saves a lot of effort and time. The advantages of satellite based remote sensing are large area coverage, synoptic view and capability to provide information over all accessible and in accessible regions.

3. Remote sensing techniques have been found to be very useful in

providing information at periods of the year when land cover and runoff consideration are critical to hydrologic studies.

4. Approach of determining real time curve number from satellite data may permit the refinement of hydrologic models.

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