CS-115

SNOW COVER MAPPING FOR BAIRA CATCHMENT (H.P.)

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PREFACE

Remote Sensing has wide ranging application . It has proved to be a useful tool for monitoring, mapping and preparing inventory of the natural resources periodically with a certain degree of reliability. Snow covered area is an important input for estimation of Snow melt . Analysis of satellite imagery and CCT are the best means for getting information on areal extent of Snow.

National Institute of Hydrology started longterm hydrologic studies in the representative basins of hydrologically similar regions of the country. One of such studies has been taken up by the NIH Regional Centre at Jammu for Baira nalla catchment above Tissa in the District of Chamba, HP. The catchment being partially snow covered during winter, it is essential to delineate snow covered area and assess snowmelt contribution to analyse hydrologic response of the catchment . It is expected that results of this report will be useful to water resources managers for planning the various projects in this area.

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ABBREVIATIONS

AVHR	Advanced Very High Resolution
CCD	Charged Couple Device.
CCT	Computer Compatible Tape
ERS	Earth Resource Satellite.
FCC	False Colour Composite.
HP	Himachal Pradesh.
IRS	Indian Remote Sensing Satellite
Landsat	Land Space Application Technology(Series of Satellites)
LISS	Linear Imaging Self Scanning Sensor
MSS	Multi Spectral Scanner
m	Meter
M	Million
mm	Millimeter
NRSA	National Remote Sensing Agency
NOAA	National Oceanic and Atmospheric Administration.
SOI	Survey of India
SCA	Snow Covered Area
TM	Thematic Mapper
VHRR	Very High Resolution Radiometer.

ABSTRACT

The Baira nalla catchment, where the NIH Regional centre, Jammu has taken up long term representative basin studies, is partly snow covered during winter. Therefore, pertinent to basin studies delineation of snow covered area is important since it is related to various parameters of flow process. The remote sensing has proved to be a useful tool for monitoring, mapping, and preparing inventory of the natural resources periodically with a certain degree of reliability. The present study was conducted using Landsat MSS and IRS-1A satellite imageries for the years 1984, 1985, 1989, 1990 and 1992.

The analysis was performed using visual interpretation technique. Out of the five years studied, the maximum snow covered area was found to be 70.22 % and the minimum 52.04% in the years 1984 and 1990 respectively . The variation of the snow covered area was about 106 Sq Km (18.2% of catchment area).

1.0 INTRODUCTION

The Himalayas are a great reservoir of snow, ice and glacier fields.Precipitation occuring in the Himalayas at heights of 2240 m & above is generally in form of snow. On the southern slopes of the Himalayas there lies the plain of India and elevation varies from 4300 m in eastern Himalayas to 3800 m in the western Himalayas. The Himalayas are a source of large river systems such as Indus,Ganga,Brahmaputra and their tributaries.The vast snow covered watersheds of Himalayas contribute about 50-60% of the total annual runoff of these rivers in summer months of April,May and June.

The correct information about snow covered area (SCA) and volume of snowmelt runoff likely to occur are of great importance for efficient planning of water resouces development for beneficial uses of agriculture, water supply, power generation, recreation, navigation, flood control and pollution control etc. However, snow covered areas in the mountainous terrain of Himalayas situated at high altitudes, are mostly inaccessible and hazardous for which informations about snow conditions by conventional methods can hardly be collected. With the advent of satellite remote sensing mapping and monitoring techniques, it is possible to have synoptic, repetitive, reliable and timely information of snow covered areas.

The National Institute of Hydrology established Western Himalayan Regional Centre at Jammu in 1990 for hydrological studies. This centre has taken up the Representative Basin

Studies for Baira catchment above Tissa (District Chamba, H.P.) for hydrological studies. The basin is partially snow covered during winter. In continuation of this study, the information about percentage snow covered area during different years was required.Therefore, an attempt has been made to map snow covered area using satellite imageries obtained from Landsat MSS and IRS - 1A for the years 1984, 1985, 1989, 1990 and 1992.

2.0 REVIEW

2.1 Development of Remote Sensing

Remote sensing technology,the term first coined by Evelyn Pruitt in 1960 has made great advances in the last decade with the introduction of several new space and airborne systems. The first known aerial photograph was taken in 1858 by a parsian photographer and baloonist Gaspard Felix Tournachon, better known as Nadar. The first recorded aerial photographs were taken from an airplane piloted by Wilbur Wright in 1909 over Centocelli, Italy.

In India aerial photography was used in 1920 for the first time. The extensive use of the aerial photography has started only after the second world war. In 1966, the Indian Photo Interpretation Institute (presently Indian Institute of Remote Sensing, Dehradun) was set up with financial aid from the Government of Netherlands. On 16th April 1975, the Government of India set up the National Remote Sensing Agency with its head-quarters at Hyderabad. The Space Application Centre (SAC), Ahmedabad is also eng... d in applications of remote sensing work. The launching of Bhaskara-I and II in 1979 and 1981 respectively and Rohini satellite in 1981 gave experience and definite inputs for operationalising the remote sensing activities in the country. Indian Landsat earth station came into operation on first January 1980. With the launch of indegenously built Indian Remote Sensing Satellites (IRS-IA/IB) in March,1988 and August, 1991 respectively, India has taken a big stride in remote sensing of natural resources.

2.2 Physics of Remote Sensing

The remote sensing model has six basic components i.e (a)radiation source, (b) transmission on the target, (c) interaction of the incoming EMR with the target, (d) Passage of the outgoing EMR to the sensor, (e) recording by the sensor and data reception, and (f) processing and interpretation.

Radiation source is of two types, passive radiation source and active radiation source. Passive radiation source is the Sun while in active radiation system artificial radiation source is used.

Radiation in atmosphere mainly undergoes scattering, absorption and refraction. The transmission path have two segments i.e. one between the radiation source on the space and target on the ground and the other between the target to the sensor on the space. The outgoing radiation in the second segment has changes in its magnitudes which is target - dependent and varying in its interaction with different targets and this change in magnitude of the outgoing radiation enable the study of the object on the ground and make the remote sensing possible.

2.3 Snow and Snow Cover

Precipitation in the form of snow occurs in the higher reaches of Himalayas during winter months from October to May under the influence of east moving extra tropical low pressure systems popularly called western disturbances. More than 50% of the annual precipitation is received during winter. Seasonal snow cover generally builds up by middle of December and persists till the end of June. The snow cover generally reaches its maximum extent of accumulation by March. The loss of snow cover is caused by settlement, ablation, evaporation and metamorphic changes. The gain of snow cover is due to addition of snow through fresh precipitation or large scale drifting of snow from neigbouring catchments.

2.4 Properties of Snow and Remote Sensing

Snow and ice have the unique physical property of possessing a high albedo in the visible portion of the spectrum. This makes them easily separable from the darker back ground associated with other natural objects. But snow albedo is reduced substantially in the near infrared (0.8-1.1 micron meter) especially if the liquid water is present though the reflectivity is still much higher than the surrounding substances. Further, the reflectivity of snow is reduced drastically in the spectrum range 1.55-1.75 and 2.10-2.35 micron meter(near infrared) in comparison to other substances. This unique property offers an opportunity for automatically separating snow from highly reflective clouds (Barnes et al 1975). The snow that is potentially ready to melt (273° k) and eventually will contribute to runoff is very important hydrologically and could be observed with a sensor in thermal infrared region. Presence of water in snowpack increases the dielectric constant with respect to dry snow and this could be sensed in the microwave range of the spectrum. Wavelengths longer than 3 cm can go through a dry snowpack and offeres an excellent indication about the snow depth.

2.5 Use of Snow Covered Area for Snow melt Runoff Studies

The information on various snow pack properties such as snow covered area (SCA), water equivalent, snow depth, snow wetness, snow albedo, and the state (frozen or thawed) of the underlying soil are required for the snow melt runoff studies. Out of these the most important input is snow covered area (SCA). The snow covered area can be obtained from various remote sensing satellites periodically with a high degree of reliability.

Various models are available to forecast the snow melt runoff from a watershed. In 1970, Martinec developed the SRM model from experimental data obtained on small mountainous watersheds of 2.64 Sq Km to 43.3 Sq Km in Europe,and the percentage SCA of the basin obtained from aerial photography, air temperature (degree days) and daily precipitation were used in the model. Since 1972 SCA could be determined from Landsat data. In 1979 Hannaford applied King's River snow melt model in Sierra Nevada. The main input was the percent of SCA obtained from Landsat imagery supplemented by NOAA imagery.In 1979 the Martinec-Rango snow melt simulation model was developed.This model also used SCA as primary input derived from Landsat imagery for each watershed elevation zone,degree days for each zone with the corresponding precipitation which occured in each zone. The other parameters are area of each zone,recession coefficients for hydrograph, daily lag factors,melt rate factors and runoff coefficients.

Aul,J.S. & Ffolliott, P.F. (1975) determined a significant linear relationship between areal snow cover and subsequent runoff for Black River watershed (Arizona) during snow pack depletion period taking data of 18th Feb,1973 and found a very good correlation coefficient (0.995).

Ramamoorthi (1978) developed a regression model using percentage SCA of Sutlej basin above Bhakra (43,230 Sq Km) derived from NOAA imageries (April) of the year 1975 to 1978 and measured seasonal snow melt runoff of the Satluj in the same year.

Gupta et al (1982) conducted study on Beas basin and concluded that the relationship between snow covered area and snow melt runoff is affected by the morphological characteristics of sub catchment. A logarithmic relationship between the snow cover area and snow melt runoff was developed.

Krishnan (1983) conducted study on Sainj river, a tributary of Beas and developed a linear regression model to forecast snow melt runoff, three to four months in advance. The model was developed on the basis of data for the years 1967-1968 to 1978-1979 and expected lean period discharge for the years 1979-1980 to 1981-82, were compared with the observed discharge. The forecast was found to exceed by 5%, 9% and 23% respectively in that periods of analysis.

Dey and Goswami (1983) used a multiple regression model, with basin snow covered area and concurrent runoff in the adjoining Kabul River as forecast parameters, explains the variability in the Indus flow better, as compared to the simple bivariate, snow covered area runoff model.They used NOAA - VHRR satellite imageries to delineate the areal extent of snow cover for April over the Indus River basin in Pakistan. A multiple regression model with first April through 31st July, 1969-1979, seasonal runoff as a function of April snow cover and concurrent runoff, first April through 31st July, in the Kabul River estimated from the snow covered area- runoff relationship, explains 79% of the variability of the measured flow in the Indus River. Seasonal flows predicted by the multiple regression model lie within 8% of the measured flow.

Seth (1983) developed a model for daily snowmelt runoff during premonsoon months for Beas basin up to Manali. The eight parameters, representing degree day factors for two parts of the season, losses from snow melt, rain on snow covered area, rain on non snow covered area, snow melt due to rain and routing (recession) factor are estimated for different alternative number of elevation zones. It was concluded that the degree day method is quite appropriate method for computation of snow melt runoff when only temperature data are available.

2.6 Snow / Cloud discrimination

Dozier (1984) used Landsat - 4 Thematic Mapper data for snow hydrology and concluded that snow cover mapping (or cloud mapping) is difficult in visible, near infrared, and thermal infrared wave lengths due to similar reflection and emission of radiance from snow and clouds. He found that in both the TM short wave infrared, TM 5 (1.57-1.78 micron meter) and TM 7 (2.10-2.35

micron meter), snow is much darker than clouds, and water clouds are brighter than ice clouds in TM 5. In both of these bands ice is highly absorptive, and snow reflectance is low and sensitive to grain size for small sizes, which explains the higher reflectance of ice clouds than snow. In TM 5 water is less obsorptive than ice, so water clouds are more reflective than ice clouds.

Ramamoorthi et al.(1990) used Landsat TM 5 imagery along with FCC of TM bands 3,4,5 (wavelengths 0.62-0.69, 0.78-0.90,and 1.57-1.78 micron meter) to discriminate clouds and snow under hill shadows respectively. In addition to this, generaly each cloud ball has a shadow and the texture is rough instead of smooth texture for snow. It is because of that snow gives continuous unbroken tone whereas clouds form an aggregation of small irregularity shaped balls.

2.7 Snow and Glacier Differentiation

Kulkarni (1991) showed in his studies on glacier inventory in Himachal Pradesh using satellite imageries that glacier ice has substantially lower reflectance than snow. Glacier gives green white tone on FCC and can easily be differentiated from the snow accumulation area. Kulkarni (1989) suggested in his studies that period between middle of August and September is suitable for glacier mapping , when seasonal snow cover becomes minimum.

3.0 STATEMENT OF THE PROBLEM

Snow and glacial melt contribute significant proportion of spring season flows in Himalayan rivers .Precipitation during winter is about 40 to 50% of annual precipitation in western Himalayas .Due to inaccessibility and complexity of Himalayan watersheds ,the snowmelt contribution remains mostly un assessed. Many investigators have developed snow melt models, wherein snow covered area is a significant parameter. Satellite data provide areal extent of snow cover periodically over these inaccessible areas to estimate melting discharge.

Western Himalayan Regional Centre, Jammu has taken up Representative Basin Studies for Baira catchment above Tissa (HP). The catchment is partially snow covered during winter.In requirement of these studies delineation of snow covered area is required for thorough analysis of precipitation - flow relationships. In addition to this, assessment of snowmelt runoff is of vital importance for water resources planning and management. The results of this study also will be useful to managers of power generation at Surgani on Baira Siul downstream of Tissa.

With these objectives the snow covered area for Baira nalla catchment has been mapped using satellite imageries.

4.0 DESCRIPTION OF THE STUDY AREA

The present study was conducted for Baira nalla above Tissa (District Chamba, H.P.) in the Ravi basin (Fig.1). The Baira nalla catchment is bounded between latitude 32° 47' to 33° 02' and longitude 75° 57' to 76° 23'. The Catchment is on the southern slopes of Pir Panjal range in the western Himalayas. The area of catchment is 585 Sq Km. The catchment has maximum and minimum elevations of 5321 and 2693 m respectively. The catchment is partially snow covered during winter. The catchment is affected due to western disturbances during winter when precipitation is mainly in the form of snow. The average annual rainfall of the area is about 1122 mm. Winter temperatures are low and are generally below zero during the months of December to February.

The catchment is densely forested. The vegetation is mainly Deodar. Agriculture is the main land use. However, there are a few pastures and uncultivated areas and barren hill slopes.

The mountain slopes are steep and are susceptible to land slips due to rains. The soils are degraded and loose and are easily prone to erosion. The sediment rate in the river is, therefore, high.

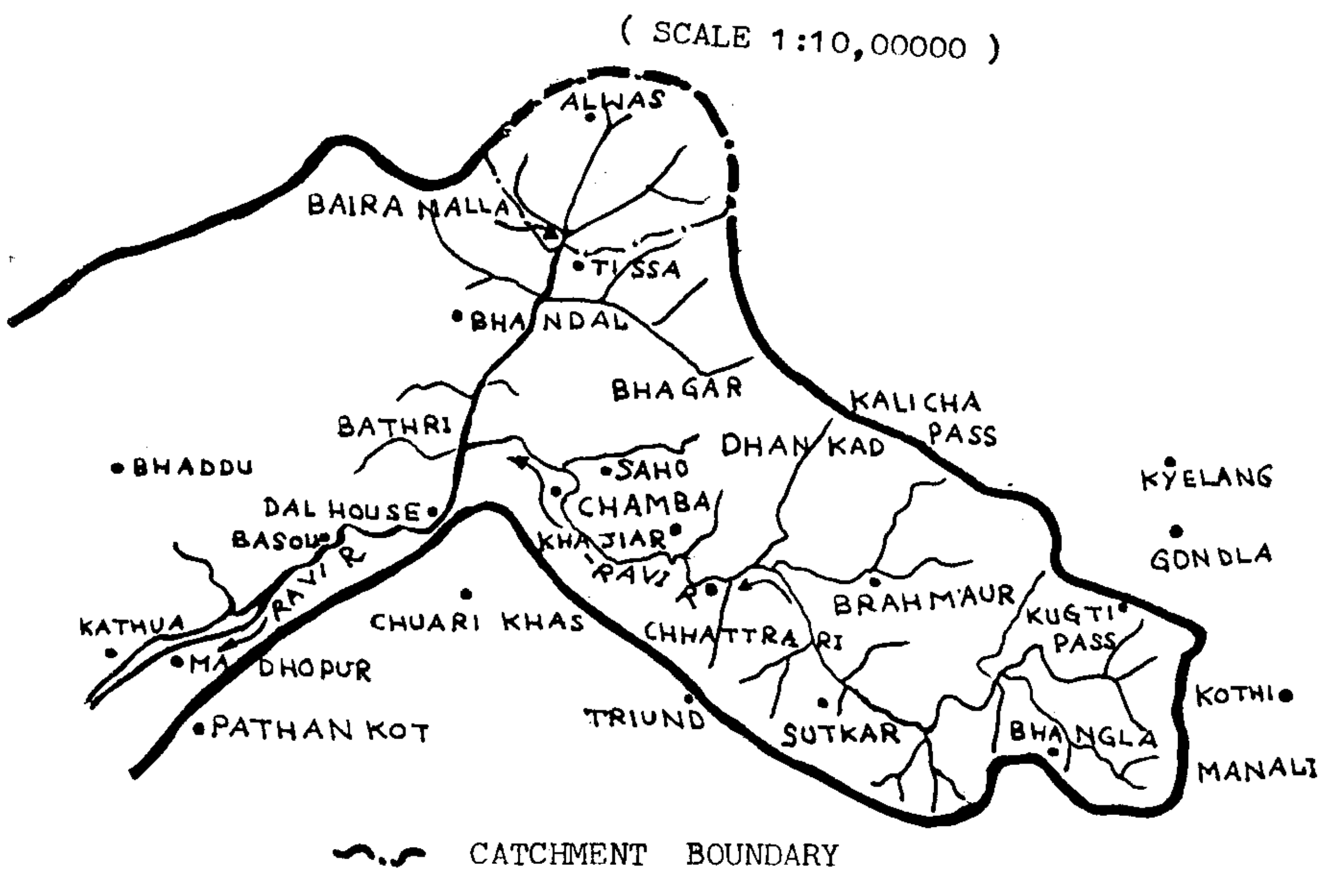


Fig. 1. RAVI BASIN SHOWING BAIRA CATCHMENT.

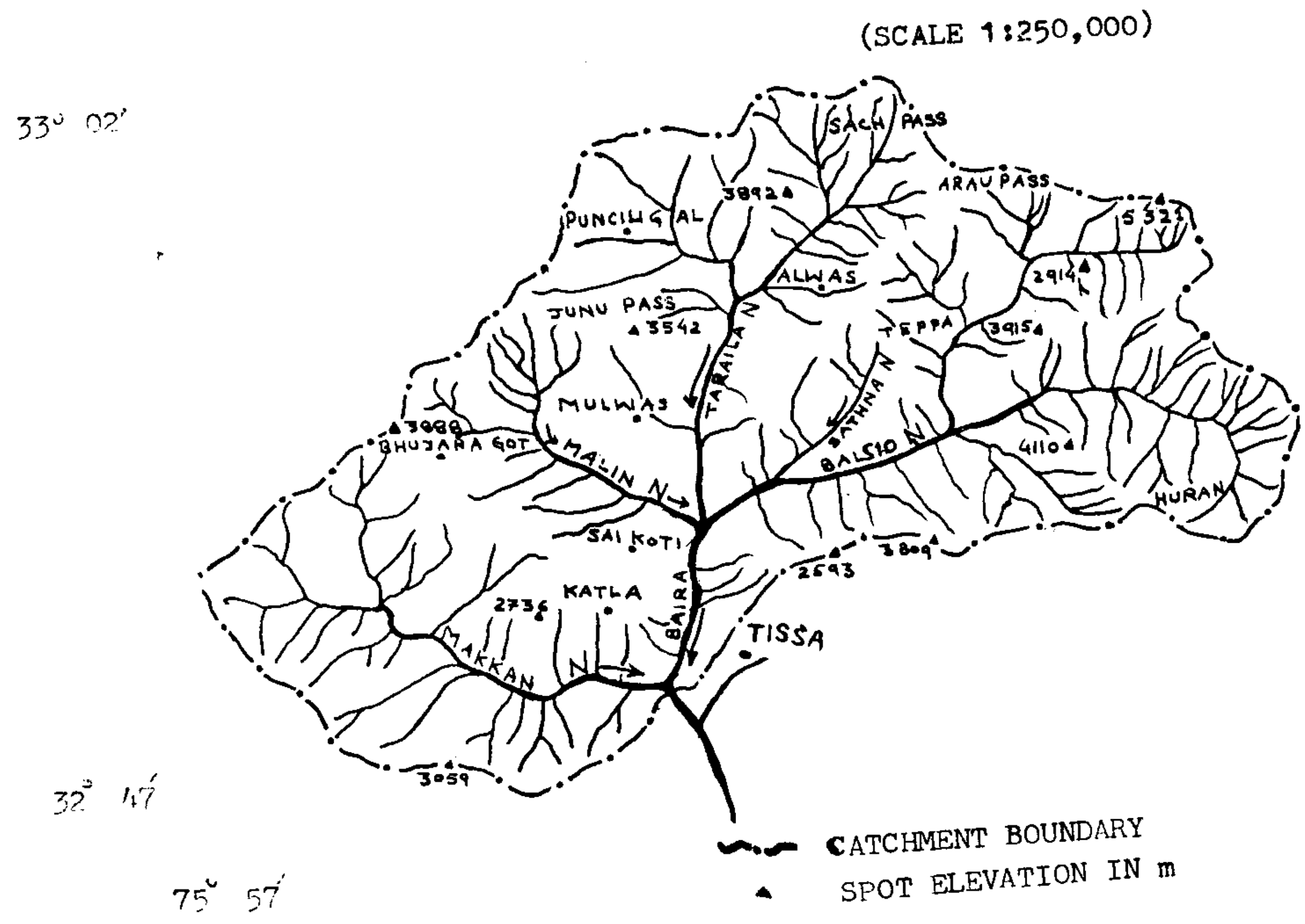


Fig 2. DRAINAGE MAP OF BAIRA CATCHMENT ABOVE TISSA (H.P)

5.0 DATA USED

The SOI toposheets (52D,52C,and 43P') on 1:250,000 scale were used to cover the entire Baira catchment. The imageries of Landsat and IRS satellites were used for snow cover mapping (Table-1). The band details of Landsat MSS and IRS-A satellites are given in Table-2.

Table-1 Details of Satellite Imageries used

S.No.	Satellite	Sensor	Date of pass	Path\Row	Product type.	Scale
1.	Landsat	MSS	13.02.1984	148\37	FCC(1,2,4)	1:1\4M
2.	Landsat	MSS	07.02.1985	148\37	FCC(1,2,4)	1:1\4M
3.	IRS-1A	LISS-1	11.02.1989	31\44	FCC(2,3,4)	1:1\4M
4.	IRS-1A	LISS-1	14.03.1990	31\44	FCC(2,3,4)	1:1\4M
5.	IRS-1A	LISS-1	31.03.1992	31\44	FCC(2,3,4)	1:1\4M

Table-2 Band details of Landsat MSS and IRS-1A satellites

Bands	Wavelength Range(Microns)		Resolution(m)	
	Landsat MSS	IRS-IA	Landsat MSS	IRS-IA
1.	0.5-0.6	0.45-0.52		
2.	0.6-0.7	0.52-0.59		
3.	0.7-0.8	0.62-0.68	80	72.5
4.	0.8-1.1	0.77-0.86		

6.0 METHODOLOGY

6.1 Basic understanding of Image Features:

Satellite remote sensing utilizes electromagnetic waves for the detection and identification of distant objects. Different objects reflect and emit differently the radiation reaching them. The reflectance and emittance of different objects are picked up by the sensor in specific spectral regions. The difference in the reflectance is a function of innumerable factors basically depending upon the material of the reflecting object and on its time and space scale. These differences in spectral radiances of each object become the basis of the identification and differentiation on a satellite image. The image elements provide clues to the analyst towards the detection and identification of objects through the use of information on the size, shape, texture, pattern and shadow of the object on the image.

6.2 Identification and Demarcation of Catchment

The Baira catchment was delineated and thereafter drainage map was traced from SOI topographical maps (52D,52C,and 43P) on 1 : 250,000 scale. Standard FCC paper prints were used for the snow cover mapping. The satellite imageries showing the catchment for different years are given in figures 3 to 6. The catchment was identified by superimposing the drainage map (Fig.2) on satellite imageries.

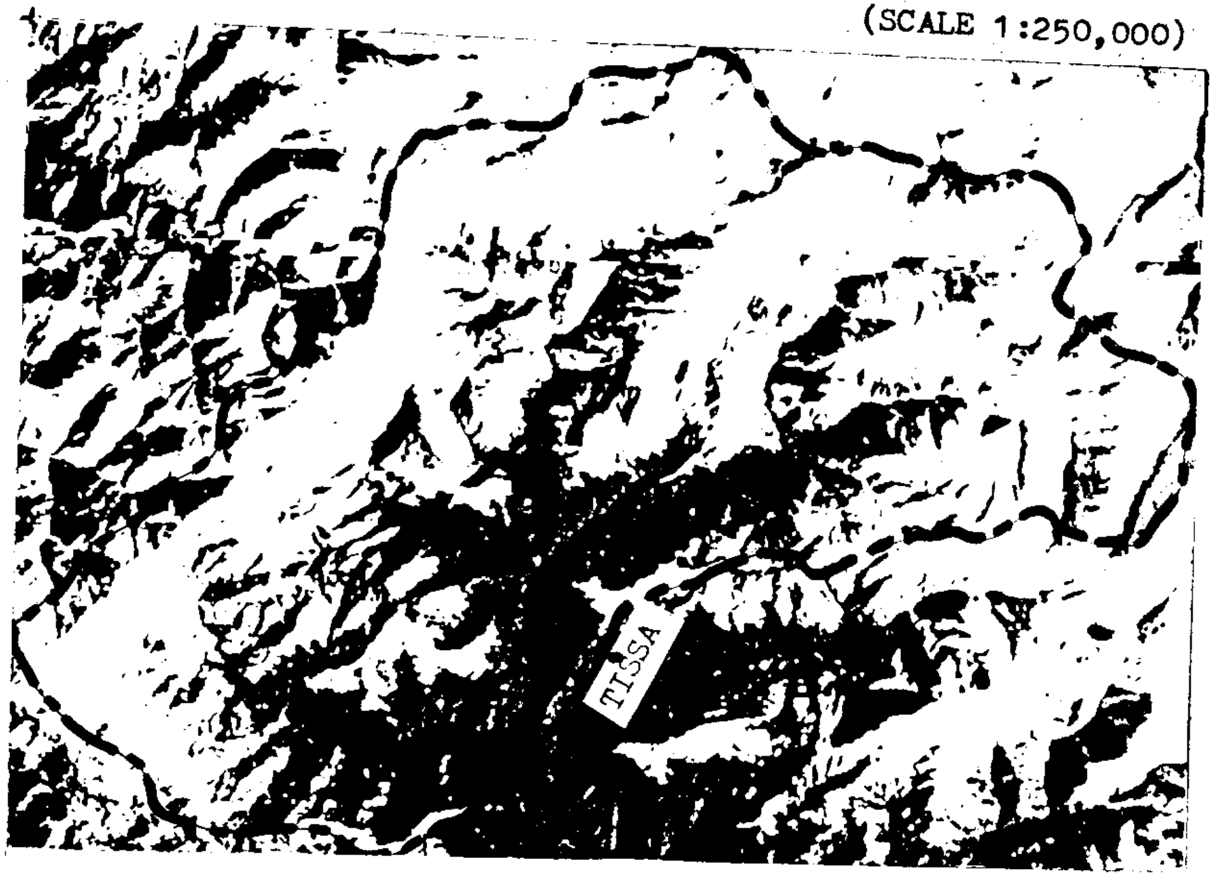


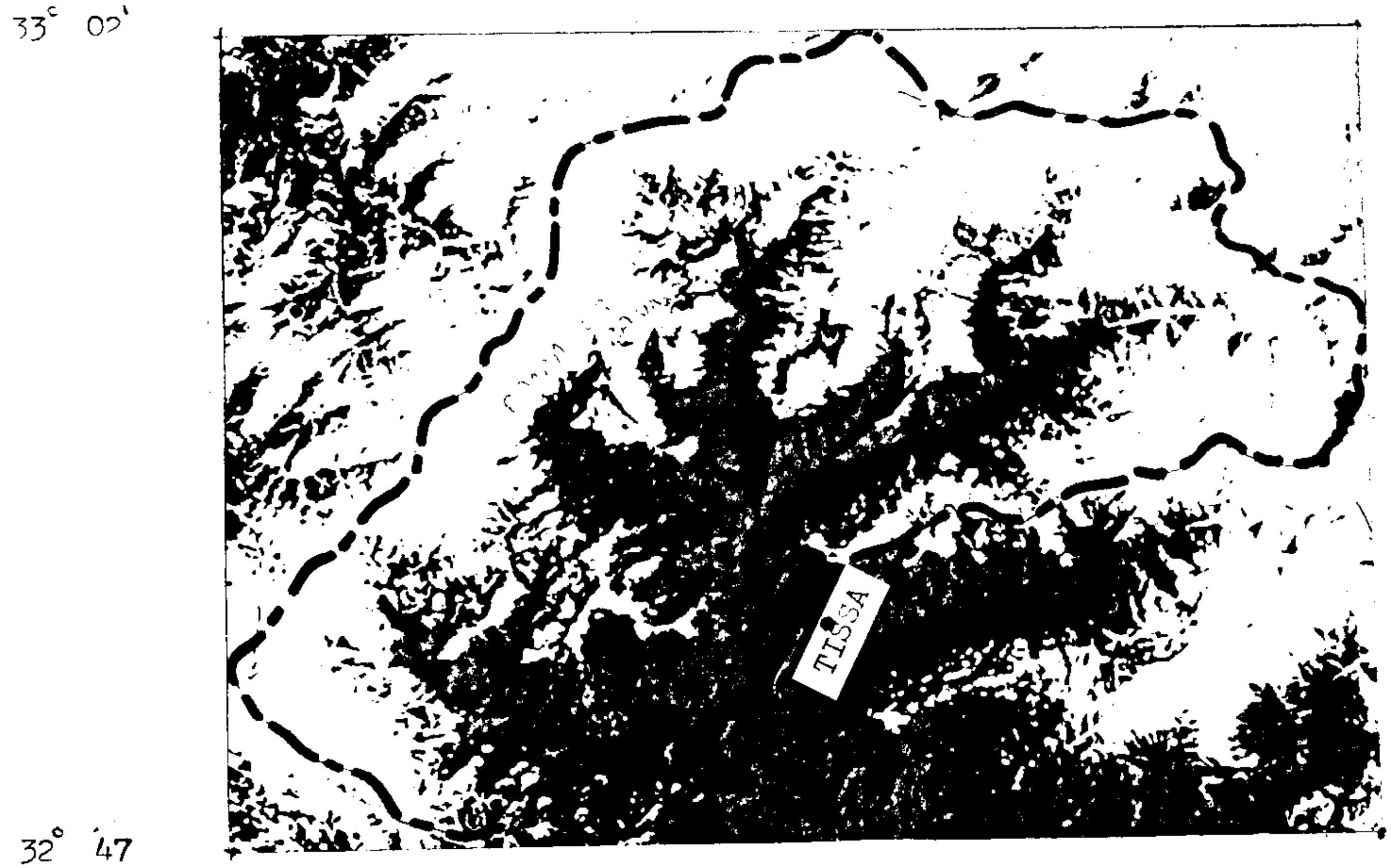
Fig. 3. LANDSAT MSS IMAGERY SHOWING BAIRA CATCHMENT ABOVE TISSA (HP) OF 13TH FEB. 1984.

(SCALE 1:250,000)

CATCHMENT BOUNDARY

Fig. 4. LANDSAT MSS IMAGERY SHOWING BAIRA CATCHMENT ABOVE TISSA (HP) OF 7TH FEB. 1985.

(SCALE 1:250,000)



CATCHMENT BOUNDARY

Fig. 5. IRS- IA IMAGERY SHOWING BAIRA CATCHMENT ABOVE TISSA (H.P) OF 14TH MARCH 1990.

(SCALE1 : 250,000)

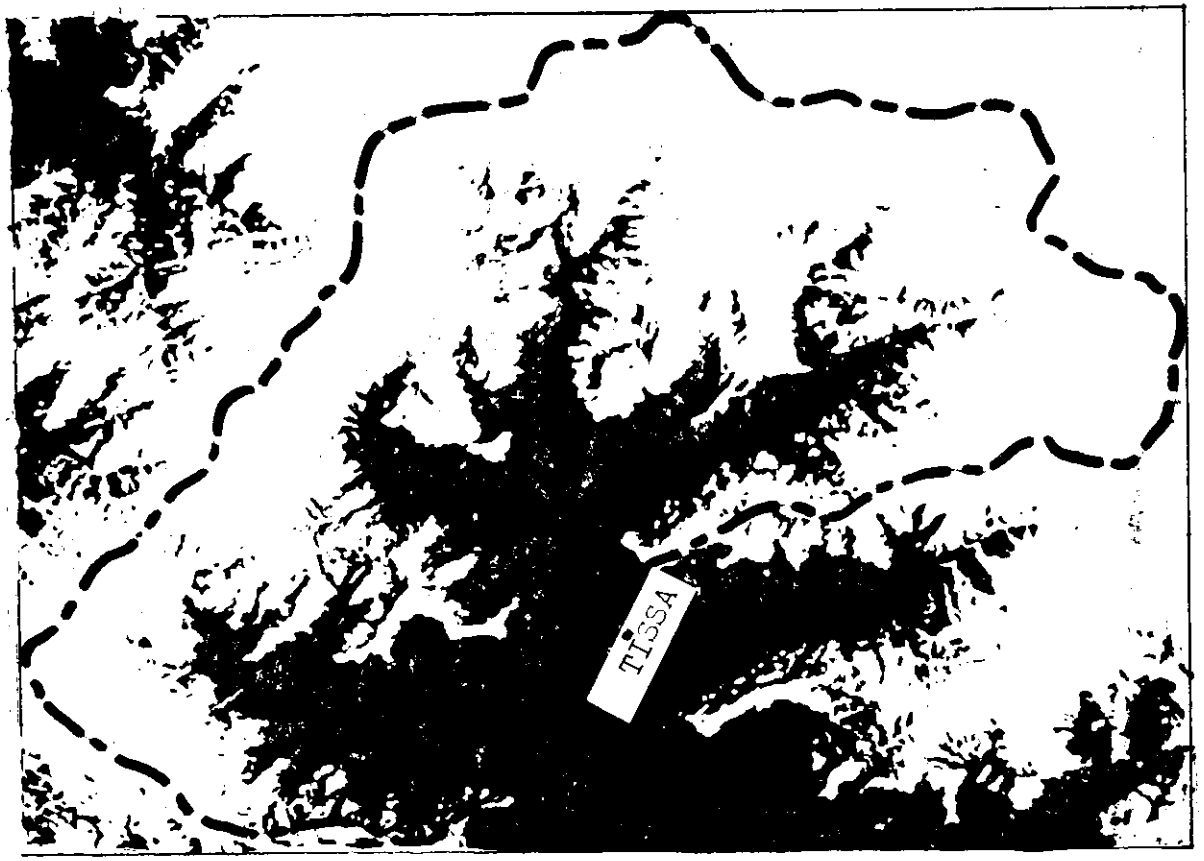


Fig. 6. IRS- IA IMAGERY SHOWING BAIRA CATCHMENT ABOVE TISSA (H.P) OF 31ST MARCH 1992.

6.3 Identification and Delineation of Snow:

Snow cover is a very distinct feature that can be detected readily from all kinds of remotely sensed data. There is a strong contrast between the snow and non snow areas due to its high albedo which facilitates easy delineation.

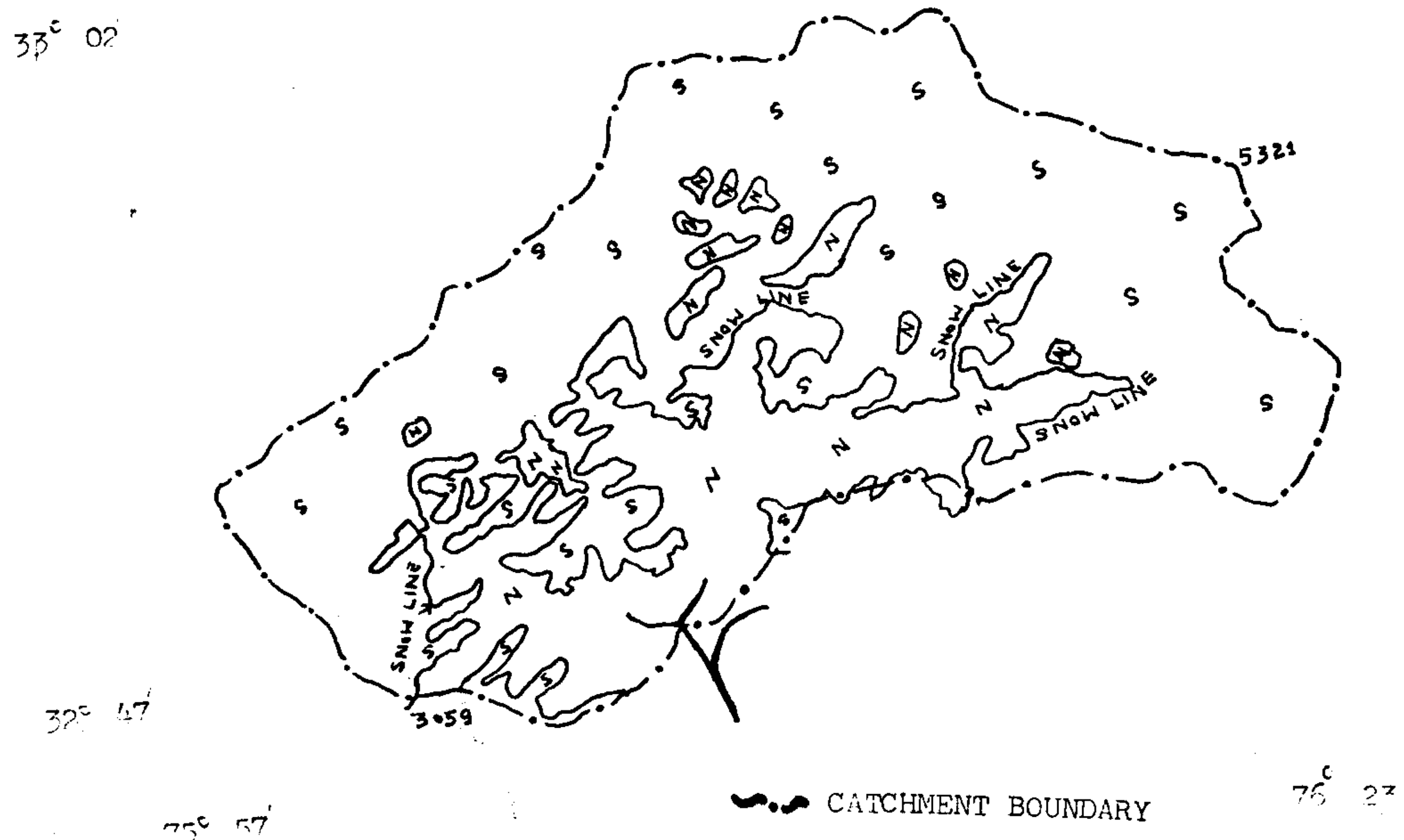
The interpretation of the snow line between snow covered and snow free areas in rugged mountains with pastures, forests, ice, rocks, and under different exposures like sun or shadow, slope or topography etc. require a great deal of care. The visual interpretation of snow bound area was performed for the years 1984, 1985, 1989, 1990 and 1992 based on the following criteria:

- Tonal aspect: Contrast between bright and dark colours of snow and snow free parts,
- Formal aspects: Size, form and edge characteristics of snow fields versus puffy cloud pattern or smaller, inhomogeneous surrounding features,
- Local aspects: Colour and brightness in shadows, the discontinuity of the shadow line because of steep rocks, melting conditions etc.

6.4 Measurement of Snow covered Area:

The snow covered area (SCA) and catchment area was measured using Digital planimeter. Percentage snow covered area of total catchment area was calculated for different years under study. The snow cover maps for different years are given in Fig.7 to 11. The results obtained using visual interpretation are discussed in the following sections.

(SCALE 1:250,000)



CATCHMENT BOUNDARY

N,S NON SNOW, SNOW

Fig. 7. SNOW COVERED AREA OF BAIRA CATCHMENT ABOVE TISSA (H.P) USING LANDSAT / MSS, FCC OF 13TH FEB. 1984.

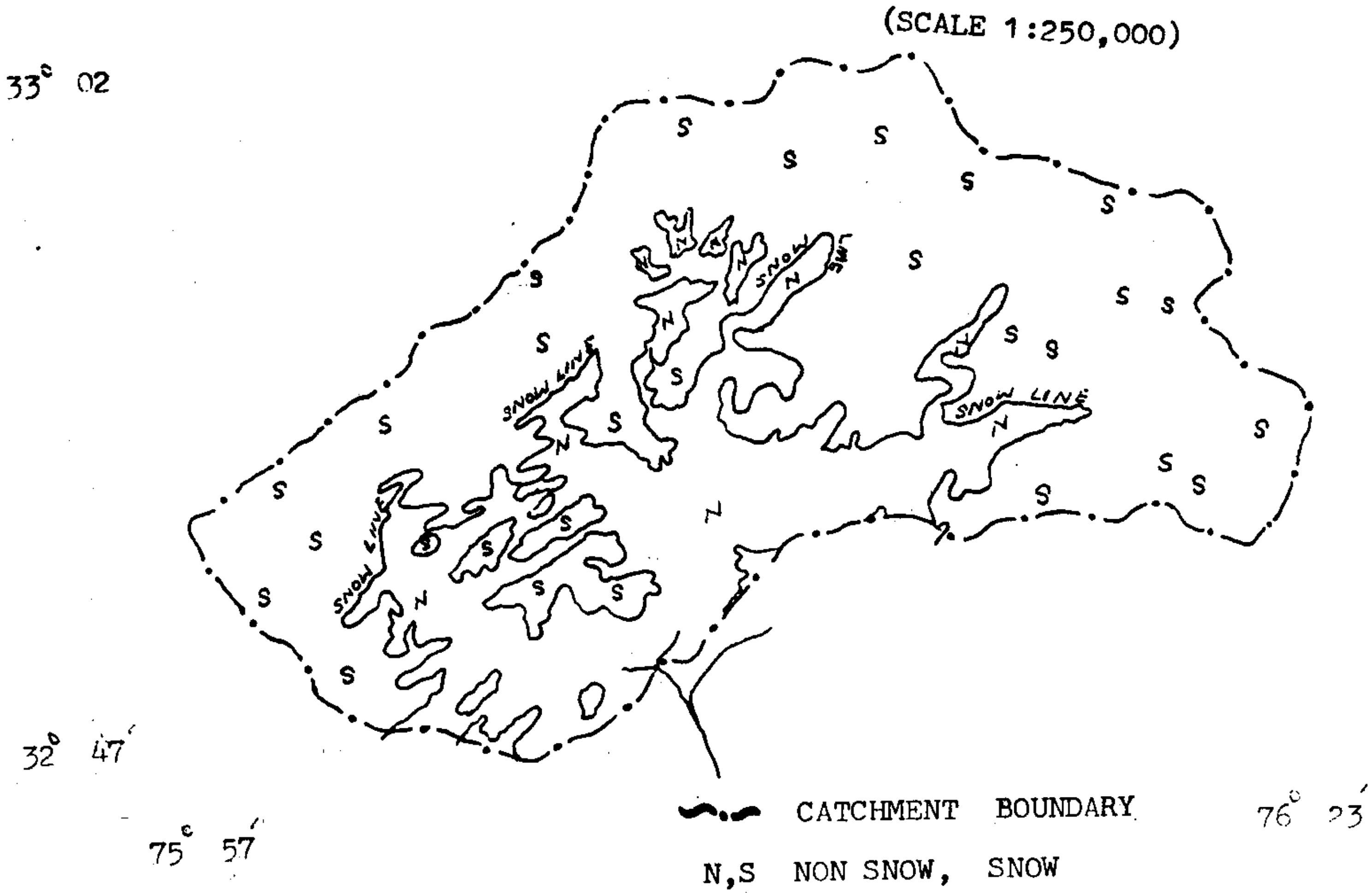


Fig. 8. SNOW COVERED AREA OF BAIRA CATCHMENT ABOVE TISSA (H.P) USING LANDSAT / MSS, FCC OF 7TH FEB, 1985.

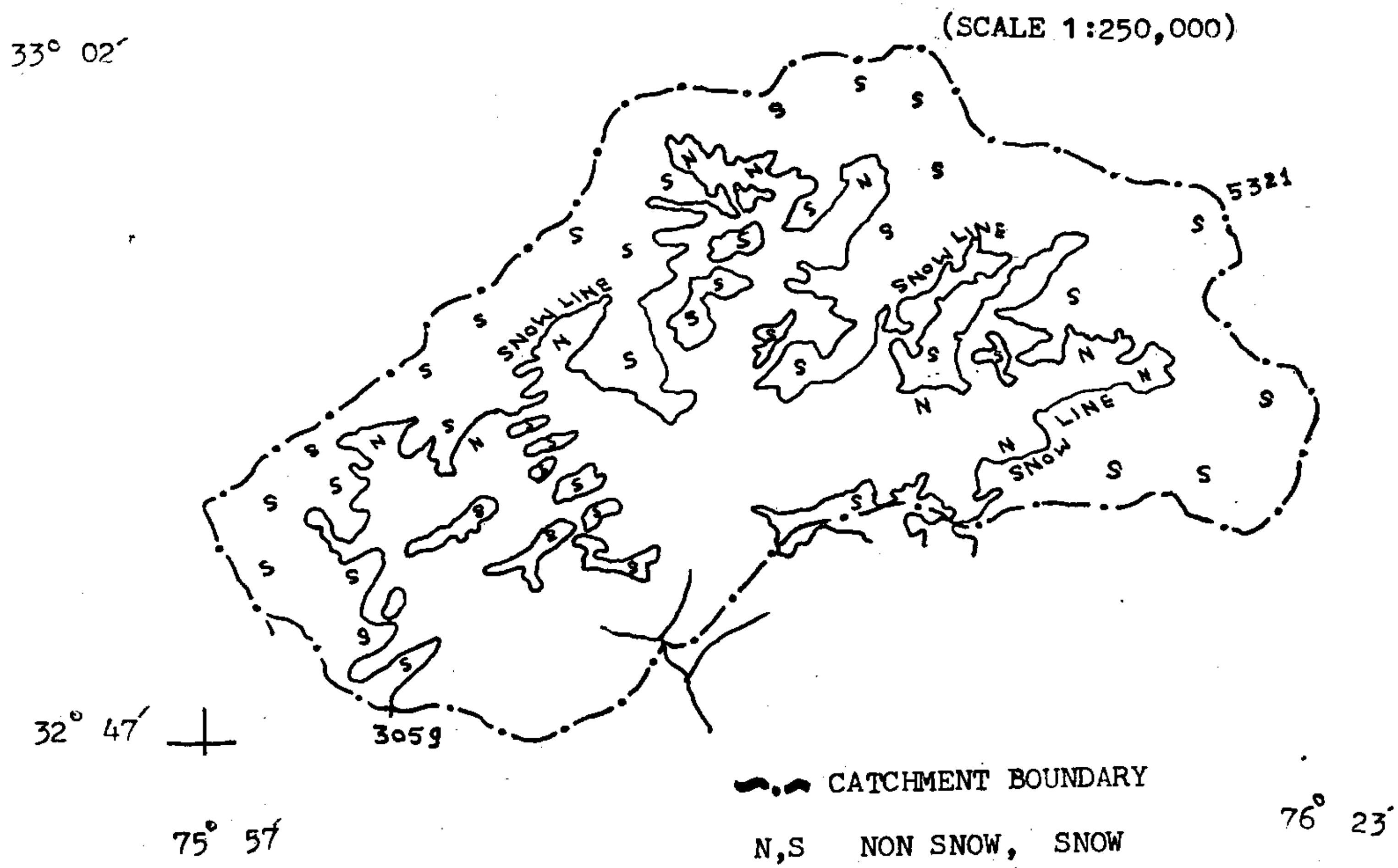


Fig. 9. SNOW COVERED AREA OF BAIRA CATCHMENT ABOVE TISSA (H.P) USING IRS/LISS-1, FCC OF 11TH FEB. 1989.

(SCALE 1:250,000)

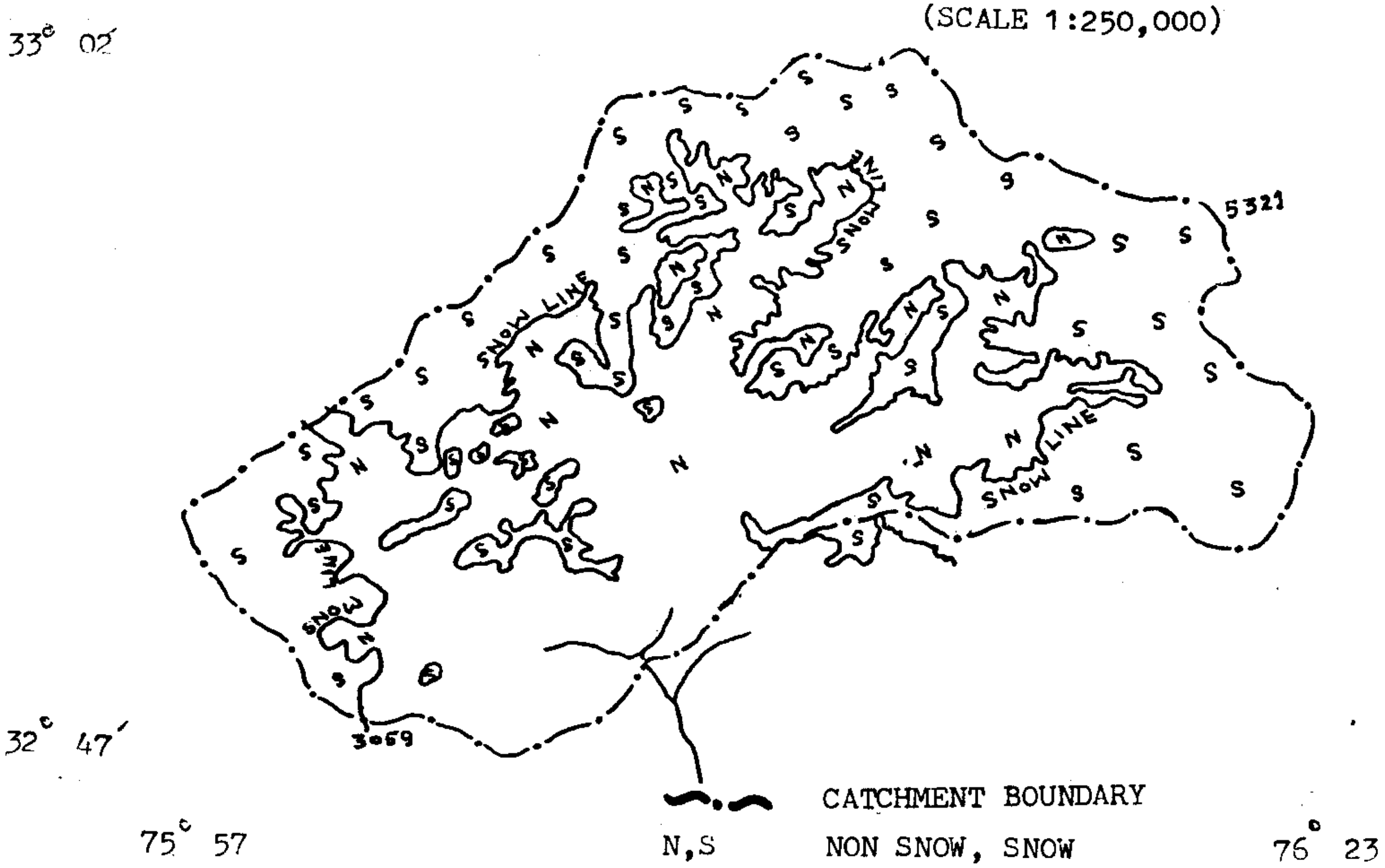


Fig.10. SNOW COVERED AREA OF BAIRA CATCHMENT ABOVE TISSA (H.P) USING IRS/ LISS-1, FCC OF 14TH MARCH, 1990.

(SCALE 1:250,000)

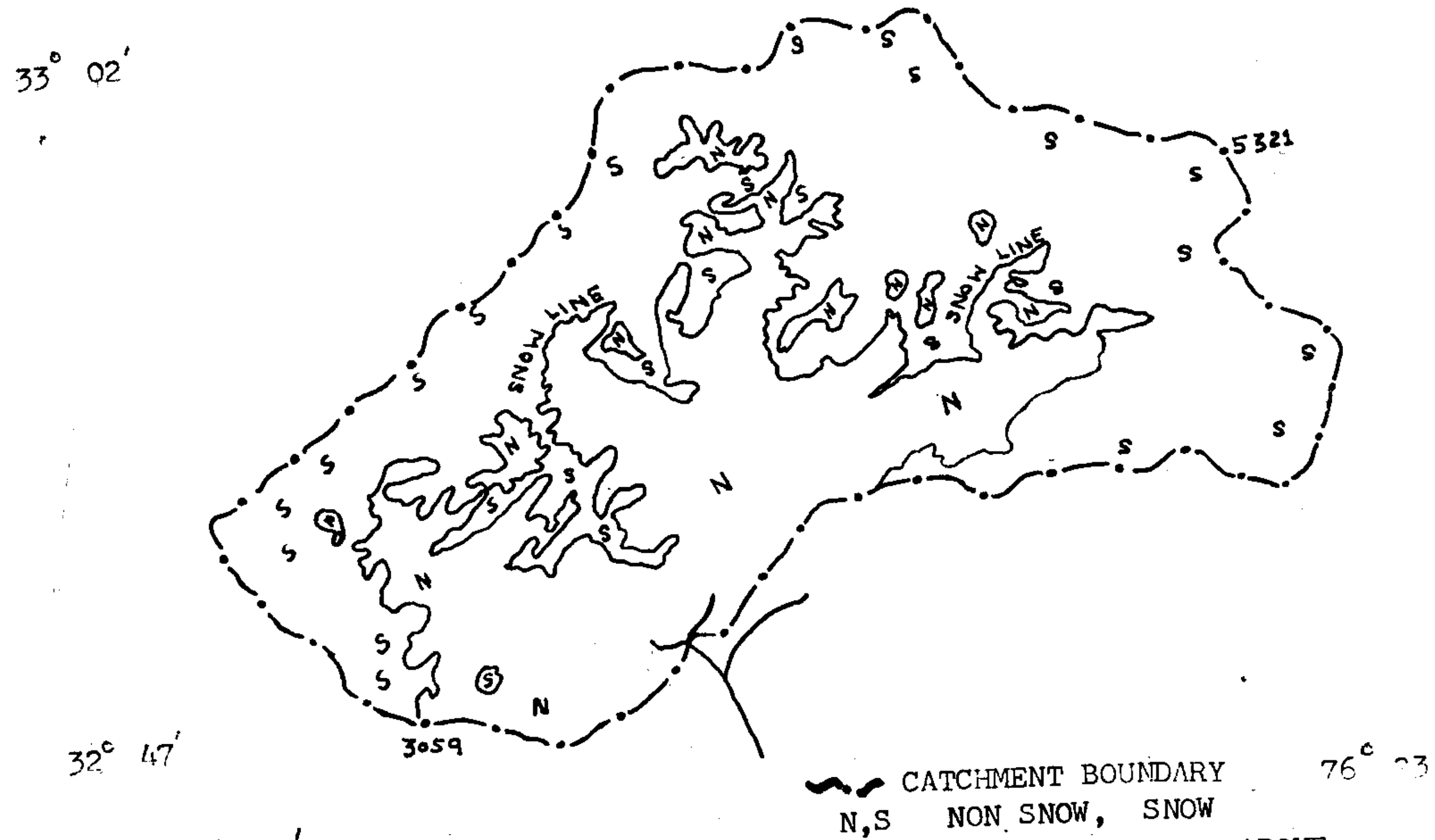


Fig. 11. SNOW COVERED AREA OF BAIRA CATCHMENT ABOVE TISSA (H.P) USING IRS/ LISS-1, FCC OF 31 ST MARCH, 1992

7.0 RESULTS

For the present study Landsat MSS and IRS-IA LISS-I data were used keeping in view the cost effectiveness. Moreover, NOAA\AVHRR data are cheaper because it has about 19 times more swath width of coverage than IRS-1A/LANDSAT. However, NOAA data were not used for visual interpretation due to its coarser resolution.It was found that the Landsat MSS imageries had higher contrast than IRS LISS-I imageries. It may be because there is relatively less band\sensor saturation in landsat MSS than IRS.

Comparative studies showed that there were relatively more geometric distortions in Landsat MSS than IRS imageries. These distortions are relatively sensor dependent.In Landsat MSS optomechanical devices are used and in IRS, charged couple devices (CCD) are used. Identification of the catchment was difficult on Landsat imageries due to these distortions. This was eleminated by superimposing the drainage map on satellite imageries. Percentage snow covered area of total catchment area for different dates\years (13th Feb 1984, 7th Feb 1985, 11th Feb 1989, 14th March 1990, and 31st March 1992) was calculated . The results are given in Table-3.

The results obtained in this study were plotted in the form of bar chart. Fig.12 shows the variation of percentage snow covered area during different years for Baira catchment . It is evident from Table-3 and Fig.12 that the maximum snow covered area was 70.22% and minimum 52.04 in the years 1984 & 1990

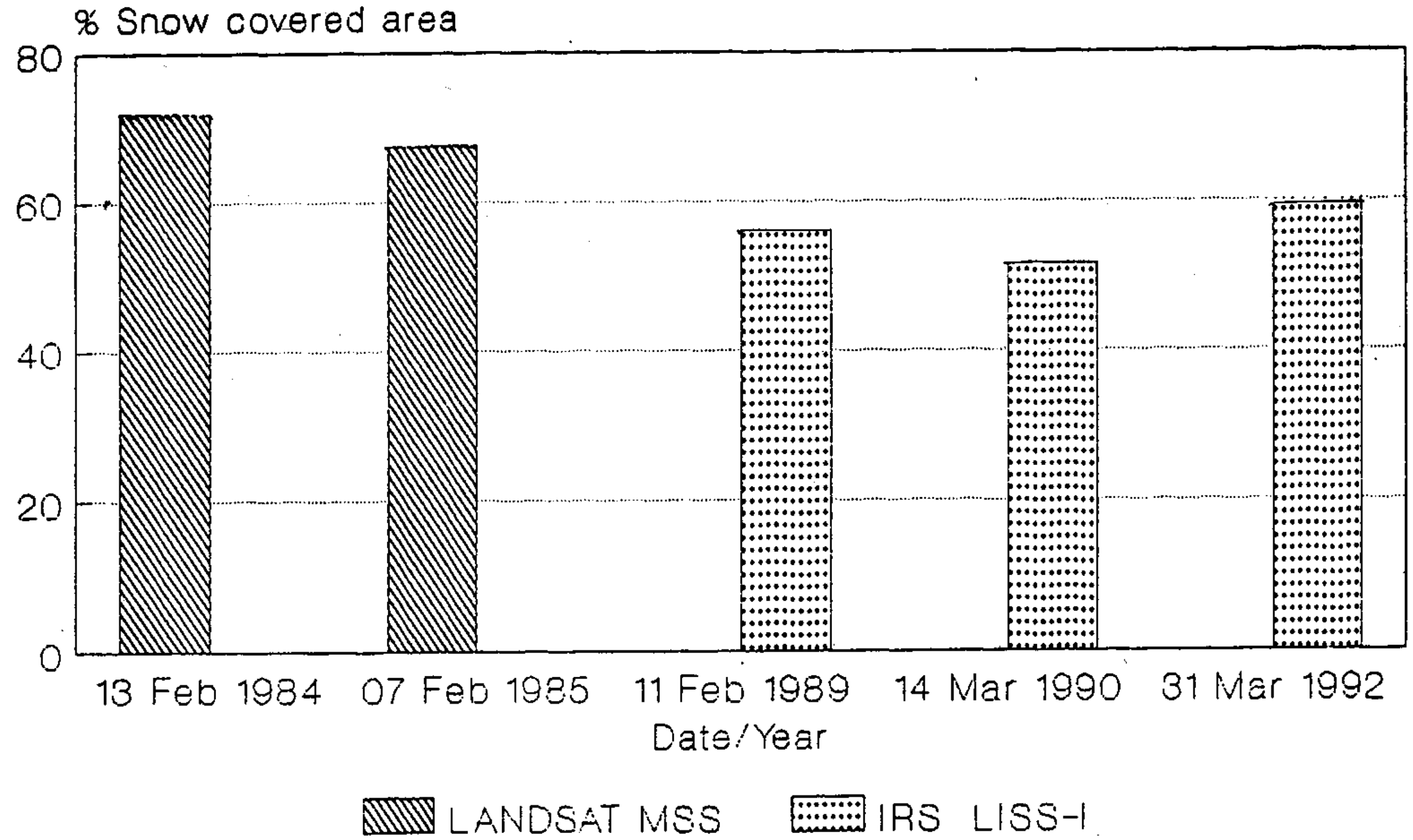


Fig. 12. VARIATION OF PERCENTAGE SCA DURING DIFFERENT YEARS IN BAIRA CATCHMENT ABOVE TISSA (H.P)

respectively in the five years of this study.It may also be concluded that the snow covered area varies year to year.It varied by about 106 sq km (18.2% of catchment area) from 1984 to 1990.The peak accumulation of snow occured some times during late March . However,for exact clarification of peak snow cover the data should be taken for both accumulation and depletion periods.

Table 3 Variation of snow covered area (SCA)

Date\ Year	Satellite\ sensor	SCA (Sq.km.)	Percent of SCA of total catchment area
13.2.1984	Landsat\MSS	410.69	70.22
17.2.1985	Landsat\MSS	395.80	67.67
11.2.1989	IRS-A\L1	329.44	56.33
14.3.1990	IRS-A\L1	304.37	52.04
31.3.1992	IRS-A\L1	350.00	59.84

It may be emphasized that percentage snow covered area (SCA) is an essential input to predict the seasonal snow melt runoff in various models. Therefore,the results of this study could be utilize to predict snow melt runoff for the catchment.

7.1 Comments on Visual and Digital Interpretation Techniques.

In the present study visual interpretation technique was adopted because the basin area was relatively smaller and analysis was cost effective. Accordingly FCC prints were used. It became difficult to map small snow patches and snow under hill shadow visually. Therefore,patches smaller than 3mm size were not taken in to account.

Snow mapping of relatively large areas and where the analysis is to be done in almost real time,the machine aided interpetation technique(Digital) should be used.However,the initial investment to establish the necessary digital analysis system and software is comparatively more. Therefore, both visual and digital methods are used keeping in mind their various advantages and disadvantages.

8. CONCLUSIONS

Based on the study the following conclusions could be drawn:

1. The percentage snow covered area varies year to year. The maximum and minimum snow covered area was 70.22% and 52.04% in the years 1984 and 1990 respectively.

2. The visual interpretation is best suited for smaller basins. However, it was difficult to map patchey snow cover, snow under hill shadows etc.

3. Landsat MSS imageries had relatively a better contrast among its features than IRS LISS-I imageries.

4. To monitor peak snow accumulation period using remote sensing techniques, it is recommended to use data for both accumulation and depletion periods.

5. The areal extent of the snow cover can be measured easily using the satellite imageries due to its high albedo.

6. Landsat TM 5 (1.55-1.75 micron meter) and TM 7 (2.0-2.35 micron meter) bands can be used for snow /cloud differentiation.

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