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GEOMORPHOLOGY AND SOIL EROSION IN JUNI NADI WATERSHED, DISTRICT UDHAMPUR, J&K

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Geomorphology and Soil Erosion in Juni Nadi Watershed, District Udhampur, J&K

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PREFACE

The geomorphological properties of watershed are generally referred to the watershed composition, which represents the topological and geometrical properties of the watershed. The linear, areal, and relief aspects of the watershed are some of the important parameters and a quantitative analysis of these parameters are important in characterisation of watershed. Geomorphological parameters of a ungauged watershed are also useful in synthesizing and understanding its hydrological behavior.

Fastly deteriorating condition of the geodynamically active Himalayan terrain has been an increasing cause of concern to environmentalists and water resource planners. Pressure of human and animal populations on the scarce land resources in the Himalaya have considerably accelerated the soil erosion. The situation is further aggravated by improper practices and faulty management of lands. Information related to soil loss of the Siwalik Hills is very important from the point of view of soil conservation, management and agricultural productivity. The soils of this region are highly eroded and consequences of this erosional process are degradation of the good forest and agricultural land in the watersheds of Siwalik Hills. Reliable soil loss estimation is a valuable design, extension and planning tool. It is useful to formulate watershed management strategies to reduce soil loss to specified acceptable levels.

In this study, estimation of geomorphological parameters and soil loss in the Juni Nadi watershed, near Katra, has been carried out. The soil loss has been estimated using well known Universal Soil Loss Equation (USLE) and GIS techniques. The results of geomorphological and soil loss studies of Juni Nadi watershed will be helpful to planners in developing soil conservation strategies.

Dr. K.S. Ramasastri
Director

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ABSTRACT

The advanced knowledge of geomorphology of the region is import in the field of flood control measures and engineering projects, since geomorphological characteristics of river basin, particularly in mountainous areas, affect the runoff process and occurrence of flood in these areas. Various geomorphological parameters, which have mostly been used by various investigators, can be broadly classified as those describing linear aspects of the channel system; areal aspects of the channel system; and relief aspects of the watershed. In this study the above mentioned aspects of the Juni Nadi watershed have been evaluated. The study may be useful in finding out the role of geomorphology on watershed runoff response and in identifying the parameters which are more closely related to runoff.

Soil erosion is of great concern to humanity as it effects food production through land degradation; limits the supply of hydro-electric power through siltation of reservoirs; and cause catastrophic floods damaging huge area of low lying fields and human settlement. In the present study, Universal Soil Loss Equation (USLE) has been used for estimation of soil loss in a small watershed of area 52.37 sq.km. Various parameters of USLE were determined with the help of remotely sensed data and Geographical Information System (GIS). The study reveals that most of the study area falls under low (<4.5 t/ha/yr) and moderate (4.5 to 11.2 t/ha/yr) class of soil loss. About one third area of the watershed comes under the high (11.2 to 25 t/ha/yr) and very high (>25 t/ha/yr) category.

Chapter 1

INTRODUCTION

The geomorphologic characteristics which relate to hydrology consist of linear aspect of stream system dealing with one dimensional overland flow lengths and length of the stream, etc.; areal aspect of the watershed relating to watershed shape, drainage, texture, etc.; and relief aspect of stream network/catchment describing elevation difference, etc. The first two categories of measurement are planimetric (i.e. treat properties projected upon a hydrological datum plane) and the third category treats the vertical inequalities of the watershed from watershed outlet to the highest point. In absence of adequate data, especially in ungauged basins, the measurable geomorphological properties can be applied to synthesize the runoff response of a basin. Some of the studies where quantitative geomorphological characteristics are used to describe hydrological properties are as follows:

- Regional unit hydrograph studies
- Regional flood frequency analysis
- Development of Geomorphological Instantaneous Unit Hydrograph
- Hydrological modeling studies (Rainfall-runoff and soil loss)

Estimates of soil erosion are needed for studies of reservoir sedimentation, river morphology, soil and water conservation planning, water quality modelling and design of efficient erosion control structures. It is estimated that out of the total geographical area of 329 Mha of India, about 167 Mha is affected by serious water and wind erosion. This includes 127 Mha affected by soil erosion and 40 Mha dergaded through gully and ravines, shifting cultivation, waterlogging, salinity and alkalinity, shifting of river courses and desertification (Das, 1977). An average soil erosion rate of 16.35 tons/ha/yr was reported by Dhruvanarayana and RamBabu (1983) for the country.

The geodynamically active Himalayan terrain is being denuded at a rate varying from 0.09 to 1.7 mm/yr (Valdiya and Bartarya, 1989). Pressure of human and animal populations on the scarce land resources in the Himalaya have considerably intensified the soil erosion. The situation is further aggravated by improper practices and faulty management of lands. The steep slopes in the Himalayas along with depleted forest cover, as well as high seismicity have been major factors in soil erosion and sedimentation in river reaches (Varshney et al., 1986). The Himalayan and Tibetan region covers only about 5% of the Earth's surface but supply about 25% of the dissolved load to the world oceans (Raymo and Ruddiman, 1992). A large scale deforestaion that occurred in the Siwalik terrain of Himalayas exposed the soil on the land surface directly to the rains, during the 1960s. This unprotected soil cover was readily removed from the land surface in the fragile Siwalik terrain by combined action of rain and resulting flow (Kothyari, 1996). Soil erosion rate in the Northern Himalayan region is of the order of 20 to 25 t/ha/yr (Garde and Kothyari, 1987). Rao et al. (1997) have reported a sediment yield from Chenab basin at Akhnoor as 10 t/ha/yr. Jain et al. (2001) have estimated soil loss of a Himalayan watershed using USLE and Morgan models. Results of both the models show that soil loss from forested area is less compared to unprotected area like fallow lands.

The present study has been done to determine the various geomorphological characteristics of Juni Nadi watershed in GIS environment with the help of established laws and procedures and using Survey of India (SOI) toposheet of scale 1:50,000. In absence of existing stream gauging sites in the area, the geomorphological parameters derived for the watershed may be used for further hydrological studies. To study and combat erosion effectively, however, extensive information on erosion status and erosion conditions is needed. This information can to a large extent be derived from satellite data (Sridhar & Muralikrishna, 1994). Soil erosion of Juni Nadi watershed is estimated using Universal Soil Loss Equation (USLE).

Chapter 2

METHODOLOGY

2.1 Morphometric Characteristics

The methodology used to study the various parameters of linear, areal and relief aspects for the Juni Nadi watershed is described below:

2.1.1 Linear aspects of the watershed

Linear aspect of the watershed characteristics include overland flow lengths of the streams of all orders. Usefulness of ordering stream system lies in the hypothesis that watershed size, stream dimensions, and stream flows are proportional to the stream orders provided investigation is made for quite large number of watersheds. Varoius parameters (Table 2.1) under linear aspect of stream system were calculated directly or indirectly using the Vector-Network module of ILWIS 1.2 GIS. The details of different parameters of linear aspects are mentioned in earlier NIH reports (Singh, 1990-91; Patwari and Kumar 1992-93 and 1993-94; Jain, 1993-94, Sreenivaslu et al., 1998-99).

2.1.2 Areal aspects of the watershed

Areal measure of a watershed relates to many of its hydrologic characteristics. The various parameters (Table 2.2) of areal aspect of the watershed, as defined by various workers, were studied using the ILWIS GIS.

2.1.3 Relief aspects of the watershed

Relief morphometry of river basin describes variation of elevation between the highest and the lowest point. This is significant in studying the flow phenomena in the watershed. The potential energy of flowing water from high altitude gets converted to kinetic energy, which is related to slope. Various losses of water like storage, infiltration, evaporation etc. and travel times are inversely related to slope. The various relief parameters (Table 2.3) defined by different workers are estimated by creating DEM and slope map of the basin.

Table 2.1: Watershed Linear Parameters

S.No	Parameters	Symbol	Definition
1	Basin Perimeter	Lp	Length measured along the basin boundary
2.	Length of main stream	L	Length measured along the longest watercourse from the outlet point to upper limit to the basin boundary.
3	Length of Stream between the outlet and a point near to centre of gravity (Snyder, 1938)	Lc	Length of stream measured from the outlet of the basin to a point on the stream nearest to centroid of the basin.
4	Basin length or Valley length	Lb	Straight line distance between outlet of the basin and the furthest point on the ridge
5	Stream length of each order	L1	Total length of streams of first order.
		L2	Total length of streams of second order
		L3	Total length of streams of third order
		L4	Total length of streams of fourth order
		L5	Total length of streams of fifth order
6	Total stream length of all orders	Lw	L1+L2+L3+L4+L5
7	Mean stream length of each order	$\bar{L}1$	L1/N1
		$\bar{L}2$	L2/N2
		$\bar{L}3$	L3/N3
		$\bar{L}4$	L4/N4
		$\bar{L}5$	L5/N5
8	Number of streams of each order	N1	Total number of streams of first order.
		N2	Total number of streams of second order
		N3	Total number of streams of third order
		N4	Total number of streams of fourth order
		N5	Total number of streams of fifth order
9	Total number of streams of all order	Nw	N1+N2+N3+N4+N5
10	Wandering ratio (Smart and Surkan, 1967)	Rw	Mainstream length / Basin length.
11	Fineness ratio (Melton, 1957)	Rf	Stream lengths / length of the basin perimeter
12	Basin Eccentricity (Black, 1972)	τ	$[(Lc^2-W_L^2)]^{1/2} / W_L$,W_L =width if the basin at the center of mass and perpendicular to Lc.
13	Bifurcation ratio (Horton, 1945)	Rb	Ratio of number stream of lower order w to the number streams of order w + 1.
14	Stream-length ratio (Horton, 1945)	Rl	Ratio of mean stream segment length of order w to mean stream segment length of order w - 1.
15	Length of overland flow (Horton, 1945)	Lo	Half the reciprocal of drainage density.

Table 2.2: Watershed Areal Parameters

S.No.	Parameters	Symbol	Definition
1	Total Drainage Area	A	Basin area
2.	Drainage Denisty	D	Total length of all streams / Basin area.
3	Constant of Stream Maintenance (Schumm, 1956)	C	Inverse of drainage density
4	Stream-Segment Frequency (Horton, 1945)	F	Number of streams segments per unit basin area
5	Drainage area of each order	A1	Total drainage area of first order.
		A2	Total drainage area of second order.
		A3	Total drainage area of third order.
		A4	Total drainage area of fourth order.
		A5	Total drainage area of fifth order.
6	Average drainage area of each order	$\bar{A}1$	Total drainage area of first order / Total number of streams of first order
		$\bar{A}2$	Total drainage area of second order / Total number of streams of second order
		$\bar{A}3$	Total drainage area of third order / Total number of streams of third order
		$\bar{A}4$	Total drainage area of fourth order / Total number of streams of fourth order
		$\bar{A}5$	Total drainage area of fifth order / Total number of streams of fifth order
7	Area Ratio (Schumm, 1954)	Ar	Ratio of mean drainage area of basin of order w to mean drainage area of basin of order w - 1.
8	Circularity Ratio (Miller, 1953)	Rc	Basin area / Area of circle having circumference equal to the basin perimeter.
9	Elongation Ratio (Schumn, 1956)	Re	Diameter of a circle having the same area as the basin / Basin length.
10	Basin Shape Factor (Wu et al., 1964)	Rs	Main stream length / Diameter of a circle having the same area as the basin.
11	Unit Shape Factor (Smart and Surkan, 1967)	Ru	Basin length / (Basin area)$^{1/2}$
12	Form Factor (Horton, 1932)	Rf	Basin area / (Basin length)^2
13	Compactness coefficient (Strahler, 1964)	Cc	Basin perimeter / Perimeter of the circle having the same as basin area.

Table 2.3: Watershed Relief Parameters

S.No.	Parameters	Symbol	Definition
1	Basin Relief (Schumm, 1956)	H	Altitude difference between highest point and outlet in the basin.
2.	Relief Ratio (Schumm, 1956)	Rh	Basin relief / Distance between the highest point and outlet in the basin.
3	Relative relief (Melton, 1957)	Rp	Basin relief / Basin perimeter.
4	Ruggedness Number (Melton, 1957; Strahler, 1958)	Rn	Product of the Basin relief and drainage density.

The primary source of information for geomorphological parameters (i.e. linear, areal, and relief aspects) was Survey of India toposheet No. 43 L/13.

2.2 Soil Erosion using USLE

The Universal Soil Loss Equation (USLE), in its original and modified forms, is the most widely used model to estimate soil loss from agricultural watersheds (Rao et al. 1994). Rainfall distribution, soil characteristics, topographic parameters, vegetative cover and information on conservation support (erosion control) practice, from which various parameters of USLE can be derived, are often available in the form of maps or can be mapped through collection of data from possible sources. Due to geographic nature of these factors, USLE can easily be modeled into GIS (Jain, 1994-95).

The USLE is an erosion model design to predict the long term average soil lossess from a specified land in a specified cropping and management system. Wishmeier and Smith (1965) developed this model and revised with more recent data in 1978. USLE predicts the long time average soil losses from a specified land in a specified cropping and management system on the basis of six parameters, as given below

$$A = R*K*L*S*C*P \quad (2.1)$$

Where,

A = average annual soil loss (tonnes/ha/yr)

R = rainfall erosivity factor,

K = soil erodibility factor,

L = slope length factor,

S = slope steepness factor,

C = land cover and management factor and

P = support practice factor

L, S, C, P are all dimensionless coefficients.

2.2.1 Rainfall erosivity index

The erosivity of a rainfall storm is a function of its intensity and duration, and the mass, diameter and velocity of raindrop. Wishmeier (1959) found that one hundredth of the products of the kinetic energy of the storm (KE) and the 30 minutes intensity (I_{30}) is the most reliable single estimate of rainfall erosion potential and was termed as EI_{30}. Annual total of storm EI_{30} value is referred to as the rainfall erosion –index. The location value of this index is the rainfall factor, R in the USLE.

In India, EI_{30} values are computed using the data of 45 rainfall stations located in different zones, and simple linear relationship between erosivity index and annual/ seasonal (June to September) rainfall has been developed (Singh et al., 1981).

$$Ra = 79 + 0.363*X \ (r= 0.83) \quad (2.2)$$

$$Rs= 50 + 0.389*X \ (r=0.88) \quad (2.3)$$

Where, Ra = Annual Erosivity Index

Rs = Seasonal Erosovity Index

X= Average Annual/Seasonal Rainfall (in mm)

2.2.2 Soil erodibility factor

The soil erodibility factor in the USLE relates to the rate at which different soils erode. It is the quantitative measures of the inherent erodibility of a particular soil. The soil erodibility factor was originally determined quantitatively from the runoff plots but Wishmeier and Mannering (1969) developed the methods for determination of K factor on the basis of soil properties. K is a function of the percentage of silt, and coarse sand, soil structure, permeability and percentage of organic matter of soil.

In India, K value (Table 2.4) has been determined from runoff plots at varios stations covering different types of soil type (Singh et al., 1981). Soil map of Jammu and Kashmir prepared by NBSS and LUP, Delhi Centre is used to determine the soil group of the study area.

Table 2.4. Soil erodibility factor, K, for various Research Stations in India

Station	Soil	Computed K (t/ha/yr)
Agra	Loamy sand, alluvial	0.07
Dehradun	Dhulkot silt loam	0.15
Hyderabad	Red chalka sandy loam	0.08
Kharagpur	Soil from lateritic rock	0.04
Kota	Kota clay loam	0.11
Ootacamund	Laterite	0.04
Rehmankhera	Loam, alluvial	0.17
Vasad	Sandy loam, alluvial	0.06

In the present study the K value of Dehradun has been used because geomorphological conditions of Juni Nadi watershed resemble with Dehradun station.

2.2.3 Topographic factor (LS)

Slope length and slope gradient are used in USLE equation to determine the soil loss. The slope length factor, L, which is the ratio of field soil loss to the corresponding loss from 22.13 m slope length, is expressed as

$$L = \left(\frac{\lambda}{22.13}\right)^m \tag{2.4}$$

Where λ is the field slope length (m), and exponent m assumes the value of 0.2 to 0.5. Wishmeier and Smith (1978) reported the value of exponent m for different slopes as follows:

Table 2.5: Value of exponent m for different slopes

Slope Gradient	Value of m
<1%	0.2
1-3%	0.3
3.5-4.5%	0.4
4.5% and more	0.5

The L value has been calculated by taking the field slope length as grid size (5 m) and creating m map for slope map.

Slope gradient Factor (S) is the slope steepness factor and is the ratio of soil loss from the field slope gradient to that from 9% slope under otherwise identical conditions. S is determined using the formula given by Wishmeier and Smith (1978).

$$S = \frac{0.43 + 0.30s + 0.043s^2}{6.613} \tag{2.5}$$

Where S is slope in percentage.

The combined LS factor was calculated by multiplying the L and S factor from the created maps.

2.2.4 Crop management factor (C) and supporting conservation practice factor (P)

C is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding soil loss from tilled, continuous fallow land. P takes into account the conservation practices such as contour cultivation, strip cropping and terrace system that will slow the runoff and thus reduce the amount of soil it carry. Crop management factor (C) and the supporting soil conservation practice factor (P) for different landuse in the present study were adopted from Priya and Shibasaki (1998), given in Table 2.6.

Table 2.6: C and P factors used for computation of soil loss in the present study

Landuse Type	C factor	Landuse Type	P factor
Fairly Open Mixed Forest	0.006	Agricultural land	0.39
Open Scrub	0.014	Other Landuse Type	1.00
Agricultural Land	0.380		
River Bed	1.0		
Earthen Work	1.0		

These different thematic data layers were analyzed in GIS environment (Integrated Land and Water Information System, ILWIS) to get soil erosion per pixel.

2.3 Generation of Maps

In the present study GIS software ILWIS (Integrated Land and Water Information System) is used for preparation of required database and for analysis of the data. ILWIS is a GIS package that integrates image processing and spatial analysis capabilities, tabular database and conventional GIS characteristics.

The main map of the study area was prepared from the survey of India toposheet at a scale of 1:50000. Drainage network, roads, contours and important point locations like villages, temples etc were digitised as segment map and point map, respectively. For the present study, Digital Elevation Model (DEM) was created using the contour interpolation algorithm in ILWIS. The interpolation of contour lines will give wrong results for hilltops, which are enclosed on all sides by a contour line. They will appear as flat areas with the same altitude as the contour line surrounding it. To improve this, the raster segment map, containing the contour lines, and a raster point map, containing the altitude of the hilltops, wherever available, was combined. The combined raster map (pixel size 5 m) was then used as the basis for the interpolation. This interpolated map gives the ground surface elevation at each pixel point in the basin. For slope map, height differences need to be computed in X and Y directions, since overall slope gradient is a function of height differences over horizontal distances in both X and Y directions. From the DEM, a slope map can be generated in degree or percentage. The landuse map was prepared by digital image processing of Indian Remote Sensing Satellite, IRS-1C, LISS III data of February 1998. Rainfall data of Katra (IMD, Station) are used for the present study.

Chapter 3

STUDY AREA

Juni Nadi is a tributary of the river Tawi in Jammu & Kashmir. The outlet of the watershed is close to the village Domel, about 35 km from Jammu on the national highway NH-1 (Fig. 3.1). The watershed lies between Latitude 32 52' to 33 N and Longitude 74 52' to 75 E, and covers an area of 52.37 sq km and a stream length of 11 km from Katra to Domail. The maximum and minimum elevation in the watershed are approximately 2000 and 500m, respectively.

Katra, with a population of 3,315 (1971 census), is the main town in the watershed which is approximately 50 km in north from Jammu. Average annual rainfall at Katra is 2,233 mm. Annual average maximum temperature was 40^0C and minimum temperature was 5^0C. As in the case of other mountainous watersheds, the Juni Nadi watershed encompasses a mixed landuse, dominated by dense and mixed forest, and followed by agriculture activities.

3.1 Geology

Juni nadiNadi watershed comprises geological formations of the Shiwalik Group (lower and middle Siwaliks), Katra terrace and Sirban limestone (mostly in the upper, northern part of the watershed). A major part of the watershed area is covered by Katra terrace (Fig 3.2), which is ill-sorted assemblage of angular to sub-angular fragments of limestone/dolomite. Based on available literature, and a limited geological survey carried out in the watershed, the following lithological succession is inferred:

Table 3.1: Geological setup of Juni Nadi watershed

Formation	Characteristics
Katra Terrace	Angular to subangular fragments of Limestone/dolomite, varying in size from cobbles and occasional boulder of dolomitic limestone
Lower Siwalik	Alternating bands of hard compact sandstone, siltstone, mudstone and clay
Sirban Limestone	Limestone and dolomite thinly bedded and highly jointed

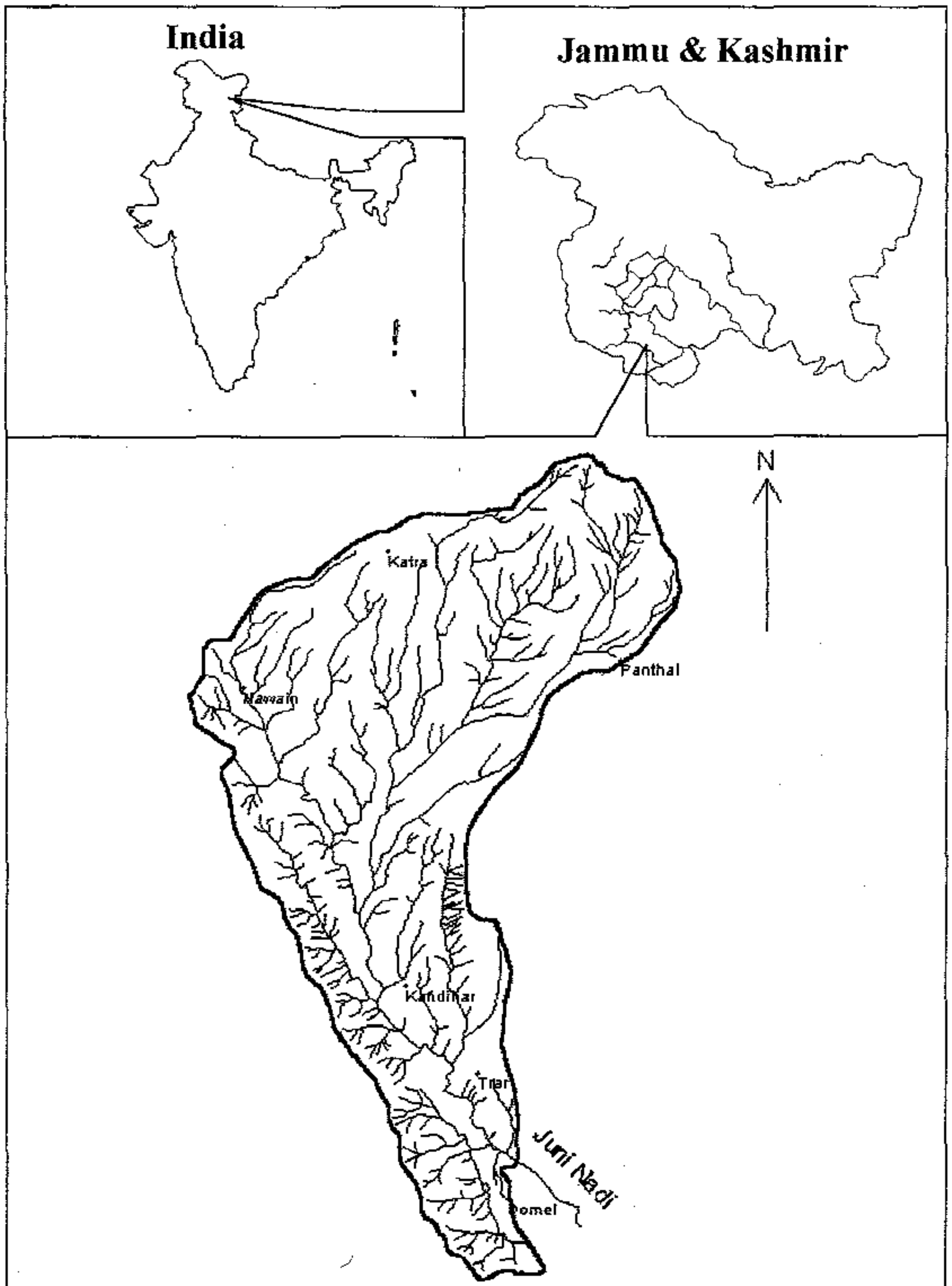

Fig. 3.1. Location Map of Juni Watershed

Sirban limestone is exposed in the northern part of the study area. The limestone is greyish blue thinly bedded, highly jointed and sheared. Ripple marks and stromatolites are reported from the limestone (Nawani et al., 1982). Sirban limestone overlies the lower Siwalik. The contact between Sirban limestone and Siwalik is thrusted by the Main Boundary Thrust (MBT).

Lower Siwalik rocks are exposed along the Domel-Katra road and along the river course. It is composed of micaceous sandstone interbedded with siltstone and clay. Sandstones are trending NW-SE with dip 60 to 80^0 towards northeast, having two sets of prominent fractures.

Katra terrace is ill-sorted fragments of angular to subangular deposits of limestone/ dolomite, covering large part of the watershed has been named as Katra terrace. It is varying in size from fine powdery material to gravel and occasional boulders are also present. Katra terrace overlies the Siwalik along the MBT. The fragmented materials are generally loose, but at various places hard and compact due to percolation of rainwater and forming cavities like structures.

3.2 Hydrogeology

Juni Nadi is a perennial stream, fed by spring water. About 35 springs have been identified in the watershed of Juni, most of which are flowing throughout the year. Main Boundary Thrust (MBT), separating the Siwalik and Sirban Limestone have crushed and sheared the rocks into fragmented form which acts as a permeable zone. The springs in the area occur along the Main Boundary Thrust. Major portion of the watershed is covered by Katra Terrace, which is porous and permeable due to assemblage of fragmented material. Lower Siwalik rocks showing two sets of prominent joints promote the infiltration capacity of the rocks.

Juni Nadi is a tributary of river Tawi, and originates from Panthal-Katra ridge above MBT. The main tributaries of Juni, namely, Sugal Khad, Nawain Khad and Danoa Khad etc are flowing in NNE to NE and NNW to NW directions reveals control of geological structures on drainage pattern. The control of geology on the streams is generally evident from the drainage pattern, e.g. trellis pattern along the western boundary of the watershed (Fig. 3.2).

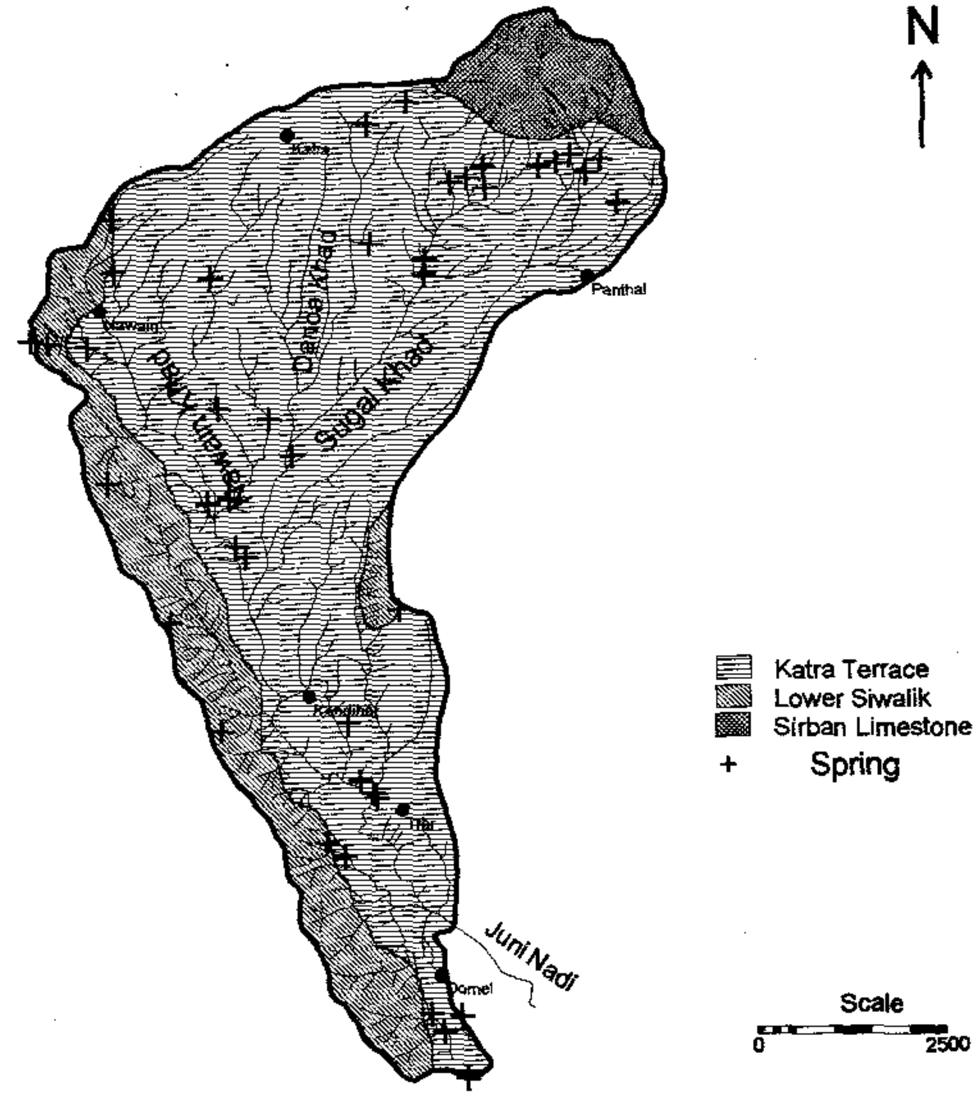

Fig.3.2. Geology and drainage pattern in Juni Nadi Watershed

3.3 Geomorphology

Geomorphologically, Juni nadiwatershed falls in the Siwalik terrain of the Himalayas. Elevation of the watershed ranges from 500m at the outlet to 2000 m at the peak of the watershed. Various landforms such as denudational hills, incised stream course, meander, and depositional and erosional terraces corroborate the evidence of neotectonic activities in the study area (Goyal et al., 1999-2000).

Chapter 4

RESULTS AND DISCUSSION

4.1 Morphometric Characteristics of Juni Nadi Watershed

For evaluating the hydromorphological parameters of Juni Nadi watershed, a topographic map of the area was drawn from the Survey of India Topo Sheet No. 43 L/13 (1:50000 scale). Boundary map, drainage map, and contour map at 20 m interval were digitized using ILWIS GIS in order to get the linear, areal and relief aspects of the watershed. The stream network has been ordered by the Horton-Strahler method using network module in ILWIS 1.2.

It can be seen from the Table 4.1 that the mean lengths which were calculated as the ratio of total length of specific order stream to the number of stream segments are 0.91, 1.16, 1.72, 3.05 and 0.39 km. for order 1, 2, 3, 4, 5 and 6, respectively. Juni Nadi watershed is sixth order basin having 293 first order, 56 second order, 14 third order, 5 forth order, 2 fifth order and one sixth order streams. Total watershed area is 52.37 km^2 up to Domel where Juni Nadi joins the Jhajhar. Since watershed of a given order can be modeled as a collection of sub elements, the number of streams of each order is an important concept in hydrology. Fig. 4.1a shows that the number of streams of a given order decreases with the increase in stream order and the negative slope of the line confirms the law of stream numbers. The average bifurcation ratio of the watershed is 3.31, which is normally between 3 to 5, and can be used as an index of hydrograph shape for basins. Perimeter of the watershed is found to be 38.79 km. The length of main stream between basin mouth and a point near center of the watershed is 8.37 km. The average stream length ratio of the watershed is 1.45, it is useful in synthesizing hydrograph characteristics. Fig. 4.1b shows stream length versus stream order. Fig. 4.1c shows mean stream length versus order of streams. It shows the increasing trend in average length of the streams and which follows Horton's law of stream length.

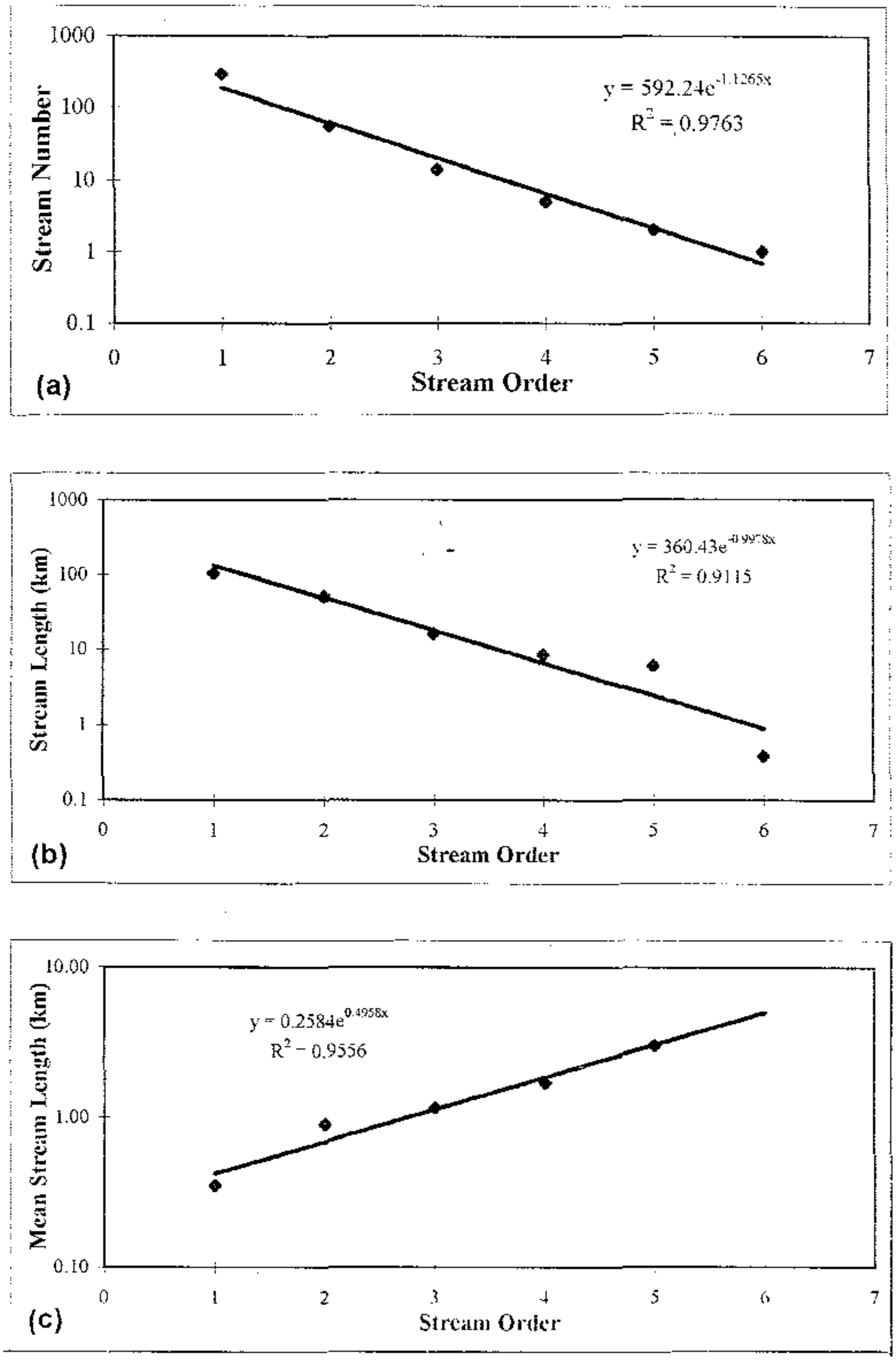

Fig 4.1 (a) Semi log plot for stream number vs stream order
(b) Semi log plot for stream length vs stream order
(c) Semi log plot for mean stream length vs stream oeder

Table 4.1: Linear parameters of the Juni Nadi Watershed

S.No	Parameters	Symbol	Value
1	Basin Perimeter	Lp	38.79 km
2.	Length of main stream	L	15.54 km
3	Basin length or Valley length	Lb	12.08 km
4	Stream length of each order	L1	103.12 km
		L2	50.92 km
		L3	16.30 km
		L4	8.59 km
		L5	6.11 km
		L6	0.39 km
5	Total stream length of all orders	Lw	185.43
6	Mean stream length of each order	$\bar{L}1$	0.35 km
		$\bar{L}2$	0.91 km
		$\bar{L}3$	1.16 km
		$\bar{L}4$	1.72 km
		$\bar{L}5$	3.05 km
		$\bar{L}6$	0.39 km
7	Number of streams of each order	N1	293
		N2	56
		N3	14
		N4	5
		N5	2
		N6	1
8	Total number of streams of all order	Nw	371
9	Wandering ratio (Smart and Surkan, 1967)	Rw	1.28
10	Fineness ratio (Melton, 1957)	Rf	0.40
11	Basin Eccentricity (Black, 1972)	τ	1.26
12	Bifurcation ratio (Horton, 1945)	Rb	Av. 3.31
13	Stream-length ratio (Horton, 1945)	Rl	Av. 1.45
14	Length of overland flow (Horton, 1945)	Lo	0.14

The various areal parameters are presented in Table 4.2. Drainage density of the basin is found to be 3.54 km/Km^2. It is largely a function of climate, lithology, and stage of basin development. The circularity and elongation ratio are found to be 0.43 and 0.68, respectively. The values of these dimensionless parameters approaches 1 as the shape of the basin approaches a circle and the computed value of elongation ratio indicates that the basin is having strong relief and steep ground slopes.

Table 4.2: Areal-parameters of the Juni Nadi Watershed

S.No.	Parameters	Symbol	Value
1	Total Drainage Area	A	52.37 km^2
2	Drainage Denisty	D	3.54 km/ km^2
3	Constant of Stream Maintenance (Schumm, 1956)	C	8.37 km
4	Stream-Segment Frequency (Horton, 1945)	F	7.08 per km^2
5	Circularity Ratio (Miller, 1953)	Rc	0.43
6	Elongation Ratio (Schumn, 1956)	Re	0.68
7	Basin Shape Factor (Wu et al., 1964)	Rs	1.90
8	Unit Shape Factor (Smart and Surkan, 1967)	Ru	2.15
9	Form Factor (Horton, 1932)	Rf	0.22
10	Compactness coefficient (Strahler, 1964)	Cc	1.51

A DEM (Fig. 4.2) is prepared with pixel size of 5 m. Elevation of the basin ranges from 500 m at the out let and 2000 m at the ridge of the basin. Slope map in percentage has been prepared using DEM and gradient filters. It has been classified into five categories i.e, 0-5 %, 5-15 %, 15-33%, 33-50 %, and more than 50 % (Fig. 4.3). Results show that 24% of the total area falls under the 0-5%, 38% area under 5-15%, 18% area under 15-33%, 10% area under 33-50% and only 10% of the total area falls under more than 50% slope. The parameters based on relief are estimated using the DEM of the basin and given in Table 4.3. These parameters are most important in influencing the runoff and other hydrological process. The basin relief is found to be 1500 m. The basin relief ratio, relative relief and ruggedness number are 0.12, 0.04 and 5.31 respectively. The relief parameters are mostly non-dimensional and have significant effect on overland flow governing the flow processes.

Table 4.3: Relief parameters of the Juni Nadi Watershed

S.No.	Parameters	Symbol	Value
1	Basin Relief (Schumm, 1956)	H	1500
2	Relief Ratio (Schumm, 1956)	Rh	0.12
3	Relative relief (Melton, 1957)	Rhp	0.04
4	Ruggedness Number (Melton, 1957; Strahler, 1958)	Rn	5.31

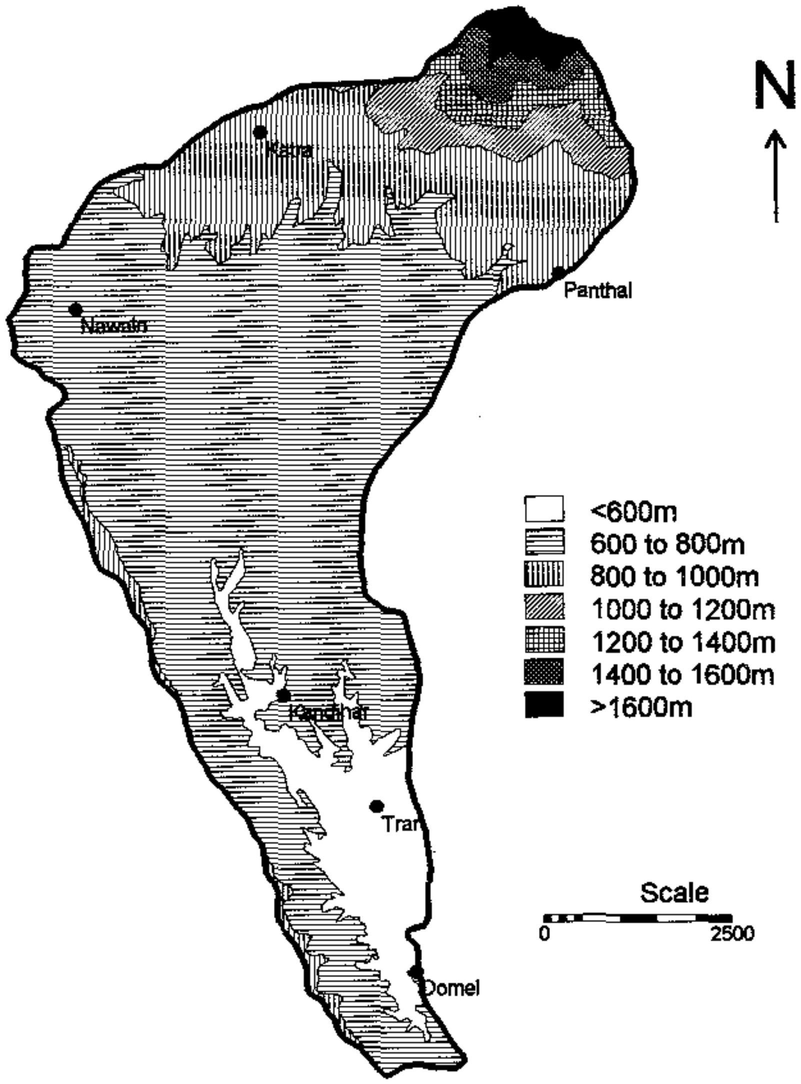

Fig. 4.2 Digital Elevation Model (DEM) of Juni Nadi Watershed

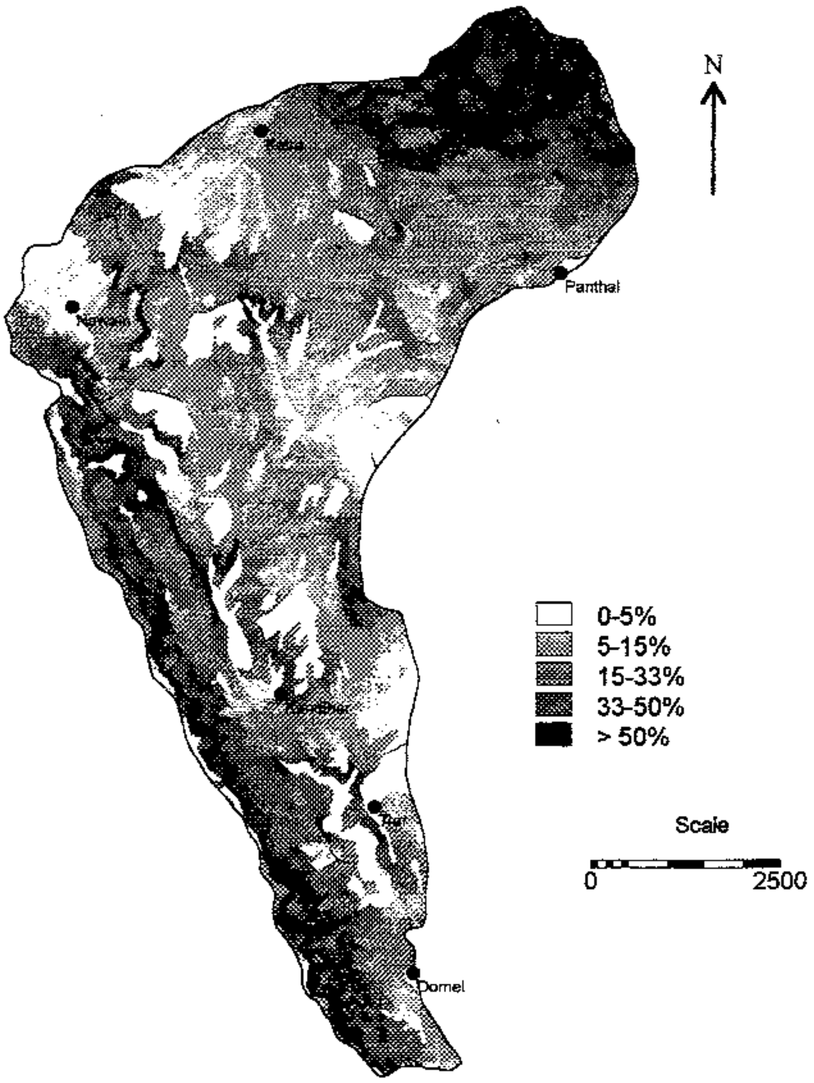

Fig. 4.3. Slope map of Juni Nadi Watershed

4.2 Soil Erosion in Juni Nadi Watershed

Various parameters of USLE were determined as explained above. Average annual rainfall of Katra station (Table 4.4) was used to calculate the rainfall erosion index, which comes out to be 890. Soil type and physiographic setting of the study area resembles to Dehradun where the K value has been computed as 0.15 (Singh et al., 1981).

Table 4.4: Average annual rainfall data (1980-1995) of Katra (Source, IMD)

Month	Rainfall (mm)
January	93
February	137
March	166
April	102
May	68
June	108
July	623
August	568
September	215
October	37
November	26
December	91
Total	2233

A combined LS factor was determined using the slope map of the area. Maximum area of the catchment falls under the 0-15% slope. Landuse/landcover map (Fig. 4.4) prepared from IRS-IC digital data for the year 1998 was used to assign the C value to each cover type. The level-I classification was adopted to divide the area into four major land use/land cover categories i.e. agriculture with sparse habitation; mixed forest (mainly pine);. open scrubland; and Channel debris fill and Earthen Work. The assigned C values for different landuse/landcover are given in Table 2.6. A value of 0.6 was assigned to the P factor for agriculture landuse and for all other landuses, a value of 1.0 was assigned.

According to Dhruvanarayan and Ram Babu (1983), soil loss within the range of 4.5 to 11.2 tons/ha/yr is considered within the tolerance limit (Table 4.5).

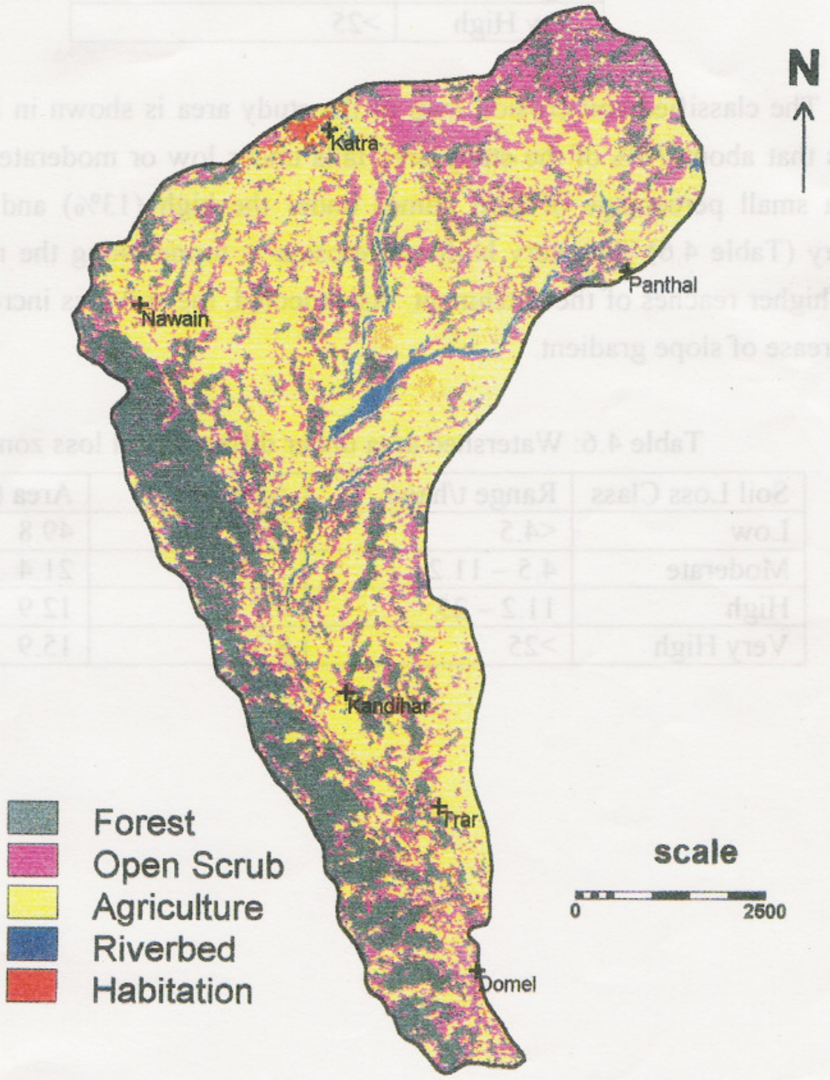

Fig. 4.4. Landuse map of Juni Nadi Watershed

Table 4.5: Classification of soil loss category

Category	Soil Loss (tons/ha/yr)
Low	<4.5
Moderate	4.5-11.2
High	11.2-25
Very High	>25

The classified soil erosion map of the study area is shown in Fig 4.5. The study reveals that about 70% of the study area falls under low or moderate class of soil loss. Only a small percentage of land comes under the high (13%) and very high (16%) category (Table 4.6). The very high soil erosion is found along the main river channel and at higher reaches of the catchment. As expected, the soil loss increases linearly with the increase of slope gradient.

Table 4.6: Watershed area under different soil loss zones

Soil Loss Class	Range t/ha/yr	Area (km^2)	Area (%)
Low	<4.5	25.9	49.8
Moderate	4.5 – 11.2	11.1	21.4
High	11.2 – 25	6.7	12.9
Very High	>25	8.3	15.9

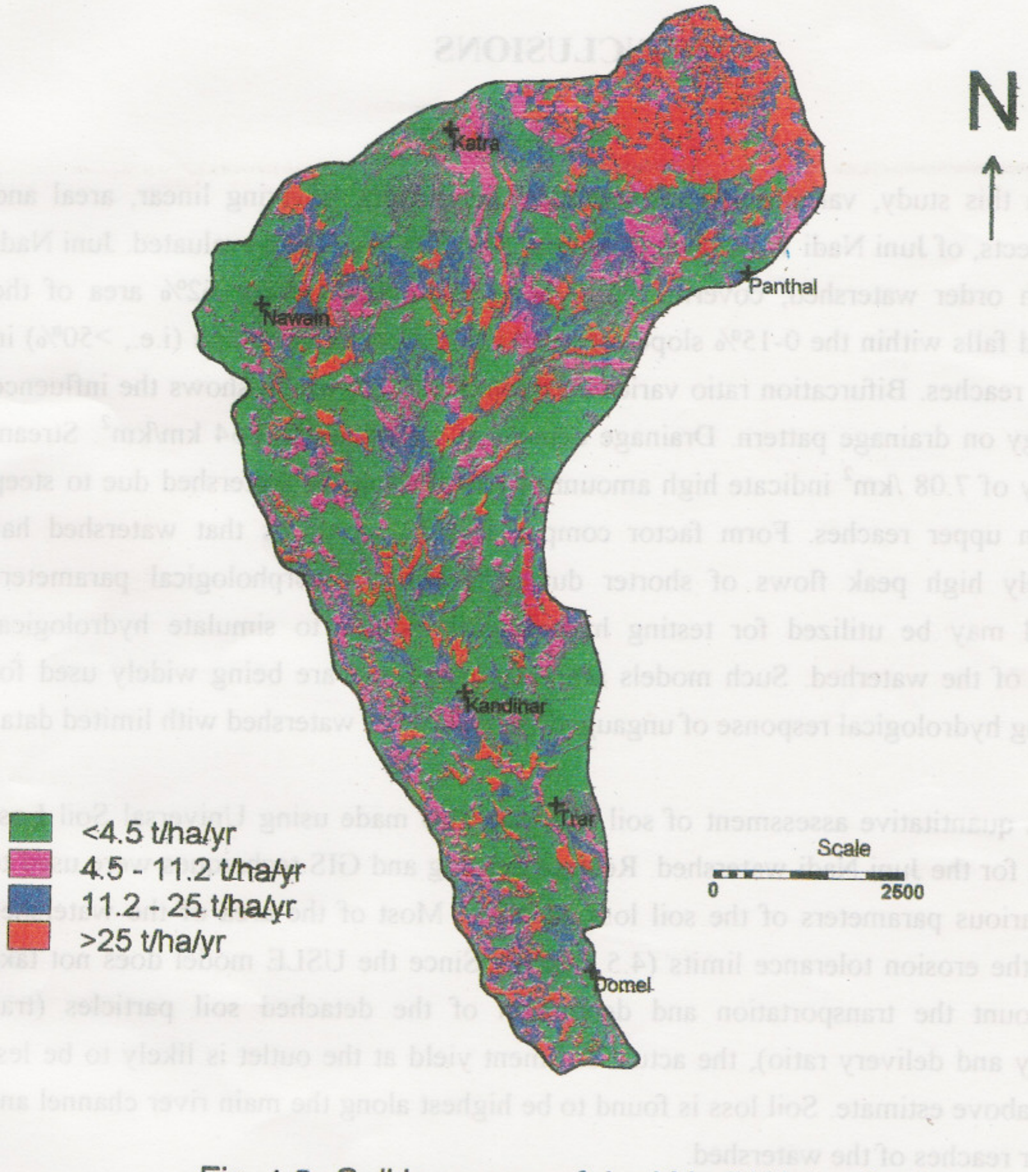

Fig.4.5: Soil loss map of Juni Nadi Watershed

Chapter 5

CONCLUSIONS

In this study, various geomorphological parameters, covering linear, areal and relief aspects, of Juni Nadi Watershed in Jammu Siwaliks have been evaluated. Juni Nadi is a sixth order watershed, covering an area of 52.37 km^2. About 62% area of the watershed falls within the 0-15% slope category while slope is very high (i.e., >50%) in its upper reaches. Bifurcation ratio varies between 2 to 5.23, which shows the influence of geology on drainage pattern. Drainage density of watershed is 3.54 km/km^2. Stream frequency of 7.08 $/km^2$ indicate high amount of runoff from the watershed due to steep slopes on upper reaches. Form factor computed (0.22) confirms that watershed has moderately high peak flows of shorter duration. The geomorphological parameters estimated may be utilized for testing hydrological models to simulate hydrological response of the waterhed. Such models are very useful and are being widely used for simulating hydrological response of ungauged watersheds or watershed with limited data.

A quantitative assessment of soil loss was also made using Universal Soil Loss Equation for the Juni Nadi watershed. Remote Sensing and GIS techniques were used to derive various parameters of the soil loss equation. Most of the area of the watershed exceeds the erosion tolerance limits (4.5 t/ha/yr). Since the USLE model does not take into account the transportation and deposition of the detached soil particles (trap efficiency and delivery ratio), the actual sediment yield at the outlet is likely to be less than the above estimate. Soil loss is found to be highest along the main river channel and on higher reaches of the watershed.

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