CHAPTER III

GEOENVIRONMENTAL SETTING OF THE STUDY AREA

3.1 INTRODUCTION

Geo-environment of a region deals with the topography, geology, seismicity and tectonics, water and soil quality along with the climate and meteorology. The Himalaya has a unique geo-environmental setting with its rich biological and cultural heritage.

The Himalaya is a complex of sub-parallel structural units produced by the northward thrust of the Indian tectonic plate beneath the Central Asian plate. A unique geo-feature of the planet, the Himalaya is considered to be the youngest mountain system (Rao and Sexena, 1994) on earth. The Himalaya extends for about 2400 km as a massive arc, covering an area of about 6, 12,021 km^2 and formed as a result of continental convergence and collision between India and Eurasia. The traditional definition of the Himalaya, sensu stricto, is that the great range of mountains extends between latitudes 26°20' and 35°40' North, and between longitudes 74°50' and 95°40' East. In this sense the Himalaya extends from the Indus Trench below Nanga Parbat (8,125 m) in the west to the Yarlung tsangpo- Brahmaputra gorge below Namcha Barwa (7,756 m) in the east. This definition includes politically, Nepal, Bhutan, a small part of Pakistan, parts of China as well as the western, central and eastern sections of the Indian Himalaya (Bruno and Messerli, 1989). It's from Pamir's Knot to Arakan-Yoma mountain ranges of Myanmar and it covers the part of Afghanistan, Pakistan, India, Tibet (China), Nepal, Bhutan and Myanmar. The Himalaya protects the Indian-sub continent from the severe impact of cold waves blowing from the Tibetan highland. The Himalaya has played a tremendous role in the economy of the country as most of the

major rivers flowing through the northern states of the country originates from this great mountain range.

Two representative river basins viz. the Subansiri and the Alaknanda are selected from eastern and western Himalayas respectively to examine and compare the salient features of both the eastern and western Himalayan regions such as geoenvironmental aspects, hydrometeorological conditions, ecological and biological features, landuse and settlement pattern and also the impact of natural and anthropogenic factors in the selected basins owing to global warming.

The study area covers the western Himalayan region represented by the Alakananda river subbasin of the Ganga basin and the Subansiri river subbasin of the Brahmaputra basin in the eastern Himalayan region (Figure 3.1).

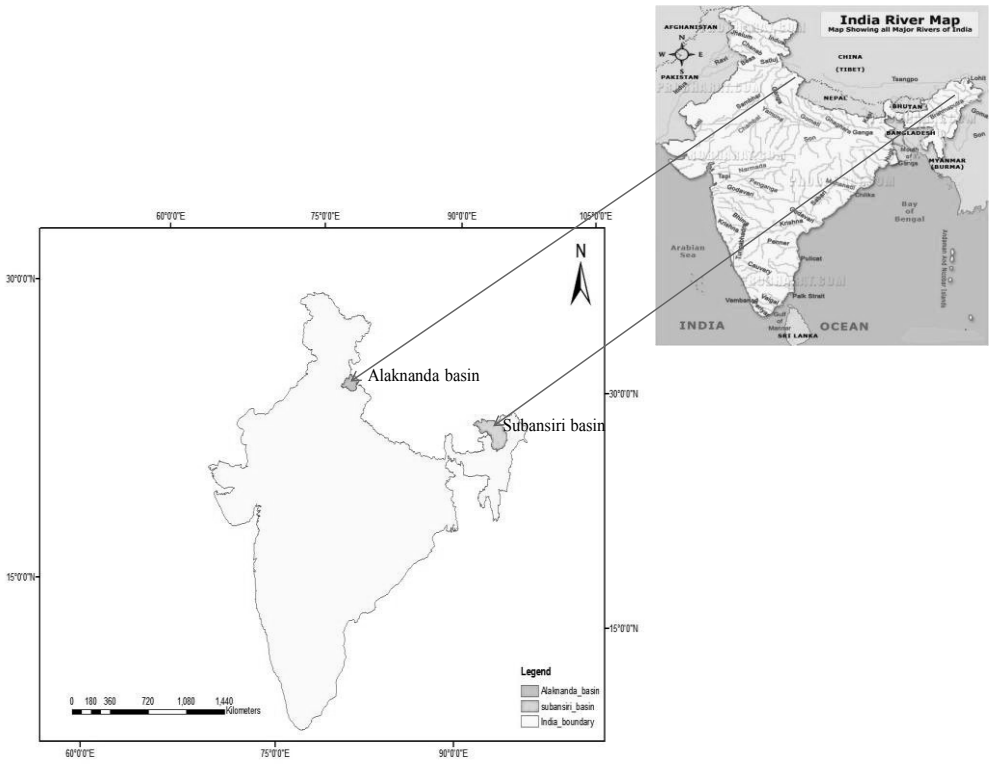


Figure 3.1: Location of the study area

3.2 PHYSIOGRAPHY OF THE HIMALAYA

Based on the geomorphological factors like rock types, structure, tectonics, geographical location and prevailing climatic conditions, the Himalaya is broadly divided into four major regions (Sah, 1993) viz. Higher Himalaya, Lesser Himalaya, Outer Himalaya and Bhabar and Terai (Figure 3.2). The Himalayas are bordered on the north by the Tibetan Plateau, on the south by the Indo-Gangetic Plain, on the northwest by the Karakoram and Hindu Kush ranges, and on the east by the Indian states of Assam and Arunachal Pradesh. The western anchor of the Himalayas — Nanga Parbat — lies just south of the northernmost bend of the Indus River, while the eastern anchor — Namcha Barwa — is situated just west of the great bend of the Yarlung Tsangpo River. The Himalayas span five countries: India, Nepal, Bhutan, China (Tibet), and Pakistan. The Himalayan range consists mostly of uplifted sedimentary and metamorphic rock. Owing to the mountains' latitude near the Tropic of Cancer, the permanent snow line is among the highest in the world at typically around 5,500 metres (18,000 ft). The Himalayan region is dotted with hundreds of lakes. Most lakes are found at altitudes of less than 5,000 m, with the size of the lakes diminishing with altitude. The Himalayas have a profound effect on the climate of the Indian subcontinent and the Tibetan Plateau. They prevent frigid, dry winds from blowing south into the subcontinent, which keeps South Asia much warmer than corresponding temperate regions in the other continents. It also forms a barrier for the monsoon winds, keeping them from traveling northwards, and causing heavy rainfall in the Terai region.

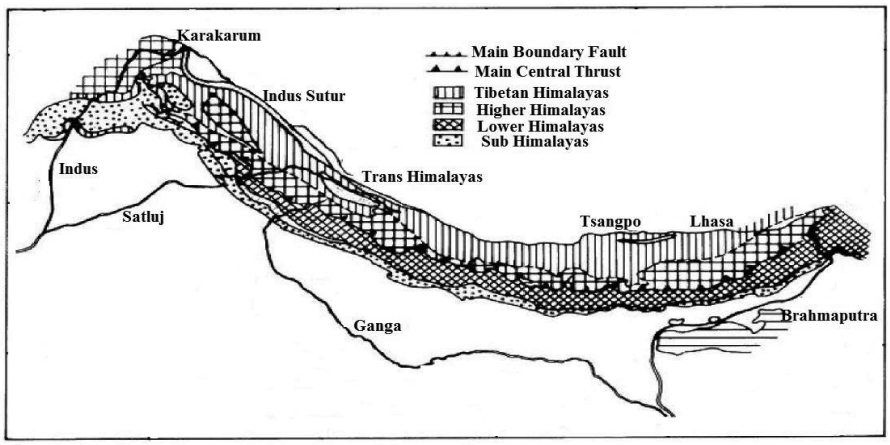


Figure 3.2: Geological sub-division of the Himalaya

(Source: Goswami, 1985)

Outer Himalaya or Sub Himalaya is the highly dissected range with elevation ranging from 600-1200 meters. In this belt, the intermountain or Dun valleys are situated. It is the southernmost zone where the Himalayan Frontal Thrust (HFT) separates it from the Ganga alluvial plain. The Sub-Himalaya forms the foothills of the Himalayan Range and is composed of Siwalik (Miocene to Pleistocene molassic) sediments derived from the erosion of the Himalaya. They are basically the newer and river borne deposits brought down by the rivers coming from the Himalaya (Ganges, Indus, Brahmaputra and others) and represent the most recent phase of the Himalayan orogeny.

Lesser (or Lower) Himalaya or **Himanchal** is inhabited by majority of population and is an important area of Himalayan belt which receives winter snow. The Lesser Himalaya is a 50-80 km wide mountain belt with elevation ranging from 2000-3500 meters. Lesser Himalaya is separated by the second major tectonic lineament from the south, the Main Boundary Thrust (MBT). This zone is mainly composed of granite and other crystalline rocks of unfossiliferrous metasediments.

Higher Himalaya or Himadri is covered by permanent snow and ice throughout the year in the form of glaciers. The Higher Himalaya is again divided into Inner Higher Himalaya and Outer Higher Himalaya or Main Higher Himalaya. Inner Higher Himalaya is also called as cold deserts. The Main Central Thrust (MCT) separates the Lesser Himalaya from the Higher Himalayan rocks. The rocks of this region are crystalline in nature and are often called Central Crystalline which are metamorphic and granitic rocks of complex nature.

Bhabar area is 15-30 km wide with an elevation of 300-600 meter. The adjoining area to the south of Bhabar with an average slope of 5-6 degree where the sub-surface flow reappears is known as Terai. This zone is 100-300 meter high and 80-100 km wide.

The Himalayas have also been divided by Sir Sidney Burrard into four transverse regions (Figure 3.3) viz., (1) The Punjab Himalaya (560 km long between the Indus and the Satluj rivers) (2) The Kumaun Himalaya (320 km long between the Satluj and the Kali rivers) (3) The Nepal Himalaya (800 km long between the Kali and the Tista rivers) and (4) The Assam Himalaya (720 km long between the Tista and the Brahmaputra rivers). Prof. S P. Chatterjee has divided the Himalayan region into 3 meso physiographic regions-(1) Western Himalaya (Kashimr, Punjab and Kumaun Himalayas), (2) Central Himalaya (Nepal Himalaya), and (3) Eastern Himalaya.

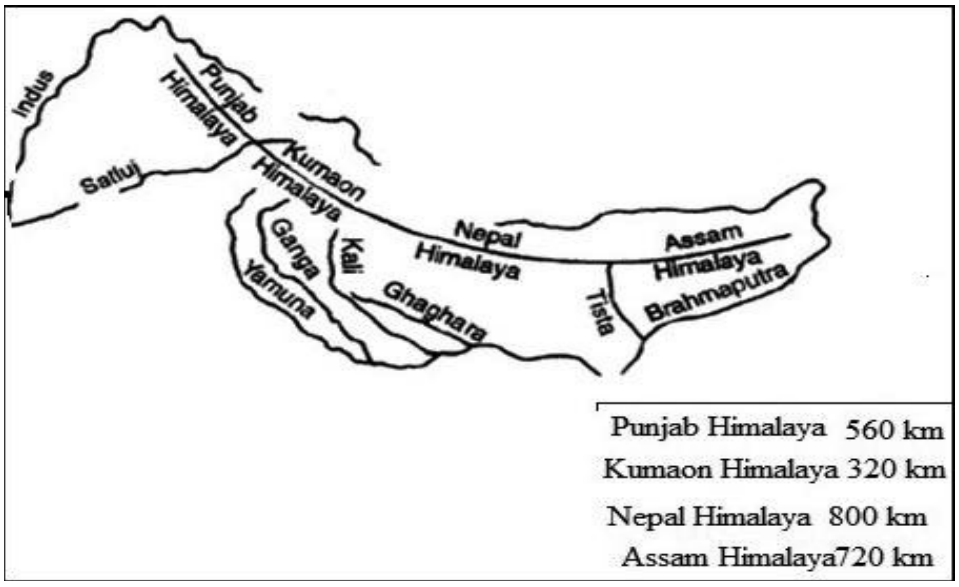


Figure 3.3: Physiographic division of the Himalaya

The major tectonic features such as the Indus-Tsangpo Suture Zone, Main Central Thrust, Main Boundary Thrust and Himalayan Frontal Thrust have contributed in sculpturing the structural and topographic architecture of the Himalayan mountain system.

3.3 PHYSIOGRAPHY OF THE SUBANSIRI BASIN

The Subansiri (Figure 3.4) is one of the largest north bank tributaries of the river Brahmaputra. It originates in the Great Himalayan range in Tibet at an altitude of more than 5000 m and flows through the hills of Arunachal Pradesh and plains of Assam before joining the mighty Brahmaputra at Subansirimukh. The geographical extensions of the Subansiri basin are 26°54' 14"- 28°55' 24" N and 91°33' 09" E - 95°04'38" E. Its total length is 468 km from its origin to the confluence with the Brahmaputra. The Subansiri is called Lokong Chu (Tsari Chu) at its source in Tibet (China). It is a perennially snow-fed trans Himalayan river traversing the Himalayas and passing through the Miri Hills. It then enters the plains in Assam and flows through it until

joining the mighty river Brahmaputra. The principal stream is known as Nye Chu and it travels a distance of 170 km. towards east and receives an important right bank tributary Loro Chu. The combined flow then traverses further 208 km eastwards where it receives another left bank tributary Yume Chu. Before the confluence point with Yume Chu the river is known as Chayul Chu. The Chayul Chu near Karutra crosses the international boundary and is known thereafter as Subansiri. Its prominent left bank tributaries are Sichi, Situ, Sigen, Dirpai, New chauldhoa, Old Chauldhoa etc. while kamala, Singen, sipu, Boginadi etc are right bank tributaries. Kamla is an important hilly Sub-tributary of Subansiri and its entire course is confined to a narrow gorge. Its drainage area is 35,771 sq. km. most of which lies in the hilly region of Arunachal Pradesh (21066 sq. km.) and Tibet (10345 sq. km.). The Subansiri contributes about 10% of the total discharge of the Brahmaputra River at Pandu near Guwahati. The Subansiri Basin comprises of the hilly terrain, deep gorges and river valley terraces. Its upper basin covers the part of Upper Subansiri district, Lower Subansiri district and Kurung Kumey district while lower basin comprises of parts of Lakhimpur and Dhemaji districts. It is famous for its rich variety of flora and fauna.

3.4 PHYSIOGRAPHY OF THE ALAKNANDA BASIN

The Alaknanda is a Himalayan River in the state of Uttarakhand. It is one of the major headstreams of the Ganges and originates at the water divide between Satopanth and Bhagirath glaciers at an altitude of approximately 3680 m situated in the southern slopes of the outer Himalayas. The river Basin (Figure 3.5) is bounded between 30° 0' N- 31° 3' N and 78°37'E - 80°2' E with a basin area of 10936.35 sq.km. and average discharge of 439.36 m^3/s. The Alaknanda has many tributaries like Saraswati, Pindar,

Mandakini, Dhauliganga, Rishiganga etc. The mountain peaks such as Nanda devi, Kamet, Trisul, and Chaukhamba etc. are located here.

The River Alaknanda has a radial and rectangular drainage pattern. It flows from Mana just upstream of Badrinath and confluences with Dhauliganaga immediately downstream of Joshimath. Most of the catchment areas of the Alaknanda and its tributaries are covered with snow and glaciers. The Khular Bank, Khuliagarvia Gal, Anadev Gal, Dakhini Nakthoni Gal, Paschimi Kamet Glacier, Tara Bank, Luri Glacier and Bhagnyu glacier etc are other major glaciers present in the catchment. There are four major lakes present in the basin viz. Arwa Tal, Rishi Kund, Sankunni and Satopanth Tal. In the Alaknanda basin the lowest place is Devprayag (500 m) and Nandadevi peak (7817 m) is the highest point. The geoenvironmental characteristics of the rivers Alaknanda and Subansiri are revealed in different angles in plates 3.1 to 3.4.

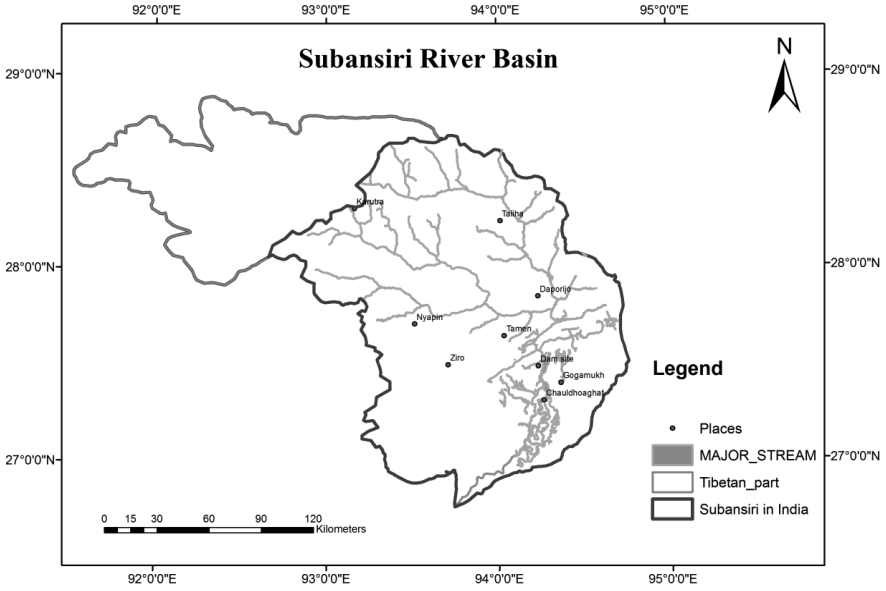


Figure 3.4: Major streams of the Subansiri basin in India

Figure 3.5: Drainage network of the Alaknanda river basin

(a)

(b)

Plate 3.1: A panoramic view of (a) the Alaknanda river and (b) the Subansiri river

Plate 3.2: The braided river Alaknanda flowing in Srinagar, Garhwal

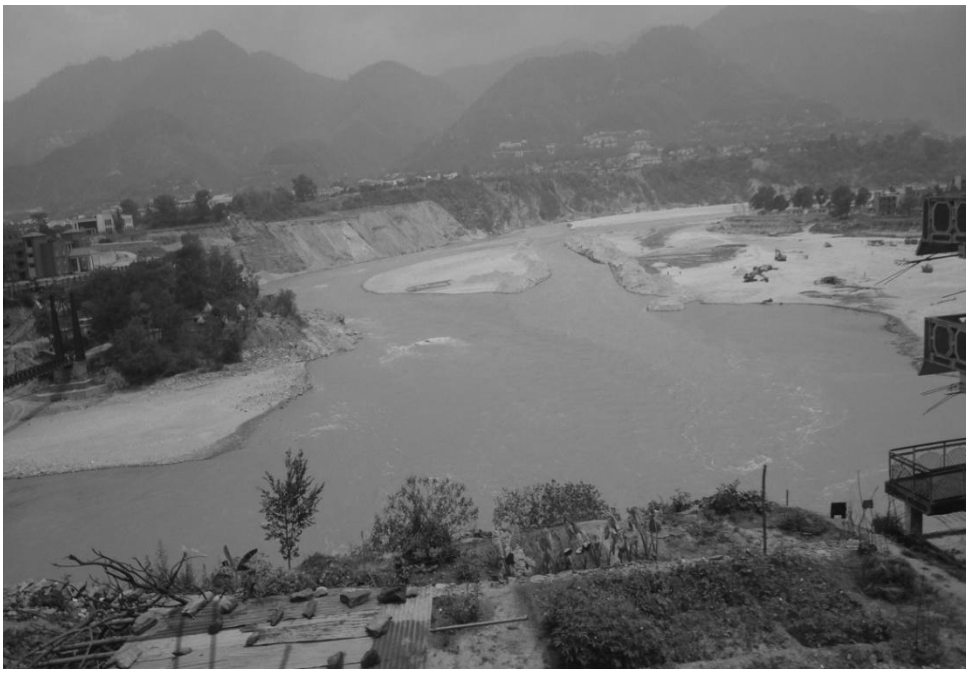


Plate 3.3: Sand bar formation by the river Alaknanda in Srinagar area of Garhwal Himalaya

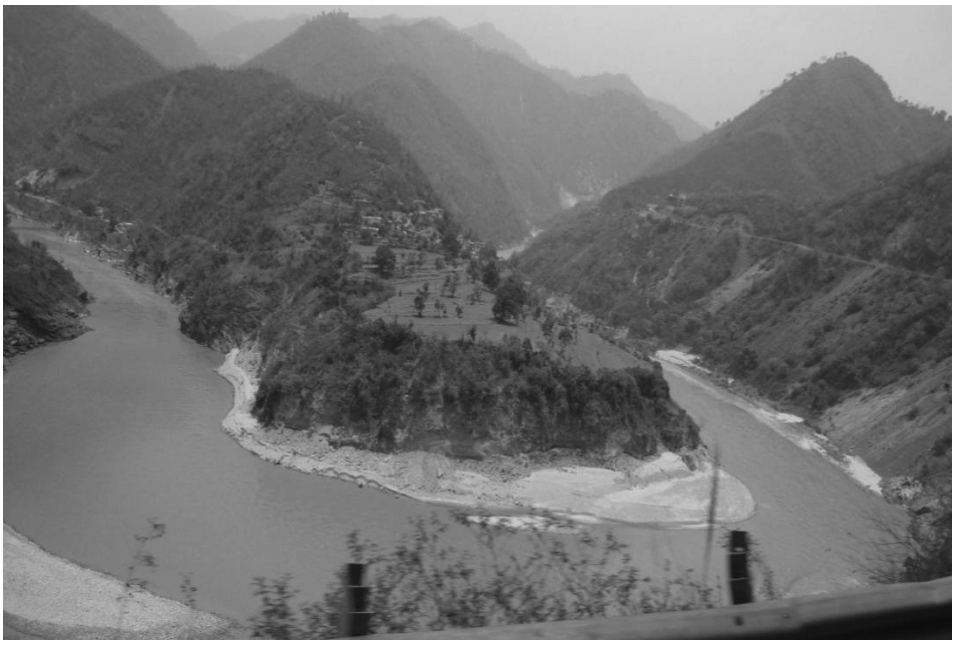


Plate 3.4: Alaknanda river flowing in Rudraprayag creating a large meander near Rudraprayag

3.5 CLIMATE AND WEATHER IN THE SUBANSIRI BASIN

The mountain topography plays a vital role in the weather and climate of the area. The climatic condition of the basin varies from place to place as well as season to season. It is also largely influenced by the variable nature of the terrain condition of the region. The Brahmaputra basin that includes is an integral part of the Southeast Asiatic Monsoon regime having a typical climatic personality. In the foot hill, the climate is moderate but the winter is cold and chilly and summer is pleasant. July and August are the warmest months. The climate of Arunachal Pradesh varies with elevation. Areas that are at very high elevation in the upper Himalaya close to the Tibetan border have an alpine or tundra climate while in the middle Himalaya, people experience temperate climate and in case of the sub-Himalayan region and sea level elevation, the climate is humid or sub-tropical. Upper Subansiri District is a mountainous tract. The hill ridges are quite dominant. The Upper Subansiri area is marked by low temperatures

throughout the year dominated by long, cold winters. Upper Subansiri District head quarter at Daporijo is situated at 500 m above mean sea level has a climate characterized by mild summers and moderate to severe winters. The mean annual precipitation ranges from 2000 to 5000 mm. Rainfall is highly seasonal and varies both in space and time. Monsoon prevails from June to middle of October and the basin receives heavy rainfall during this time. The foot hills of the Subansiri basin witnesses heaviest rainfall in Assam due to which the districts Dhemaji and Lakhimpur experience flood havoc almost every year. Relative humidity is high throughout the year but the winter months are less humid. An Isohyetal map of the Subansiri basin based on available rainfall data is shown in Figure 3.6.

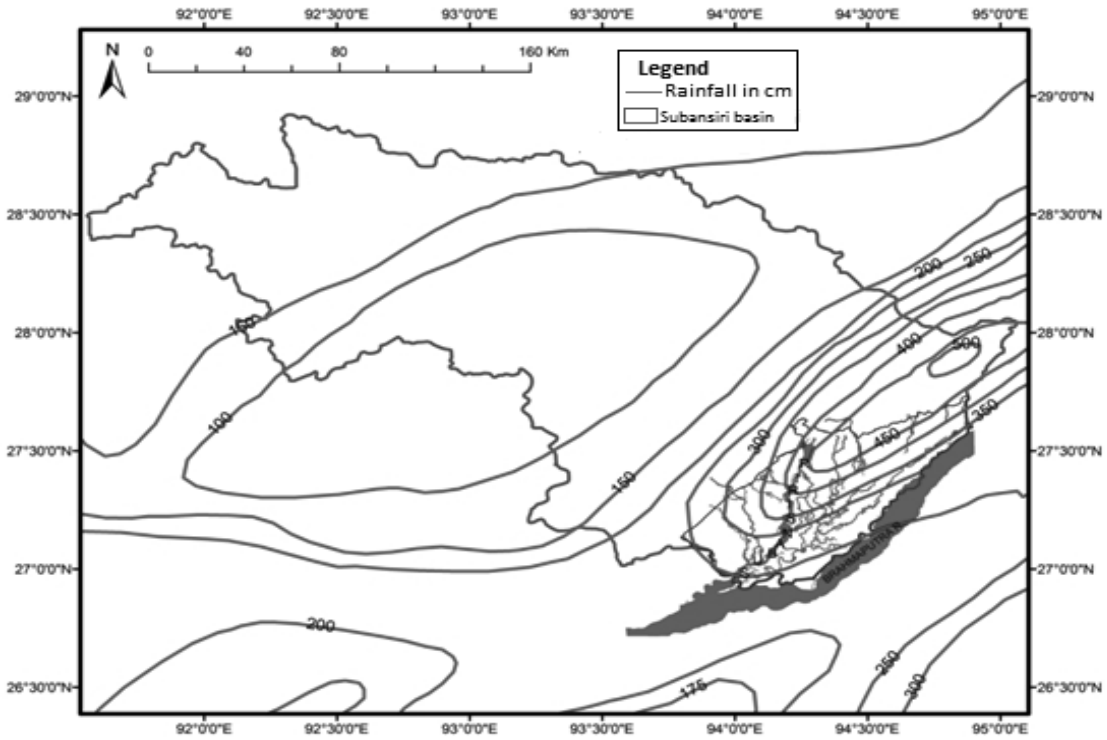


Figure 3.6: Isohyetal map of average annual rainfall (in cm) in the Subansiri basin. (Source: Based on Brahmaputra Board, 2002)

3.6 CLIMATE AND WEATHER IN THE ALAKNANDA BASIN

In the Alaknanda basin the climate varies from sub-tropical to alpine depending upon the altitudinal and physiographic variation. Despite of the diverse physiographic characteristics, sub-regional variations in the average seasonal temperature are not so high. Srinagar is a wide valley, enclosed by two mountain ranges from the north and the south and between these two ranges, the Alaknanda River flows. It has very contrasting climatic conditions. During the summer, it receives high temperature and during the winter, extreme cold waves hit the whole region. Temperature varies from season to season and from valley to higher elevations. The whole Alaknanda basin receives lowest temperature and the area above 2000 meter receives heavy snowfall during four months of winter. Summers are conducive and favourable for health except a belt extending between Karnprayag to Devprayag where average temperature remains about 30 degree. Heavy snowfall was observed in Jan 1993, when the low-lying areas (about 900 m elevation), were also covered by snow. Heavy tourist-flow can be observed in the towns of the basin along the Alaknanda River. Large numbers of pilgrims also visit the two pilgrimages i.e., Badrinath and Kedarnath during the summer. Rainfall variability in the basin is due to the direction of slope-leeward and windward. The maximum rainfall is observed in monsoon months due to south west monsoon which normally strikes the Garhwal Himalayas towards the end of June and withdraws from the region towards the end of September.

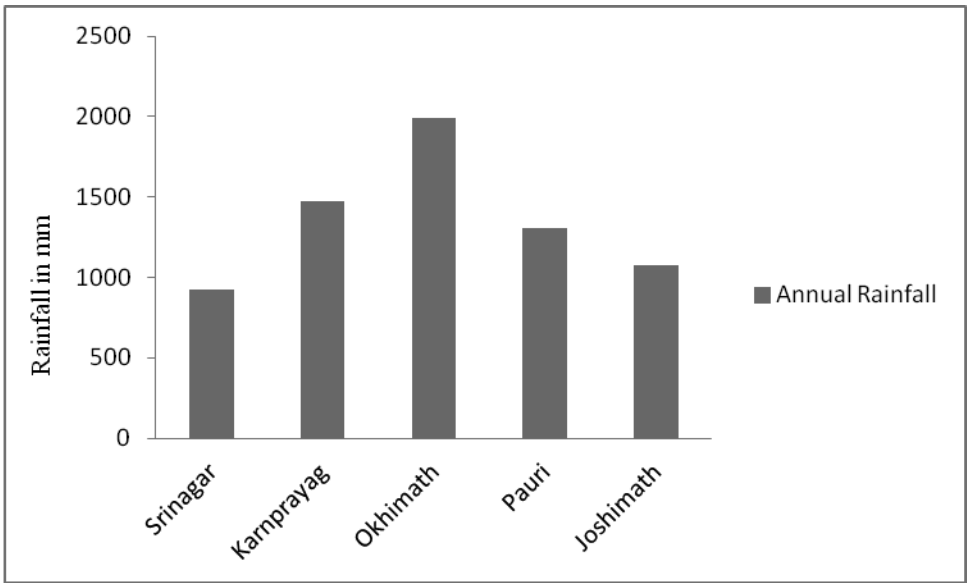


Figure 3.7: Annual Rainfall (mm) in major towns of the Alaknanda basin in 2008

(Source: Forest Working Plan, Nainital Working Circle in Sati, 2009)

Wind pattern is extremely complicated and has local influences in the Alaknanda basin (AHEC, 2011). The entire region gets intensive rain that varies from the valley regions (low rain) to the highlands (high rain) and from north-facing (leeward) to south-facing (windward) slopes. The basin characterizes the cold chilly winters of highlands and humid monsoon climate in valley regions. Cloudbursts, debris flows, landslides, landslips, mass movements and flash floods are very intensive as well as frequent. The entire region is worst affected due to these catastrophes during the monsoon season. During heavy rains, there are many instances where the low-lying river valleys were swept away, causing loss of life and property. During the winter, rainfall occurs due to western disturbances. The wind that originates through the western disturbances makes the entire region cool and as a consequence, cold waves blow. Mostly during December–January months, precipitation occurs in the form of snow in the higher reaches above 2000 m and rain in the mid-altitudes and the valley

region. Figure 3.7 (Data in Table I in Appendix 1) shows the rainfall in four major towns of the Alaknanda basin. Highest rainfall is seen in Okhimath (199.4 cm) followed by Karnprayag (147.1 cm) while lowest rainfall is noticed in Srinagar (92.5 cm). This data reveals that in the high altitude rainfall is higher than that of the valley regions. However, there are higher regions where low rainfall occurs; for example, Joshimath, which is located at an altitude of 1875 m, received only 107.5 cm annual rainfall because it is located in the leeward direction.

This region is characterised by high humidity throughout the year; but the percentage of humidity differs depending upon season and altitude. During the rainy season humidity remains high throughout the whole region, whereas during the summer, humidity decreases especially in the valley regions. Presence of high humidity in the atmosphere provides suitable conditions for growing crops even during the droughts. The drought of 1987, which affected the entire India and led to the situations of starvation and acute food scarcity, did not affect the Alaknanda Basin (Sati and Kumar, 2004). This was predominantly because of the presence of high humidity in the atmosphere. The Great Himalayan ranges occupy 433 km^2 of the Alaknanda Basin and the perpetual snow clad ranges of these ranges regulate the climatic conditions viz. temperature, rainfall and moisture.

3.7 GLACIER AND SNOW COVER OF THE SUBANSIRI AND THE ALAKNANDA BASINS

The Himalaya is one of the youngest mountain ranges in the world and accounts for nearly 70% of non-polar glaciers which has considerable impact on the climate,

hydrology and environment. The Himalaya has more than 12000 glaciers (Kaul, 1999; ICIMOD, 2001) covering an area of about 33000 km^2 (Rai and Gurung, 2005 in Thayyen and Gergan, 2009). Over 30% of earths land surface is seasonally covered by snow, and 10% is permanently covered by glaciers. The snow cover in the Himalayas occurs and exists depending on the terrain and climatic conditions of the region. Snow cover may be of different types viz. temporary, seasonal, and permanent and glaciers (NIH, Roorkee, 2000-01).

The snowline is defined as the line delimiting an area with complete snow cover from an area free of snow. The permanent snow line varies in altitude from about 4267 m in the eastern part to 5182 m in the western Himalayas. The permanent snow line for Subansiri basin has been estimated at 4500 m (CWC Report, 2013). In Alaknanda basin the mean snow line elevation was 4659 m in November, 2010 (Dhankar, 2015).

In the state of Arunachal Pradesh, land under the snow and glaciers of the Subansiri basin constitute 8.18% of the total area. The highest snow and glacier area was reported in Upper Subansiri and Kurung Kumey districts while no such areas exist in the Lower Subansiri district (CWC Report, 2013). On the other hand, snow covered areas start from Chamoli district in the Alaknanda basin.

3.8 GEOLOGY AND TECTONICS OF THE SUBANSIRI AND THE ALAKNANDA BASINS

The general geology of the whole Subansiri subbasin in its lower part mainly consists of Quaternary sediments i.e. Older alluvium which are unconsolidated

sediments represented by boulders, cobble, pebble sand and sandy clay beds. The geo-tectonic setting of the Subansiri basin is extracted from the GSI's Geological and Mineral Map of North east India, 1998 (Figure 3.8).

In Arunachal Pradesh there are Miri and Bichom formations of Gondwana Group, Khetabari, Tenga, Buxa and Potin Formation of Bomdila Group, Se La Group, Hapoli Formation, Nuimi formation, Kimin Formation etc. Middle Siwalik Group is seen in Arunachal Pradesh which is salt and pebble, lithic arenite of Mio-Pliocene. Miri Formation is observed in between the thrust lines which include purple to pinkish, white to grayish white feldspathic quartzite, purple micaceous shale, diamictite conglomerate of Lower Palaeozoic. Bichom Formation includes Sesa member, Bomte member and Rilu member. Khatabari Formation is made of metasediments comprising sericite-quartz phyllite, garnetiferous phyllite and schist, graphite/carbonaceous phyllite, quartzite, minor carbonates chert and para-amphibolite exposed around Khetabari in the Lower Subansiri district. Se La Group is structurally the highest unit consisting of high grade schist, gneiss and migmatites, graphite schist, calc-silicate, marble, amphibolites and schistose quartzite. Extensive area of the Lesser Himalaya of Arunachal Pradesh is occupied by a gneissic complex referred to as Bomdila Gneiss which is a sequence of low to medium grade metasediments with associated gneisses and younger granitoids. Hapoli Formation which is newer alluvium includes sand, clay and peat of Holocene to Recent time. According to Laskar (in Krishnan, 1954) a sequence of cross bedded and ripple marked quartzite, banded in hues of pink, lavender, grey, light green and white, at the confluence of Kamla River and Pepiajuli stream in the Subansiri valley which is called Miri Formation.

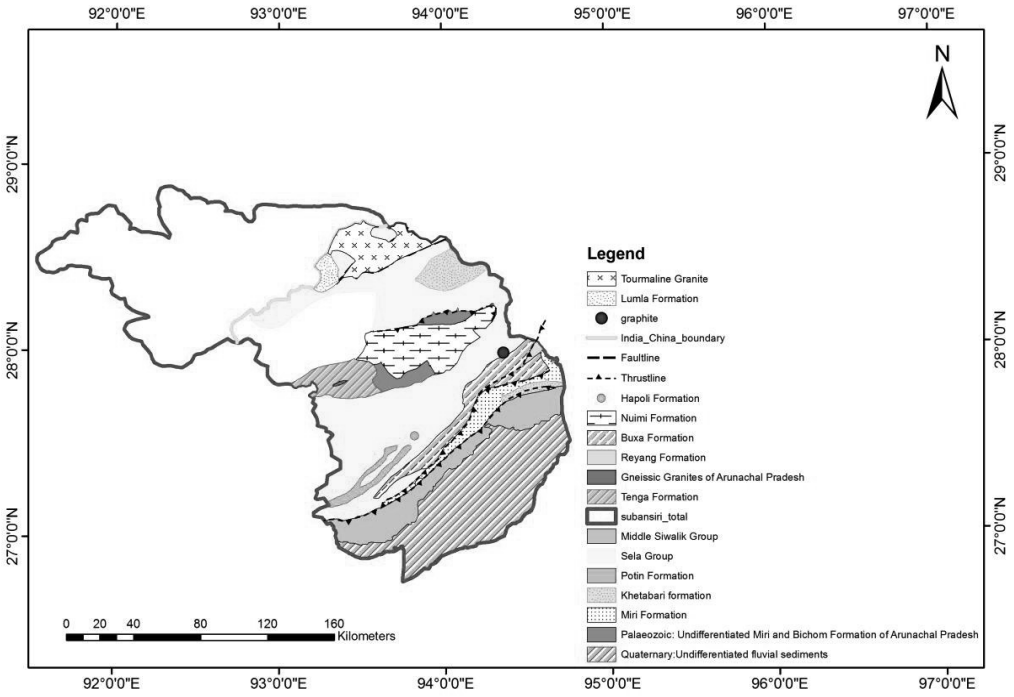


Figure 3.8: Geological map of the Subansiri basin

(Source: Based on GSI, 1998)

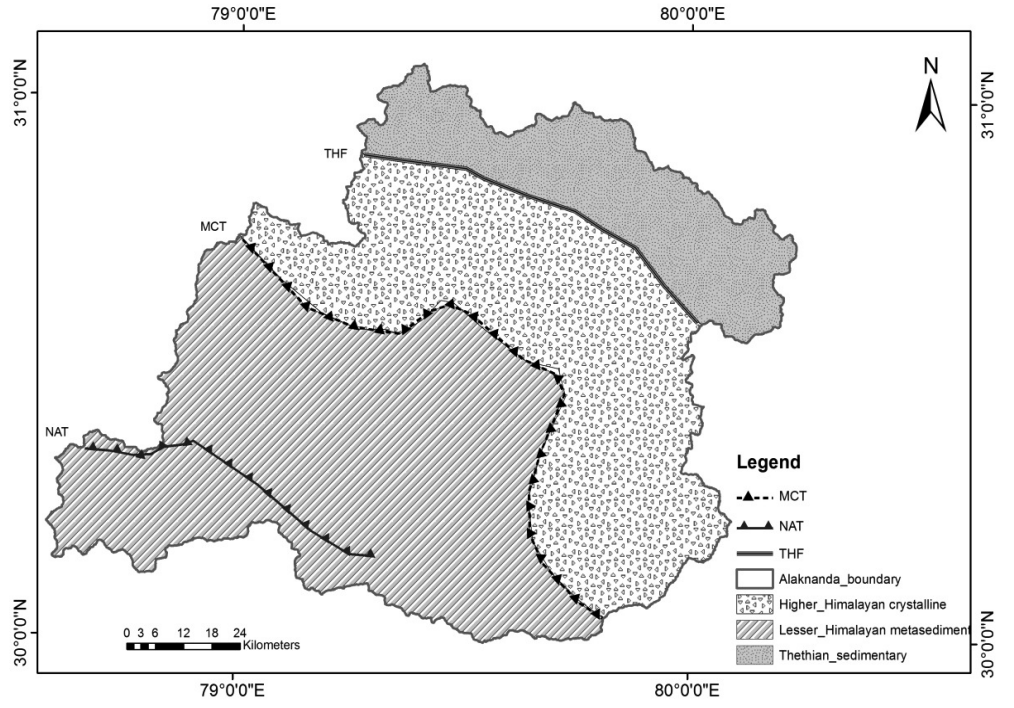


Figure 3.9: Geological map of the Alakanda basin

(Source: Based on Sati et al., 2007)

The physiographic belts of the Himalaya show specific rock and geological characteristics. The Tethys Himalaya is made of sedimentary rocks, the Great Himalaya is made up of metamorphic rocks (Central crystalline zone), the Lesser Himalaya is made up of Precambrian sedimentary rocks and some metamorphic rocks (Krol belt, Inner Sedimentary belt) and the Sub-Himalaya is made up of young friable sedimentary rocks (Siwalik zone). These belts are separated by regional tectonic lineaments (AHEC/2011).

The Alaknanda River catchment is underlain by both sedimentary and highly metamorphosed gneissic rocks (Gansser, 1964; Valdiya, 1980). In its upper course, the Alaknanda flows through the Higher Himalayan Crystalline zone, which is composed of migmatized and granitized Archean metasediments (Figure 3.9). After passing the Central Crystalline, the river traverses through limestones, marbles and quartzitic sequences of the Tejam and Berinag Formations. Before its confluence with the Bhagirathi, the stream passes through the limestone and dolomite-bearing Uttarkashi Formation and the outcrops of phyllite and micaceous graywackes of the Chandpur Formation. The tributaries of the Alaknanda also flow through a varied terrain of quartzites, limestones, shales and slates (Singh and Hasnain, 1998).

3.9 SOIL TYPE

Soil pattern and texture varies from the Greater Himalaya to the mid-altitudes and the valleys, and accordingly, soil fertility is varied. Landscapes of the greater Himalaya, consisted of very steep to steep slopes, are dominantly occupied by very shallow to moderate shallow, excessively drained, sandy-skeletal and loamy skeletal, neutral to slightly acidic, low water holding capacity soils, without profile development in association with rock outcrops.

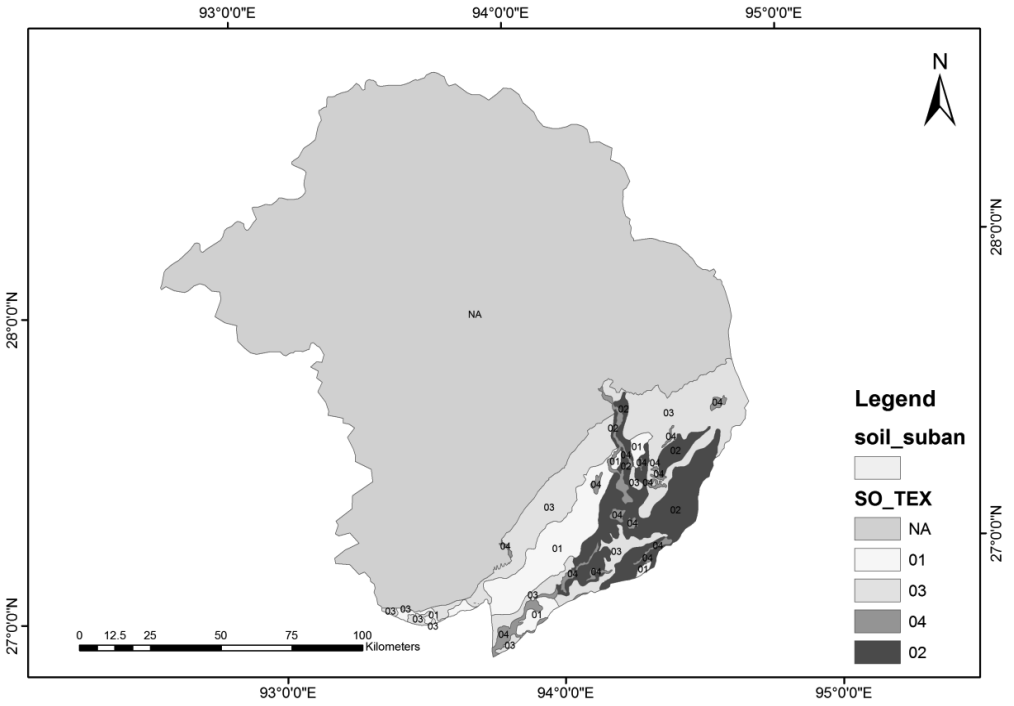


Figure 3.10: Soil map of the Subansiri basin in India

(Source: Based on NBSS & LUP)

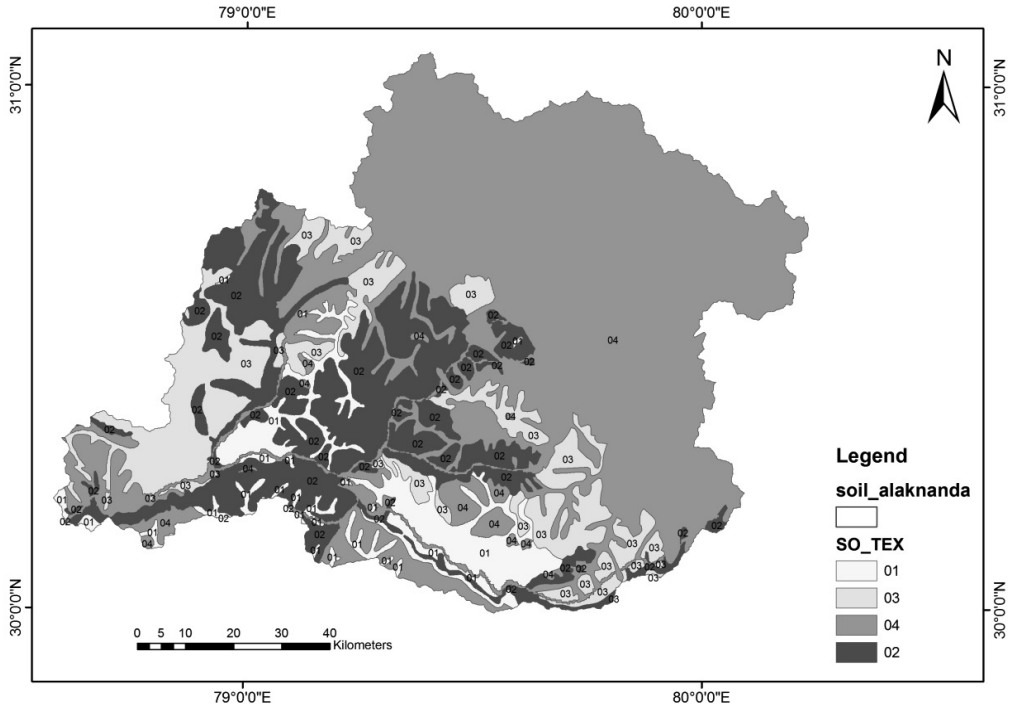


Figure 3.11: Soil map of the Alaknanda basin

(Source: Based on NBSS & LUP)

In the Lesser Himalaya, soils can be seen on steep to moderately steep slopes, that are shallow to moderately shallow, excessively drained, sandy/loamy skeletal/loamy with moderate erosion and moderate to strong stoniness. In the side slopes or terrace slopes, soils are moderately deep to deep, excessively drained, fine loamy, slightly to moderately acidic with slight to moderate erosion and stoniness. Soils in glacio-fluvial valley are moderately shallow, excessively drained, coarse loamy, slightly acidic and moderately stony.

In the state of Uttarakhand, large varieties of soils are seen. They vary from deep alluvial and fertile soils of the terai tract to the recently laid down alluvium of the dun valleys, the thin fragile soils of the Shiwalik hills, the black soils of the temperate zones and the arid, bare soils of the inner dry valleys (Chauhan, 2014).

Table 3.1: Description of the soil categories

Soil mapping unit	**Description**	**Taxonomy**
01	Clay, loamy clay, sandy clay, silty clay, sandy clay loam, silty clay loam	Fine texture
02	Loam, silt loam, silt, sandy loam	Medium texture
03	Loamy sand, sand	Coarse Texture
04	Rocky, other non-soil categories (-up, water bodies)	Others
NA	Data not available	

(Source: NBSS& LUP)

From the soil maps (Figure 3.10 and 3.11) and Table 3.1 it is observed that the soil of both the Subansiri and the Alaknanda basins are classified in four taxonomic classes viz. fine texture which includes clay, loam clay, sandy clay, silty clay, loam, silty clay loam and sandy clay; medium texture describes the loam, silt loam, silt and sandy loam; coarse texture includes loamy sand and sand while others includes rocky, built-up area, water bodies etc. In case of the Subansiri basin, only for the lower portion, soil type and taxonomic class descriptions are available. But the Alaknanda basin has a complete description of soil texture in the map. In the higher elevation mostly snow, glacier and barren land with rocky areas are available whereas in the lower elevations, all types of taxonomic classes of soils are seen.

3.10 SEDIMENT CHARACTERISTICS OF THE SUBANSIRI AND THE ALAKNANDA BASINS

Both the rivers, the Subansiri and the Alaknanda, originate from the high Himalayas and traverse maximum distance in hilly regions having deep gorges and steep slopes due to which they carry enormous quantity of sediment load along with heavy water discharge specially in the monsoon season. Deforestation, intense rainfall, landslides and erosion add more amount of sediment in the river water which leads to rising of the river bed.

The flow regime of most Himalayan rivers is directly dependent on the precipitation patterns in their watersheds. According to Sinha et al. (2002), high sediment production in the Himalayan region is favoured by monsoon rains in the source areas. Ferguson (1982) reported that sediment transport during monsoon season

exceeds 97% of annual load in some parts of the Hindu-Kush Himalayan Rivers (Chakrapani and Saini, 2009).

Suspended sediment load at Chauldhoaghat in the Subansiri basin is presented in the Figure 3.12 (Data in Table II in Appendix 1). The Subansiri carries an annual suspended load of 992 ha.m and its sediment yield is 959 ton/km^2/year (Bora, 2004).

Figure 3.13 (a and b) shows the sediment load and suspended sediment concentration characteristics in the Alaknanda river of western Himalaya for the period of 2004-05 (Data in Table III in Appendix 1). It is observed that the sediment load is relatively high in the monsoon period than the pre and post monsoon periods.

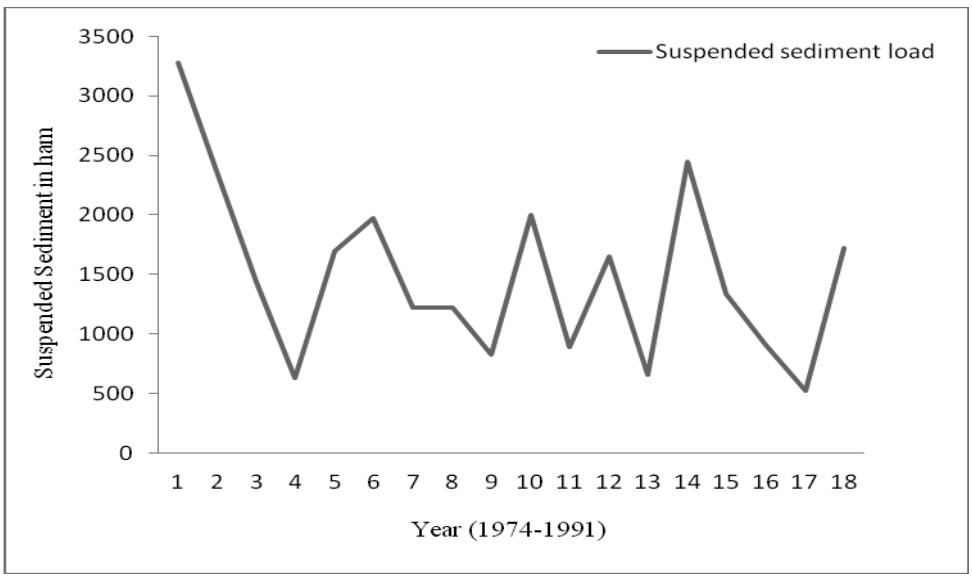
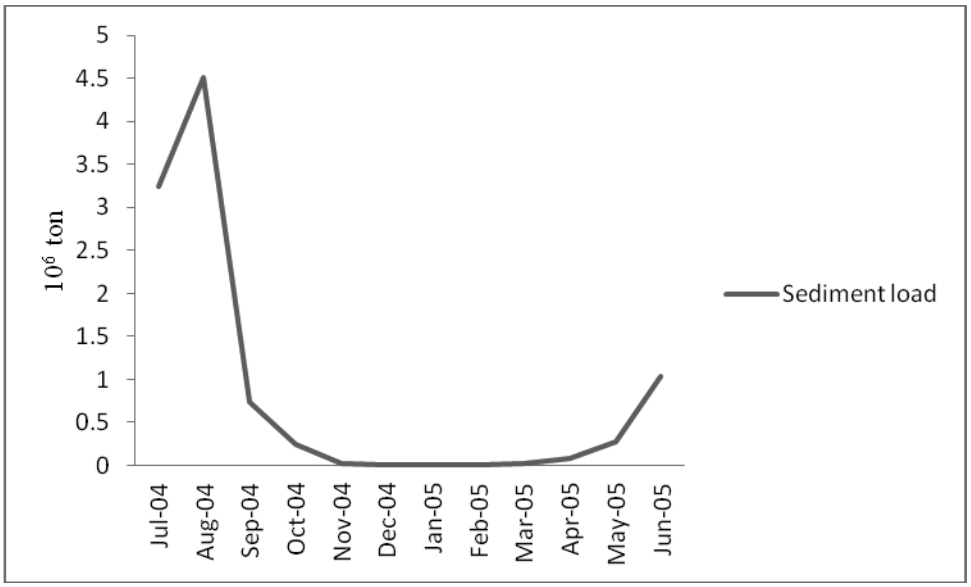
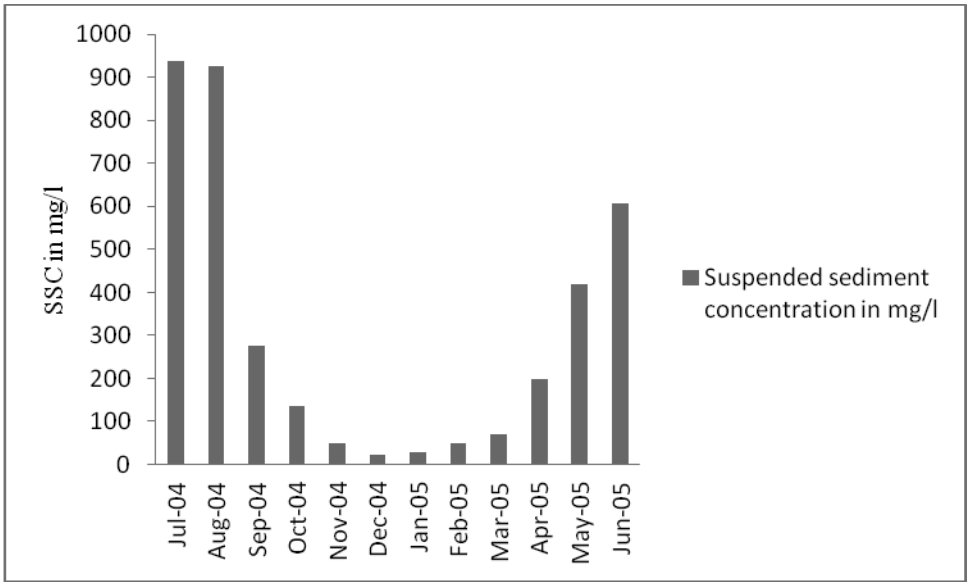


Figure 3.12: Suspended sediment load (ha.m) at Chauldhoaghat in the Subansiri basin

(Source: Brahmaputra Board, 2002)



(a)



(b)

Figure 3.13: (a) Sediment load and (b) Suspended sediment concentration in the Alaknanda basin for the year 2004-05

(Source: Chakrapani and Saini, 2009)

3.11 FOREST AND ECOLOGY OF THE SUBANSIRI BASIN

The entire Himalayan region is endowed with rich biodiversity. It may be due to the climatic variation from valley region to the elevated region. Forests are most important, both environmentally and economically.

The entire Subansiri basin especially the lower part is dotted with a large number of wetlands, locally known as beels. These are ecologically significant area which provides the habitat to a variety of floral and faunal species. There are several reserved forests (RF) in the basin such as Subansiri, Dulung, Kakoi, Kadam, Pava reserved forest etc. Both the Subansiri and Dulung RF constitute the Subansiri Important Bird Area which has global significance for bird conservation. There are varieties of fish species found in the basin. Among the aquatic fauna, the Gangetic River Dolphin is the most prominent one in the river confluence. There are 3 species of fishes found to be under endangered category. Besides fishes, turtles, some amphibians and dolphins are also under Schedule-I endangered species in the lower Subansiri basin (NHPC report on Subansiri Lower HEP, 2010). Fishing community is totally dependent on the adjoining areas of Subansiri river for fishing. It is seen that the foothill of the Arunachal Himalaya is highly rich in forest resources. Except the Tibetan region the entire part of the Subansiri basin in Assam and Arunachal Pradesh belongs to ten forest types. According to Champion and Seth Classification (1968) , the ten types of forests are (i) Tropical Wet Evergreen, (ii) Tropical semi Evergreen (found near alluvial plains), (iii) Tropical Moist Deciduous, (iv) Subtropical Broadleaved Hill (up to 900-1800 m), (v) Subtropical Pine (1000-1800 m), (vi) Himalayan Moist Temperate, (vii)

Himalayan Dry Temperate, (viii) Sub Alpine forest, (ix) Moist Alpine Scrub and (x) Dry Alpine Scrub.

Alpine forests are found in the elevation range 3000- 5500 m while Temperate Broad leaved forests are seen in between 1800-2750 m. Some of the plant species found in the lower Subansiri basin i.e. in near alluvial plains are Teak (*Tectona Grandis*), Jamuk (*Syzygium cumini*), Nahar (*Mesua ferra*), Bonsun, Titasopa (*Michelia champaca*), Gameri, Nuni or Mulbery (*Morus australis*), Som (*Persea bombycina*), Banana, Amoora wallichii, Hollock (*Terminalia myriocarpa*), Moj (*Albizia lucida*), Simul (*Bombax ceiba*) etc. In the range 900-1800 m, *Michelia spp., Rhododendron spp., Albizia spp*. etc are found. *Pinus roxburghii, Pinus wallichiana and Pinus merkusii* are observed in the elevation range 1000-1800 m. Temperate Broad leaved forests (1800-2700 m) include *Quercus lamellose, Quercus spp., Castanopsis indica* etc. *Rhododendron spp., Primula spp.* and *Saxifraga spp*. belonging to the Alpine type forest is found in 3000-5500 m elevation in the Subansiri basin. Besides these, the secondary forests such as Bamboo Brakes (*Bambusa pallida*), *Dendrocalamus hamiltonii* are found in the basin. It is reported that more than 23.52% of the flowering plants of India are found in Arunachal Pradesh. The state is rich in faunal wealth also. The larger animals like elephant, tiger, gaur, deers, and bears are distributed in the foothills and along the riverine forests of the flood plains. Arboreal animal like monkey, squirrels; various species of reptiles are also available in the basin area. Out of 3,500 endemic species of North East India 238 endemic taxa are listed from Arunachal Pradesh.

Some of the endemic species occurring in Arunachal Pradesh are *Aconitum lethale, Aglaia edulis, Albizia arunachalensis, Amentotaxus assamica, Anoectochilus sikkimensis, Aeschynanthus parasiticus, Begonia aborensis, Camellia siangensis, Curculigo crassifolia, Dioscorea wattii, Gastrodia arunachalensis, Grewia denticulata, Hedychium longipedunculatum, Litsea mishmiensis, Magnolia griffithii, Petasites kamengicus, Rhododendron nuttallii, R. tawangensis, Strobilanthes aborensis, Syzygium mishmiense* etc.

As per the study of Department of Botany, Gauhati University, the flora in the submergence area of Lower Subansiri HEP consist of 9 rare, threatened and endangered species but these are widely distributed in other parts of the State. Study shows that three threatened species namely *Begonia aborensis* (rare and endemic) and two orchids namely *Pholidota wattii* (endemic) *Vanda coerulea* (Rare) are recorded from submergence areas of Lower Subansiri HEP, Lower Subansiri district. As many as 220 endemic species have been listed from Arunachal Pradesh, out of which Subansiri Basin has 62 endemic species which account for 28% of the State's endemic flora. This is indicative of high endemism in the Subansiri Basin. There are 7 endemic species of Ericaceae, 3 endemic species of Begoniaceae and 1 species each of Orchidaceae and Arecaceace which are threatened as well (Final Report of CWC, 2014).

3.12 FOREST AND ECOLOGY OF THE ALAKNANDA BASIN

Among the other natural resources, the geographical area covered by forest is reported to be around 42.2 % in the Alaknanda Basin. From the valley region to the higher elevation, biodiversity is very rich. Alpine meadows (Kharak or Bugyal, locally

known) are found from the valley region. In the middle altitude, Pine (Chir) are found while in the upper reaches, temperate coniferous forest mainly Kharsu (*Quercus semicarpifolia*), Tilonj (*Q. dilitata*), Rianj (*Q. lanuginose*) and Banj oak (*Q. leucotricophora*) are abundantly found. Different types of fodder plants are found in the Alaknanda basin such as bhimal and khadik etc. The main forests are (i) Deodar Forests (*Cedrus deodara*; found in between 1650-2300 m; (ii) Blue Pine Forests (*Pinus wallichiana*; found in between 1650-2300 m) also known as Kail; (iii) Chir Forests (*Pinus roxburghii*; found in between 1000-1650 m); (iv) Oak Forests (*Quercus species*; found in between 1325-1625 m) and (v) Fir (*Abies pindrow*) & Spruce (*Picea smithiana*) forests found between 2300-2950 m. In the high altitude, these forests help to increase the soil fertility because soil is brought with rainwater and deposited in the lowlands (Sati 2006a, b, c, d, e, and f).

The state of Uttarakhand where the Alaknanda basin lies is declared as the Herbal State by the Government in 2003 and is blessed with thousands of species; about 320 species have been identified in terms of their medicinal value. The region is well known for growth of wide variety of medicinal and aromatic plants. Within the Alaknanada basin, the Nanda Devi NP and Valley of Flowers NP are two areas with rich biodiversity values that have also been designated as UNESCO World Heritage site. These basins have high floral and faunal diversities and some valleys have unique biodiversity values and high densities of species particularly, Rare, Endangered & Threatened (RET) species.

3.13 WETLANDS OF THE SUBANSIRI BASIN

Wetlands are the transitional lands between terrestrial and aquatic ecosystems and one of the most productive ecosystems in the world. Under the Convention on Wetlands (Ramsar, Iran, 1971) 'wetlands' are defined as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters. It holds and purifies water and provides shelter to a number of aquatic flora and fauna. Plants found in wetlands help control water erosion. Wetlands play a significant role in climate stability, maintenance of ecological sustainability and also recreation to the society. Wetland statistics of the Subansiri basin is shown in the Table 3.2.

The part of the Subansiri basin lying in the state of Assam shows a decreasing trend in the number of wetlands with a total number of 664 existing wetlands in 1967-68, 423 wetlands in 1990, 346 in 2000 and 318 in 2007 (Gogoi, 2013).

Table 3.2: District wise wetlands in the Subansiri basin in Arunachal Pradesh

Serial no.	District	Geographical area (in sq.km)	Wetland area (in ha)	% of total wetland area	% of district geogr. area
1	Lower Subansiri	10125	3607	2.32	0.36
2	Upper Subansiri	7032	3365	2.16	0.48

(Source: CWC Report, 2013)