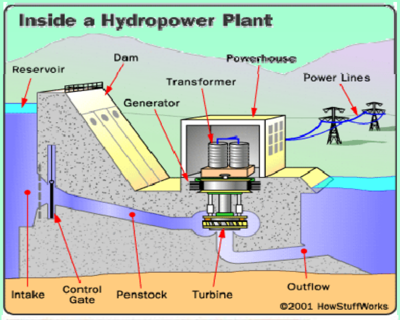
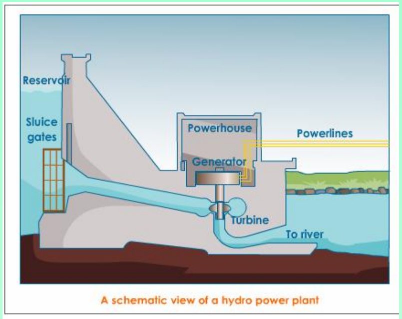
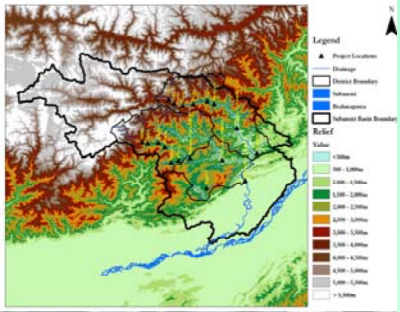
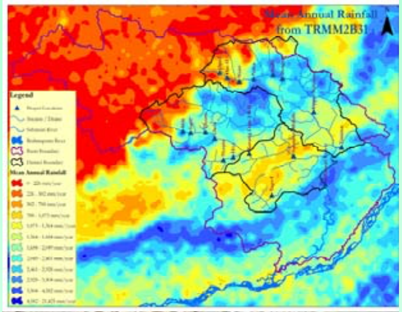
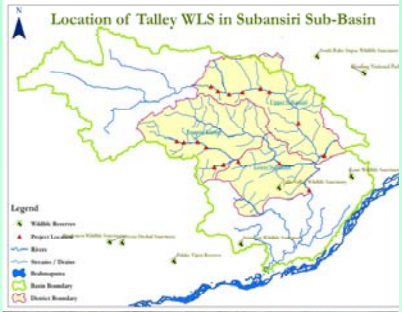
Cumulative Impact and Carrying Capacity Study of Subansiri Sub Basin including Downstream Impacts











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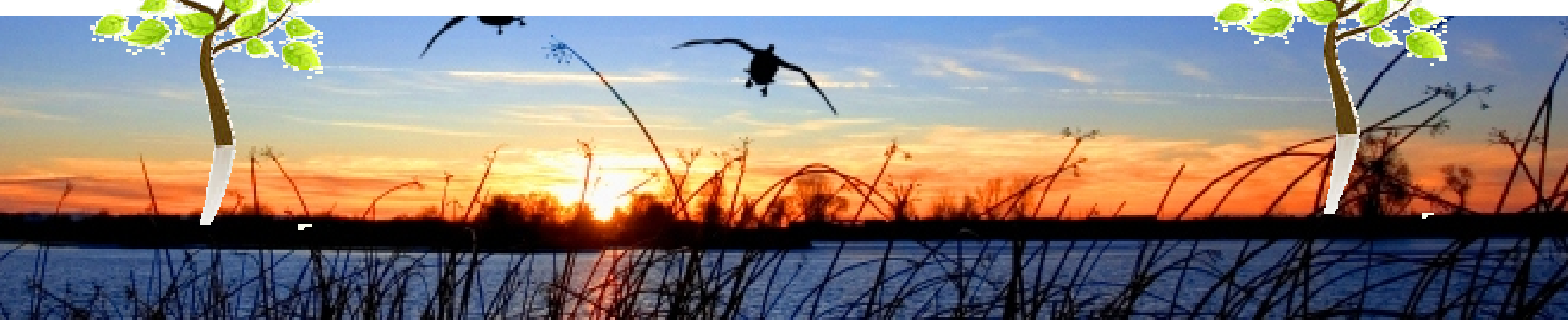

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Chapter 1: Introduction

1.1 Background

Central Water Commission (CWC), Government of India has undertaken the task of conducting, "Cumulative Impact and Carrying Capacity Study of Subansiri basin including Downstream Impact in Brahmaputra River Valley" with an objective to assess the cumulative impacts of hydropower development in the basin. Expert Appraisal Committee (EAC) for River Valley and Hydroelectric Projects of Ministry of Environment & Forest (MoEF) GoI has provided the Terms of Reference (TOR) for this study. IRG Systems South Asia Pvt. Ltd. has been awarded the study by CWC based on techno- commercial bidding. The study initiated from December 2011 involved extensive field data collection in different seasons to establish baseline status, data analysis and cumulative impact assessment, followed by recommendations for long term sustainable hydropower development in the basin.

As per Central Electricity Authority (CEA) estimates, the basin has 6092 MW hydropower generation potential (60% load factor) with a probable installed capacity of 13767 MW. This potential is planned to be harnessed by setting up about 19 hydropower projects spread throughout the basin.

Such a large-scale development expected to take place over a period of next 10-15 years in otherwise pristine area, can cause serious environmental impacts. EIA notification of September 2006, issued under Environmental Protection Act, 1986, has the provision of evaluating the impacts of individual projects of capacities 25 MW or more by SEAC/EAC before issuing environment clearances. However, in a situation where several projects are planned in cascade utilising the same natural resource; assessment of cumulative impacts is essential to plan development in environmental friendly manner and to mitigate and manage the impact comprehensively. Therefore, the current study of Subansiri Basin has been prepared with a view to provide optimum support for various natural processes and allowing sustainable activities. The study covers the following:

- Inventorisation and analysis of the existing resource base
- Determination of regional ecological fragility / sensitivity
- Review of hydropower development plans
- Evaluation of cumulative impacts on various facets of environment due to hydropower development
- Broad framework of environmental action plan to mitigate the adverse impacts on environment, in the form of: Preculsion of an activity; Modification in the planned activity and Implementation of set of measures for amelioration of adverse impacts.

The basin study is a step beyond the individual EIA of such projects as it incorporates an integrated approach to assess the impacts due to various developmental projects.

1.2 Study Area

The study area being covered as a part of the Basin Study is entire Subansiri Basin. The study area lies between latitude 27°N & 29° North and longitude 91°45` East & 94°45` East and administratively falls in Upper Subansiri & Kurung Kumey district of Arunachal Pradesh. **Figure 1.1** describes the study area.

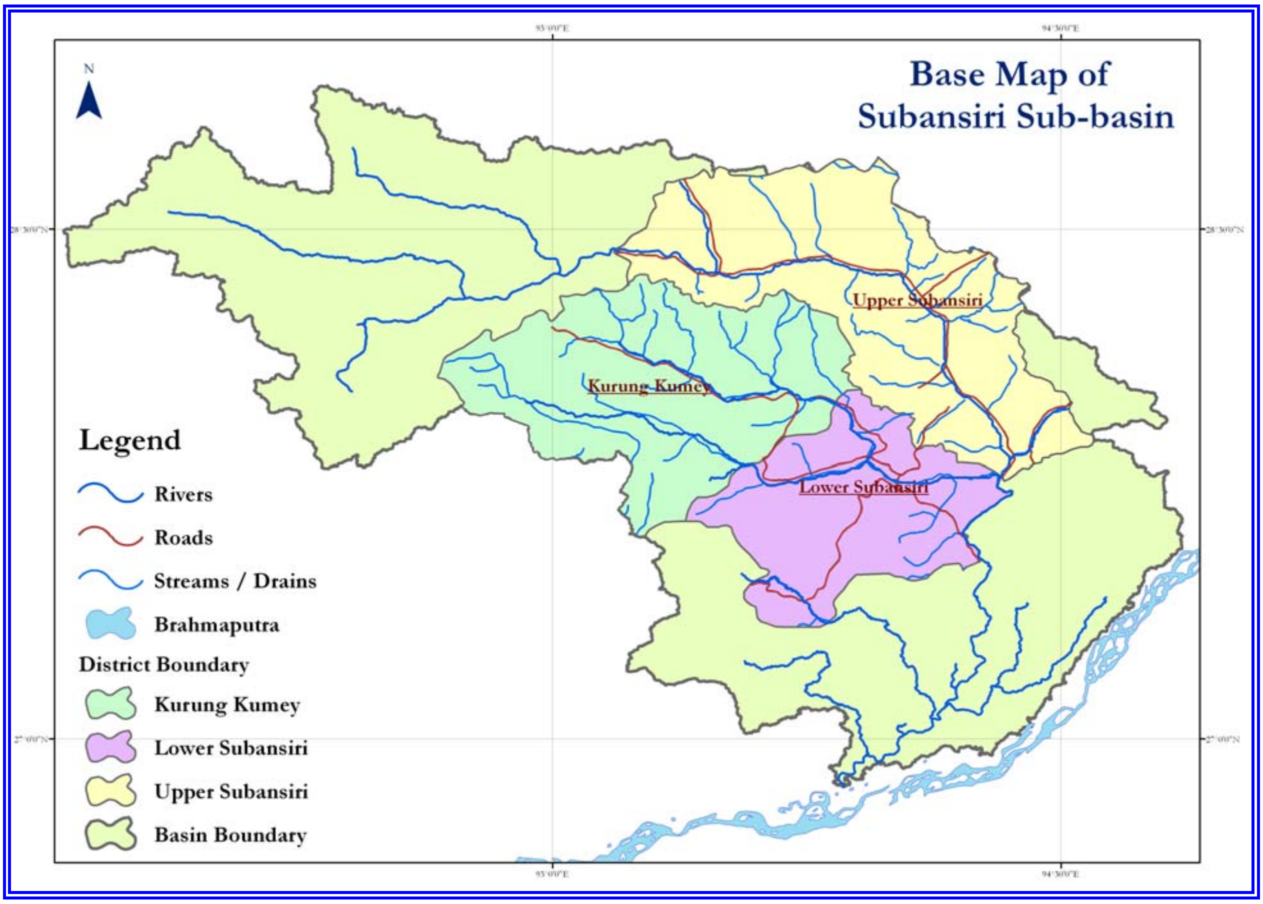


Figure 1.1: Study Area

1.2.1 Hydro Electric Projects Envisaged in Subansiri Basin

11,096 MW hydropower potential in the basin has been planned to be harnessed by setting up about 19 hydropower projects spread throughout the basin. Out of nineteen planned hydropower projects, fourteen projects have been allotted while five projects namely Mili, Sape, Tamen, Tago – I and Tammu HEPs are CEA identified projects and have not been allotted to any agency (as on 12/06/2014). Only one Environmental Clearance to a project (Lower Subansiri HEP) has been awarded in the basin.

1.3 Scope of Work (SoW)

The Terms of Reference (TOR) of this study was earlier approved by EAC, MoEF and the SOW and approach and methodology of this study has been formulated by CWC in line with this TOR. The SoW of the current study is as per item A (1 to 6) and item B of the MoU is given in **Annexure – 1.1**.

1.4 Outcome of the Study

The key outcomes of the study are:

- Provide sustainable and optimal ways of hydropower development of Subansiri River, keeping in view of the environmental setting of the basin.
- Assess requirement of environmental flow during lean season with actual flow, depth and velocity at different levels.
- Downstream impacts on Assam due to hydropower development in Subansiri basin in Arunachal Pradesh.

1.5 Outline of the Report

The Final Report consists of 11 chapters as given below.

Chapter 1 describes Introduction and Background

Chapter 2 describes Basin Characteristics

Chapter 3 Hydropower Development in Subansiri Basin

Chapter 4 Hydrometeorology

Chapter 5 Methodology

Chapter 6 Terrestrial Ecology

Chapter 7 Aquatic Ecology

Chapter 8 Environmental Flows

Chapter 9 Downstream Impacts due to Hydropower Development

Chapter 10 Cumulative Impact Assessment

Chapter 11 Conclusions & Recommendations

Chapter 2: Basin Characteristics

2.1 Introduction

Arunachal Pradesh is a thinly populated hilly state on the extreme northeast part of India. It is situated between latitude 26°40'N and 29°25'N and longitude 91°35'E and 97°25'E. The state shares international border with Bhutan in west, China in north and northeast and Myanmar in east and interstate borders with Nagaland in southwest and Assam in south. It covers an area of about 83,743 sq km extending along south slope of Eastern Himalaya and the western slope of the Patkoi hills around the Brahmaputra Valley. The capital of the state is Itanagar, which falls in Papum Pare district. The state is administratively divided into 17 districts viz. Tawang, West Kameng, East Kameng, Papum Pare, Lower Subansiri, Kurung Kumey, Upper Subansiri, West Siang, East Siang, Upper Siang, Lower Dibang Valley, Dibang Valley, Lohit, Anjaw, Changlang, Tirap and newly created Longding district. The Subansiri basin falls in three districts viz. Upper Subansiri, Lower Subansiri & Kurung Kumey.

Subansiri River originates in Tibet (**see Figure 2.1**) and is the major right bank tributary of Brahmaputra traversing through Arunachal Pradesh. There are six major river basins in Arunachal Pradesh viz. Kameng, Subansiri, Siang (Dihang), Dibang, Lohit and Tirap with large number of their tributaries draining the waters of vast catchment area into the Brahmaputra (**see Figure 2.2**). Subansiri River offers phenomenal hydropower potential due to topographical conditions accompanied with rainfall in its catchment ensuring significant discharge in the river throughout the year.

2.2 Physiography & Drainage Network of River Subansiri

River Subansiri rises from the Kangig glacier range in Tibet at an elevation of 7090 m (23260 ft) above mean sea level. Total length of the river in India is around 326 km. up to its confluence with Brahmaputra. Major tributaries of the river are Laro, Nye, Yume, Tsari, Kamla, Jiyadhol, Ranganadi and Dikrong. The Subansiri River meets Brahmaputra about 25 Km downstream of Jorhat.

In the upper reaches it is called Nye Chu, which receives its waters from the snow clad peaks of Krakang, Shubuta, Baru and Mata. Near its source, several snow – fed mountain torrents drain into Nye Chu on both its banks. From its origin, the river flows in south – eastern direction and is joined by Laro Chu near Chayal. After its confluence with Laro Chu the river is called Chayal Chu, which flows in the eastern direction.

Char Chu, rising from the snow clad peaks in the North and flowing in south – eastern direction is joined by Yume Chu and the combined flows of the two streams join Chayal Chu near Karutra, a few kilometers upstream of the International Boundary Line. Tsari Chu, another tributary rising in the North meets Chayal Chu near Siyum and the combined water of these streams flow as Subansiri for about 200 km from this point, finally out falling into Kherkutia Suti, a spill channel of the Brahmaputra. In higher reaches, where Subansiri is known as Tsari Chu, it is flowing in Easterly direction. The River cuts across the Central Himalayan ridge, which has a series of high peaks of 5000 m and above. It follows a South – Easterly course along the lesser Himalayan zone with an average height of about 3048 m and takes the name Subansiri.

After crossing the International boundary, it approaches the Indian Territory in Arunachal Pradesh; the river runs in an unexplored valley. In its early reaches, as the river gathers more and more torrents in the Himalayas, it rushes through deep gorges far below the snow capped mountain peaks. Initial course of Subansiri after entering in Arunachal Pradesh is little known as the valley is covered with dense vegetation and impenetrable forests. Throughout its journey from the central Himalaya to the Arunachal foothills, the Subansiri receives the discharges of numerous mountainous big and small streams. The number of its tributaries is more in the Siwalik foothills than in other zones. The Subansiri debouches into the plains of Assam near Dulangmukh. Before entering the plains, Subansiri cuts a steep gorge through the Siwalik rocks of Arunachal Himalaya. The total length of the river in the mountainous terrain is about 208 km. Within Indian Territory the foothills, the riverbed falls from a height of 4206 m to 80 m near Dulangmukh. After flowing for about 70 km from the hills, the river falls into the Kherkutia Suti and thereafter flowing for another 60 km it outfalls into the River Brahmaputra.

The Subansiri basin can be divided into four parts viz.; A) Chinese / Tibetan high elevation stretch till the international border; B) the stretch lying between the international boundary and upper reaches of Arunachal Pradesh; C) the Arunachal Pradesh stretch upto the inter-state boundary of Assam and Arunachal Pradesh and D) the plains of Assam. The first two belong to the great Himalayan range, the third belonging to the Sub-Himalayas and the fourth in the fertile plains of Assam.

The percentage contribution of Subansiri River as observed at Chouldhowa Ghat with respect to the discharges observed at Pandu near Guwahati from 1956 onwards is of the order of 10.3%. The catchment area of the Subansiri basin partly lies in the Himalayan ranges of Arunachal Pradesh including Tibet and partly in the Himalayan foothills of Assam. The total catchment area up to the confluence with the Brahmaputra is about 37,000 sq. km. out of which 14,000 sq. km. is in Tibet (40%) and the rest (60%) lies in India (21,800 sq. km. in Arunachal Pradesh and 1,200 sq. km. in Assam). The topography of the Basin is mostly mountainous terrain, where the Hill Ranges vary approximately from 1000 to 4600 metres above sea level. A greater part of it falls within the higher mountain zone consisting of peaks and valleys. The limit of perpetual snow line in the North Eastern part of Himalayas varies widely depending upon various local factors. The present snow line varies in altitude from about 4267 m in the eastern part to 5182 m in the western Himalayas. About 4000 sq. km. of drainage area of Subansiri falls in the perpetual snow. In the upper reaches, the river and its tributaries are fed by snow melt and in the lower reaches by rainwater. The permanent snow line for Subansiri basin has been adopted at EL 4500 m (**See Figure 2.4**). The catchment area in Tibet and Arunachal Pradesh is highly mountainous and is covered with very thick and dense forest. The catchment is of crescent shape with its concavity on the western side.

The Subansiri flows through the Districts of upper and lower Subansiri leaving the Lower Subansiri District at Dulangmukh Circle, it ultimately joins the Brahmaputra in the plains of Assam.

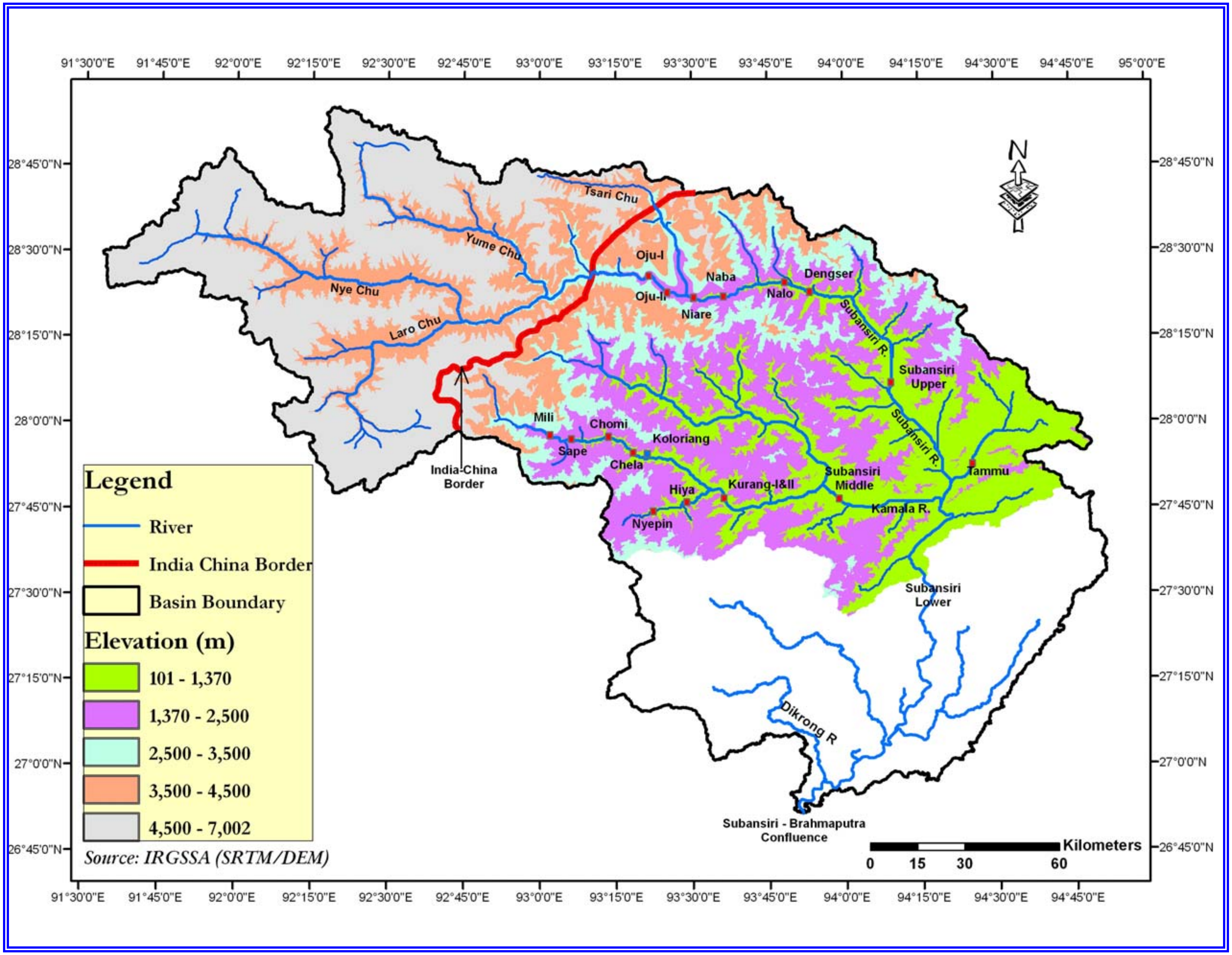


Figure 2.1: Drainage Map of Subansiri River from its Origin in Tibet up to confluence with Brahmaputra

The Main River

Figure 2.1 indicates that the principal stream is known as Nye Chu which travels a distance of about 170 km. towards East and receives an important right bank tributary Laro Chu. The combined flow then travels 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 Chayal Chu. The Chayal Chu near Karutra crosses the international boundary and is known as Subansiri. A small left bank tributary known as Sang Chu joins the River Subansiri 23 km. eastward of the confluence point of Chayal Chu with Yume Chu. The river then flows eastward up to a distance of 38 km. where it meets with an important left bank tributary Tsari Chu. From this point, the river travels a distance of about 27 km. up to the boundary of hill catchment near Gerukamukh. Here this river again receives left bank tributaries like, Sichi River, Siyu River and Sigen River at a distance of 27 km., 93 km. and 111 km. respectively from the confluence point of Tsari Chu. Right bank tributaries like Singen, Kamala and Sipu River joins the River Subansiri at a distance 71.5 km., 101 km. and 129 km. from the aforesaid confluence point.

The main course of the Subansiri after entering the Miri hills in Arunachal Pradesh runs between the Dafla and Abor hills. Even in this reach, it is covered with dense vegetation and impenetrable forest.

After Gerukamukh, the river enters in the plains of Assam and receives important right bank tributaries like Boginadi. A few left bank tributaries like, Dirpai, New Chauldhowa, Old Chauldhowa meets the River Subansiri just after Gerukamukh. In the broad and flat valley, the river flows in slow and sinuous curves. In spate during monsoon, it is a swirling mass of brown water heavily charged with silt. But in winter it flows smoothly with surface of luminous green. The drainage map of the river in Arunachal Pradesh is given in **Figure 2.3**.

Tributaries of Subansiri River

The river system of Subansiri consists of 17 numbers of main sub-tributaries out of these 8 (eight) numbers are left bank tributaries and 9 (Nine) numbers are right bank tributaries. An overview of the major tributaries of Subansiri River is given in **Table 2.1**, with description given below.

Kamla River

Kamala is an important hilly Sub-Tributary of Subansiri. It rises as three main channels from glaciers in the southern great Himalayas and joins the Subansiri on the right bank, at a distance of about 148 km. from the point of confluence of the Yume Chu and Tsari Chu. The river runs along for another 30 km. through steep gorge to emerge from the hills through a short canyon to the Subansiri River. The entire course of the Kamala is confined to narrow gorge. The river drains in Central Arunachal Pradesh. The Kamla River flows in a general direction towards North-West to South East and joins the Subansiri River near Rachrath.

Phura River and Panya River in the left bank and Kurung River, Rein River & Persen River on the right bank of Kamla River and other numerous sub-tributaries of these rivers flow into the Kamla River. Kamla River & Kurung River confluence is near Rai and Boa. The entire catchment of this river bears thick forests. Niktak, Par, Hachi, Onga and Gocham are some villages along this river.

Source: www.internationalrivers.org

Figure 2.2: Administrative Map of Arunachal Pradesh showing districts and different River Basins

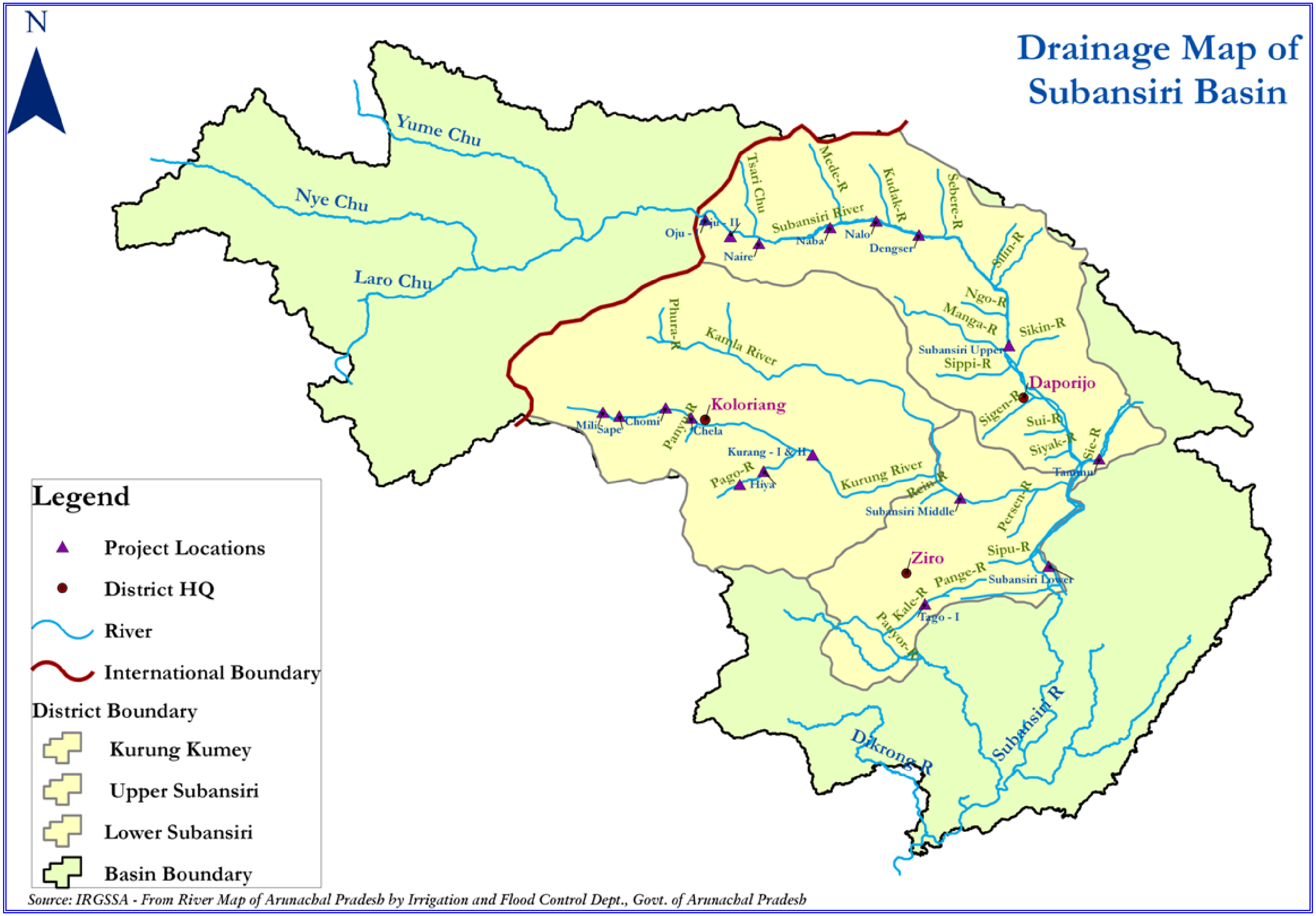


Figure 2.3: Drainage Map of River Subansiri

Kurung River

Streams originating from glaciers in the Southern Himalayas merge to Kurung River upstream of Mili. It flows in South East direction in Kurung Kumey district & takes a left turn in Lower Subansiri district to merge with Kamla River.

Panyu River and Page River on the right bank of Kurung River and other numerous sub-tributaries of these river flows into the Kurung River. Kamla River & Kurung River confluence is near Rai and Boa. The entire catchment of this river bears dense forests. Amongst the settlements that have come up along the Kurung River are Dui Yambi, Takum, Palin and Bindula.

Table 2.1: Drainage Profile of Subansiri River System

Main Tributary	Catchment Characteristics	Right Bank / Left Bank	Confluence point with the Subansiri River	Major Streams joining the tributary
Kamla River	The drainage network of this catchment is represented by combination of rectangular & dendritic pattern. The upper part of the catchment is covered with snow clad mountains & glaciers, barren & rocky waste land. Most part of the catchment is covered with semi-dense mixed subtropical, semi evergreen forest.	Right Bank of Subansiri and Left Bank of Kurung River	Near Rachrath village	**Left bank of Kamla River:** Phopan N, Lomi N, Tolo N, Loba N, Phusay N, Suko N, Panyo N, Kaleng N, Patey N Selu N Hagong N, Pai N, Nyhaya N, Jongsai N, Palam Kro, Pal Suko, Pal Lada, Kueni Kro, Puku Kro, Roh Kro, Paja Kro, Pein Kro, Panya N and Pa Kro. **Right bank of Kamla River:** Folong N, Hopar N, Kede N, Pado N, Palin N, Tamin N, Hate N, Cherak N, Tiri N, Cherak N, Hate N, Pale N, Pale N, Poush Suko, Chemba Kro, Charli Kro, Pim Kro, Podu Kro, Pal Kro, Pet Kro, Pain Kro Pa N, Pal N, Simla Kro, Miji Kro Pa N, Tektir N, Didi Kro, Kachi Kro, Sidi Kro Gote Kro etc.
Kurung River	The drainage network of this catchment is represented by a combination rectangular & dendritic pattern. The upper part of the catchment is covered with snow clad mountains & glaciers, barren rocky, waste land. Most part of the catchment is covered with semi-dense, mixed subtropical & semi evergreen forest.	Right Bank of Kamla River	Near Rai and Bao village	**Left bank of Kurung River:** Soro N, Panga N, Wasalu N, Lalung N, ShlkaviN Wabhang N, Phayang N, Phullk N, Muju N, Phurchi N, Pate N, Pate N, Paya N, Pape N, Papha N, Palbung N, Pateng N, Chlku N, Pyani Sekho, Pabi Pabung, Sinni N Pate N, Paring N, Panap N, Pabya Pabung and Pal Suko. **Right bank of Kurung River:** The right bank tributaries are Wajai N, Bhalu N, Phum N, Phimiri N, Kini N, Kush N, Dokyo N, Pachu N, Gate Pabung, Pai Pabung and on Panyu River two tributaries are Phimiri N and Kini N and some of the tributaries on Page River are Pinchi N, Biyo N, Payu N, Pani N, Yachi N, Sukya Pabong Kiding Pabong Paji N, Yomiba N, Rake N and Anna.

For the convenience of the study and analysis of various physical and biological parameters and their interpretation, entire Subansiri basin in India has been delineated into three sub – basins comprised of major tributaries and covering varied domains as well as proposed hydroelectric projects (**Figure 2.4)**. The characteristics of each sub-basin have been listed in **Table 2.2**.

Table 2.2: Characteristics of Sub-basins of Subansiri River basin

S. No.	River/Sub -basin	Altitudinal Range (m)	Projects	River/Stream
	Subansiri			
1	Subansiri / Singit	120 - 1868	Oju – I Oju – II Niare Naba Nalo Dengser Subansiri Upper	Subansiri
2	Siu	360	Tammu	Siu
3	Subansiri	120	Subansiri Lower	Subansiri
	Kamla			
4	Kamla	131	Subansiri Middle (Kamala HEP) Tamen	Kamla
5	Kale	1024	Tago -I	Kale
	Kurung			
6	Kurung	660 - 1285	Kurang – I&II Mili Sape Chomi Chela	Kurung
7	Payam	1011 - 1274	Nyepin Hiya	Payam

2.3 Relief

The Subansiri catchment area has been divided into 12 elevation bands **Figure 2.4**. Each of the intermediate elevation bands covers elevation range of 500 m. The southernmost part of the basin adjoining the state of Assam near its confluence with Brahmaputra ranges from about <500m to 1000m. This band is also prevalent in the lower Subansiri and its channels. More than 55% of the basin area lies in the 500 to 1500 m elevation band. Similarly area between 1500m to 2500m also covers nearly 23% of total basin area.

2.4 Slope

More than 85% of the basin lies in three categories i.e. Extremely Steep, Very steep and Steep slopes. The Extremely Steep slope category itself account for 52% of basin area. Gentle to moderate slopes cover little more than 1% of the area and such areas are distributed in the basin, particularly along the river and slopes along the stream banks. Strongly sloping areas cover 1% of the basin area and are prevalent mostly alongside the rivers. The extremely sloping category is characteristic of headwater regions of the Subansiri River **Figure 2.5**.

2.5 Geology

In Arunachal Pradesh, two young belts E - W Eastern Himalayas and N - S Indo - Myanmar mobile belts exist, which meet almost at right angles to each other. The region has been divided into four physiographic segments, with major tectonic features lineaments separating each segment as given below. The geological features and mineral Map of Arunachal Pradesh including Subansiri basin are given in **Figure 2.6**.

Eastern Himalayan Mobile Belt rises abruptly from the Brahmaputra plain and merges with Tibetan plateau in the north. This belt covers about 350 km of Eastern part of Himalayas, known as the Arunachal Himalayas and extends from Eastern Nepal in the west to the West Siang district of Arunachal Pradesh in the east, terminating against N – W trending para-metamorphites and diorite - granodiorite complex of Mishmi block of Lohit district of Arunachal Pradesh. The eastern mobile belt embodies a succession of northerly dipping thrust sheets covering almost the whole of Arunachal Pradesh.

Deep erosion along these thrust contact brings about the four well known E – W trending physiographic units of the eastern Himalayas namely Sub - Himalayas, Lesser Himalayas, Higher Himalayas and Tethyan belt or Tibetan Himalayas. North of it lies zone of Indus - Tsangpo suture. Upper part of Subansiri basin falls in this belt.

Mishmi Block lies adjacent to the Naga - Patkai ranges of Arakan – Youma Mountains to the south along another tectonic plate - the Mishmi thrust. The Himalayas at the eastern end gets terminated along the Tidding suture and meets another chain of mountains - the Mishmi hills, which are the part of Mishmi block mobile belt. These mountain ranges, trending NW - SE are said to be a continuation of the hill ranges of northern Myanmar (Burma), but are also considered to be in continuation of the Ladakh ranges lying to the north of Indus - Tsangpo suture.

These are made up of diorite - granodiorite complex with a frontal belt of high grade schists and migmatites, and inner belt of low grade schist with crystalline limestone and serpentinite lenses. The important tectonic activities in this block are Mishmi thrust, Tidding Suture, Lohit thrust and Pochu fault.

Indo - Myanmar (Burmese Belt) Mobile Belt: The Patkoi - Naga - Manipur - Chil Hills - Arkan Yoma region forms a westerly convex arcuate belt in the eastern part of the Arunachal Pradesh, which is an eastern portion of the Indo - Myanmar (Burmese) mobile belt and is made up of Paleogene - Neogene sediments.

Brahmaputra Plains: This is an ENE - WSW trending relatively narrow valley bounded by two young mountain belts to the north and south east, Mishmi block to the north east and Meghalaya plateau to the south. The valley is filled by thick alluvium with a few inselbergs of basement rocks from Tezpur west wards. Almost flat lying tertiary shelf sediments overlie the basement whose thickness increases from south to north towards Himalayas.

Geological features in the Subansiri Basin show marked variation ranging from Higher / Lesser Himalayas, foothills and plains falling in Bomdila group, Miri Group, Gondwana Group and Siwalik Group as well as Alluvium. This indicates that basin has different types of formation with very significant slopes, ultimately terminating into plains at the confluence with Brahmaputra.

The geological features further indicate the tendency of river to bring down material, which deposits as alluvium in the plain.

It can be inferred that though significant slopes in the basin offer good hydropower potential, it also indicates the vulnerability of the catchment at the proposed sites, the degradation of which if any in future can lead to soil erosion & siltation.

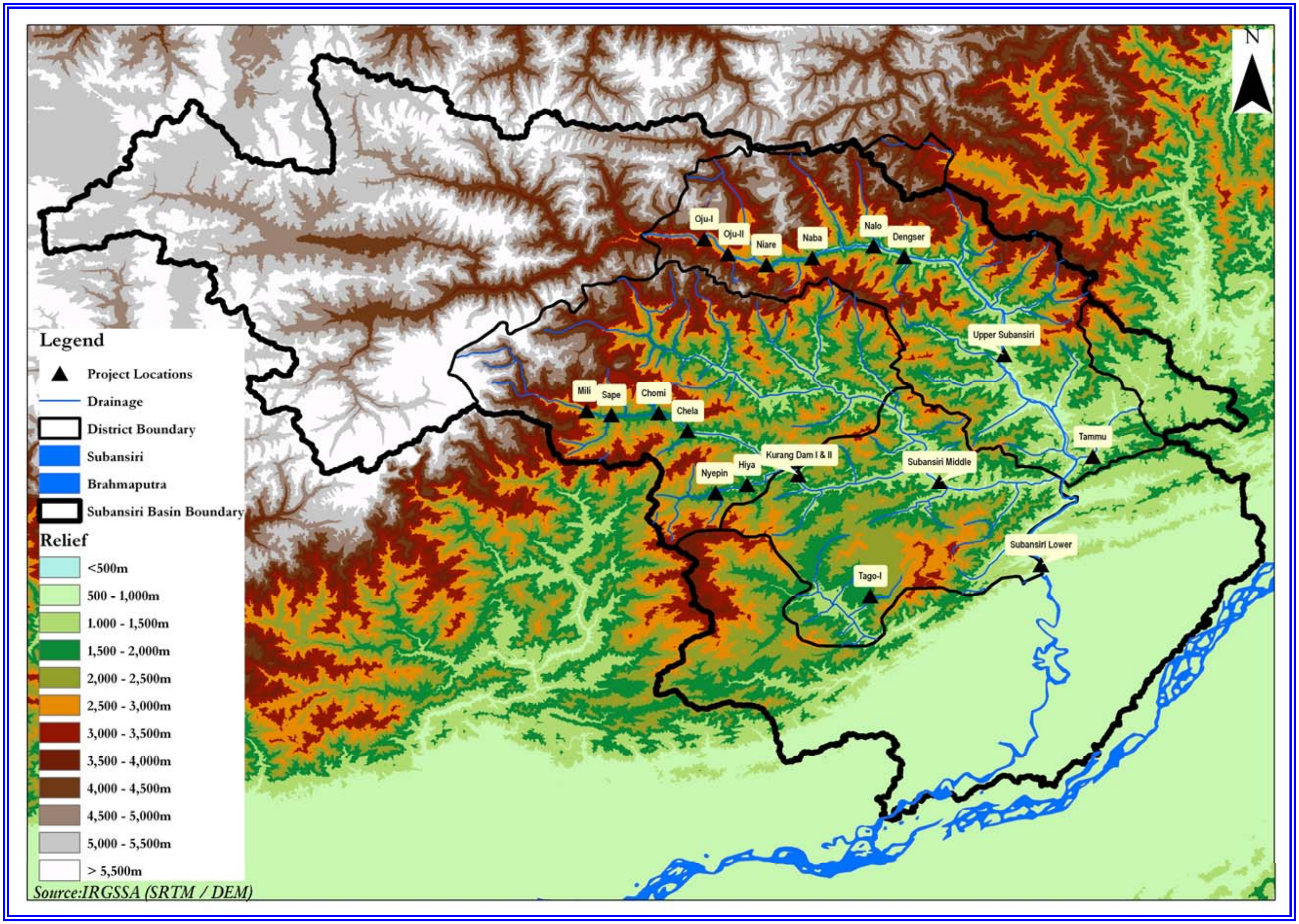


Figure 2.4: Relief Map of River Subansiri basin showing area under different elevation ranges

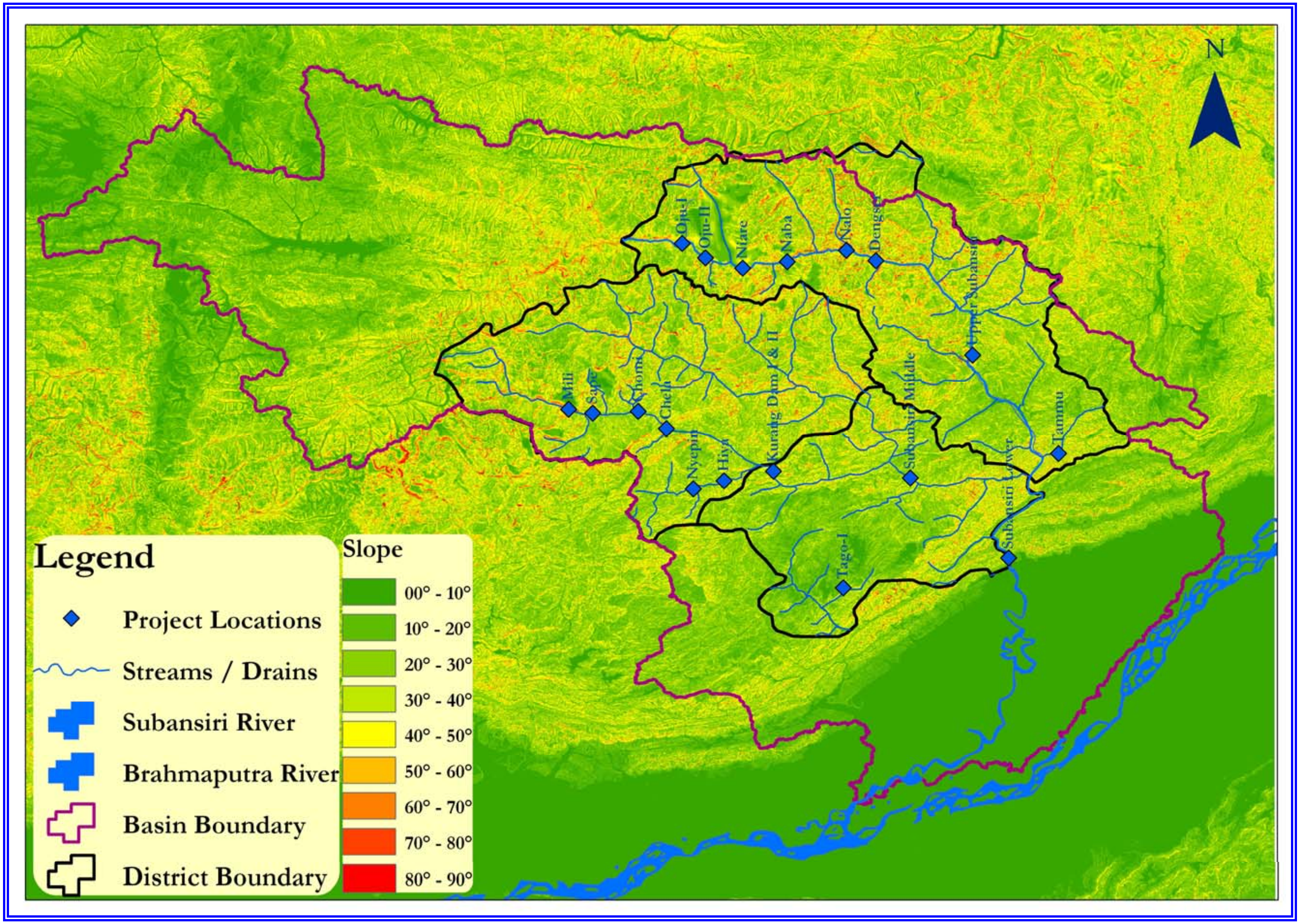


Figure 2.5: Slope Map of Subansiri Sub-Basin

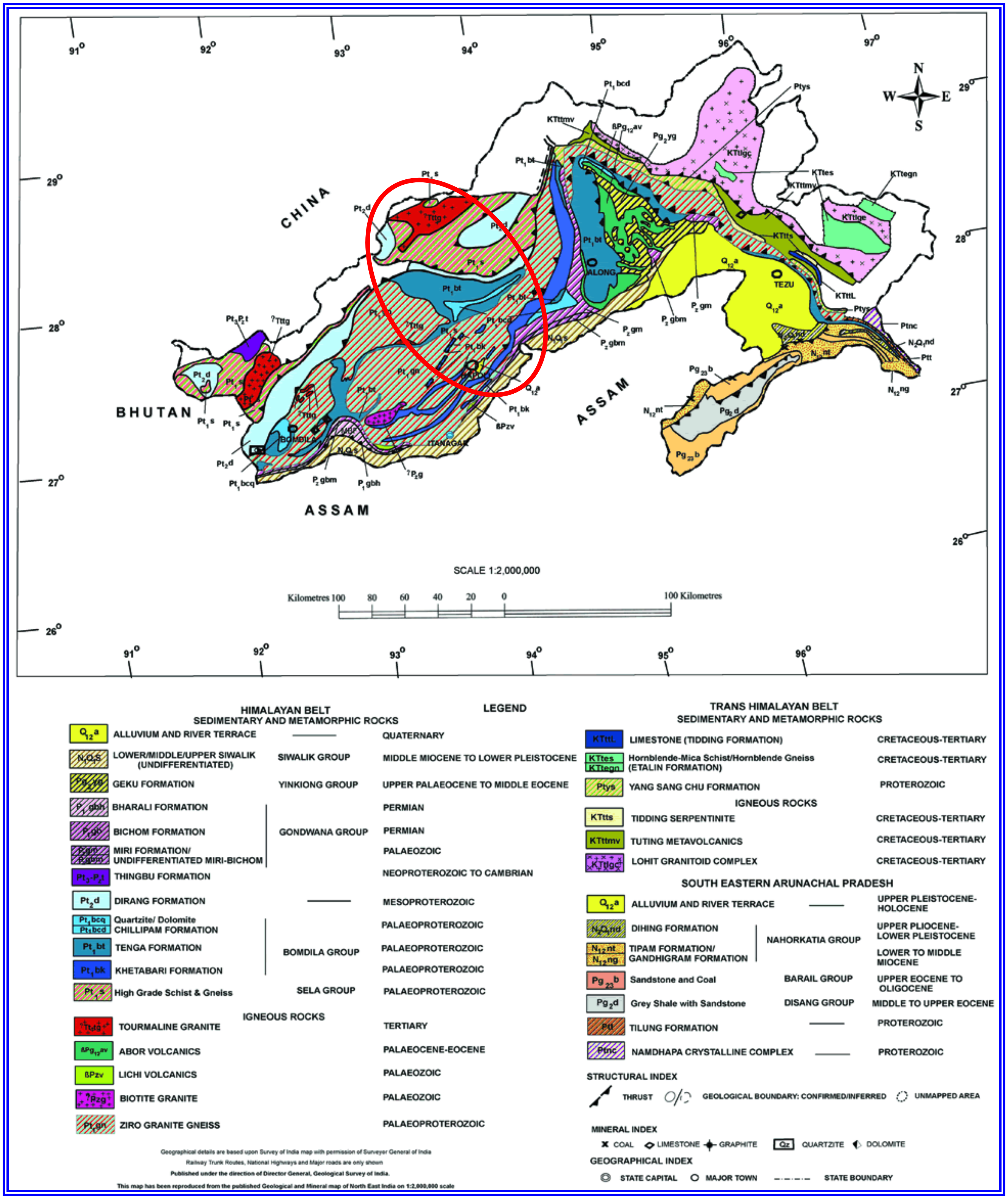
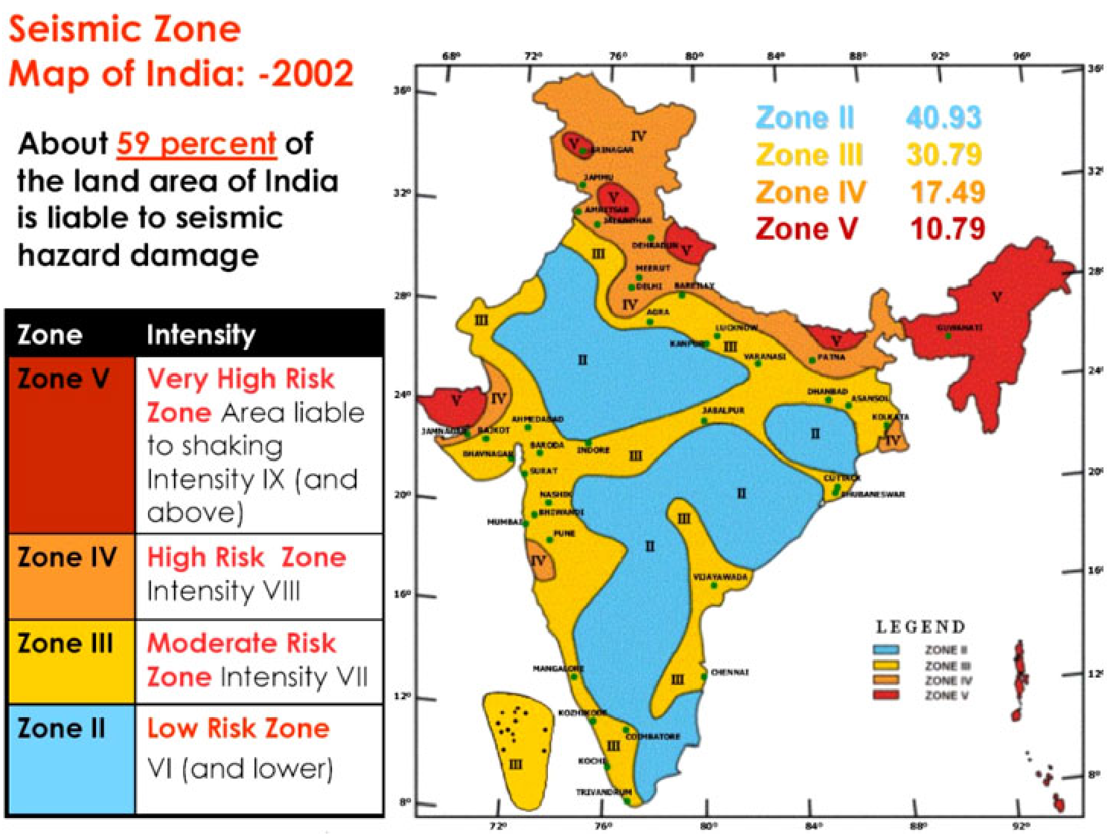


Figure 2.6: Geological Features and Mineral Map of Arunachal Pradesh including Subansiri Basin

Seismicity and Tectonics

The Subansiri basin falls under seismic Zone–V as per Seismic Zoning Map of the country given in IS 1983 (part I): 2002. The seismic zoning map is enclosed as **Figure 2.7** below. The important structural elements of the area are Tidding suture with dismembered ultra - mafic suite which mark the boundary between low grade sediments of Himalayan orogenic belt and moderately reworked metasedimentary belt and Mishmi thrust. These thrust systems trend NW - SE in contrast to NE - SE trend of Naga fold thrust belt. The historical record of important earthquake events in this region are during 1897 (Ms = 8.7) and 1950 (Mb =8.0, Ms = 8.6). Zone V seismicity in the Subansiri basin warrants strong safety factor in any proposed project intervention.



Source: National Institute of Disaster Management (2006)

Figure 2.7: Seismic Zoning Map of India

2.6 Soils of Subansiri Basin

The study area of the Subansiri basin falls under Upper and Lower Subansiri districts and Kurung east and west administratively. Physiographically, two district divisions are described namely:

1.1 Greater Himalayas & Lesser Himalayas

1.1.1 Summits and ridges
1.1.2 Hill side slopes

1.1.3 Narrow valleys with hillocks
1.1.4 Moderately steep hills with narrow valleys
1.1.5 Dissected low lands

1.2 Shiwaliks

1.2.1 Summits and ridges
1.2.2 Hill side slopes
1.2.3 Purwanchal
1.2.4 Low amplitudinal hills
1.2.5 High amplitudinal hills

Figure 2.8 presents the physiographic divisions of Arunachal Pradesh as knowledge of these divisions help us to understand the soil environment.

Accordingly to National Bureau of Soil Survey and Land Use Planning (NBSS Publ. 55 – Soil Series of India) for optimizing land use in Arunachal Pradesh, soil map with 22 soil mapping units (SMU) covering the description on its major and its associated soil in terms of physiography, drainage, textural family and surface textural group, degree of soil erosion and stoniness and taxonomic classification at family and subgroup level as per USDA Taxonomy have been presented below.

Figure 2.9 shows the distribution of SMU in the study area. A detailed soil mapping legend is also given to understand the details about the problems / merits of each SMU for optimizing production. Broadly, the soil map Legend is presented in two headings namely: i) Soils of Eastern Himalayas covering 16 SMU and ii) Soils of Siwaliks (17-25 SMU).

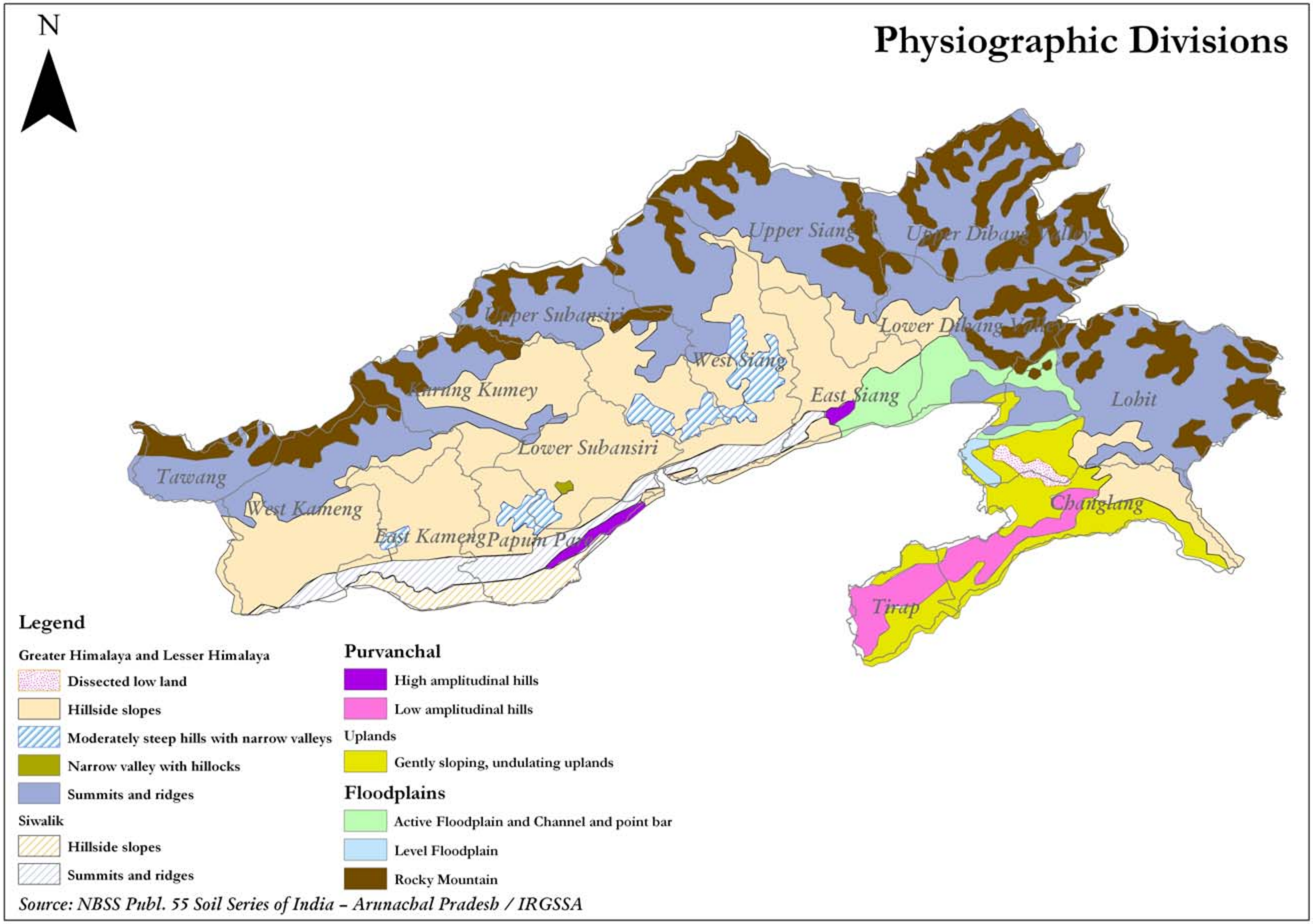
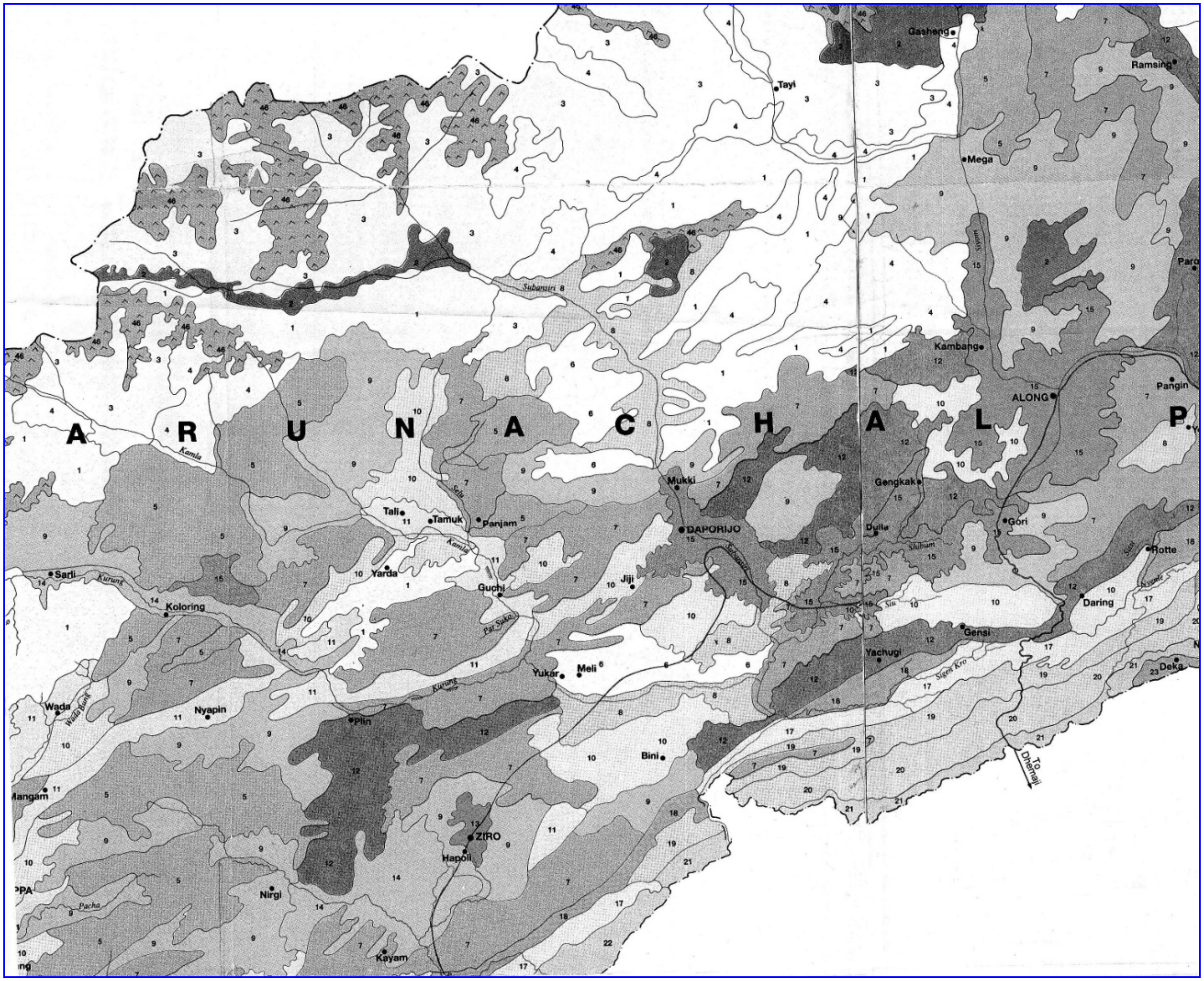


Figure 2.8: Knowledge of Physiographic Divisions of Arunachal Pradesh



Source: NBSS Publ. 55 Soil Series of India – Arunachal Pradesh

Figure 2.9: Soil Map of Subansiri basin showing Upper Subansiri district, Lower Subansiri district and Kurung Kumey district.

Mapping Unit	Description	Soil Taxonomy
Soils of Eastern Himalayas		
01	Shallow, excessively drained, loamy-skeletal soils on very steeply sloping hill summit having loamy surface with very severe erosion hazard and moderate stoniness: associated with ; Moderately deep, somewhat excessively drained, loamy skeletal soils on moderately steeply sloping side slopes with severe erosion hazard and moderate stoniness.	o Loamy – skeletal, Lithic Udorthents o Loamy – Skeletal, typic Udorthents
02	Deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping summits having loamy surface with severe erosion hazard and moderate stoniness: associated with; Moderately shallow, excessively drained, sandy-skeletal soils on steeply sloping summits with very severe erosion hazard and slight stoniness.	o Loamy-skeletal, Entic Haplumbrepts o Sandy – skeletal, Typic Udorthents
03	Shallow, excessively drained, loamy – skeletal soils on steeply sloping summits having loamy surface with severe erosion hazard and slight stoniness: associated with; Moderately deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side slopes and slight stoniness	o Loamy – skeletal, Lithic Udorthents o Loamy – skeletal, Dystric Eutdrochrepts
04	Shallow, excessively drained, loamy-skeletal soils on very steeply sloping summits having loamy surface with severe erosion hazard and strong stoniness: associated with; Moderately deep, somewhat excessively drained, sandy-skeletal soils with very severe erosion hazard and moderate stoniness.	o Loamy-skeletal, Lithic Udorthents o Sandy-skeletal Typic Udorthents
05	Very deep, well drained, fine soils on moderately steeply sloping side slope of hills having loamy surface with moderate erosion hazard and slight stoniness: associated with; Very deep, well drained, fine-loamy soils on moderately steeply sloping side slope of hills with moderate erosion hazard.	o Fine, Humic Hapludults o Fine – Loamy Umbric Dystrochrepts
06	Shallow, excessively drained, sandy-skeletal soils on very steeply sloping side slopes of hills having loamy surface with severe erosion hazard and strong stoniness: associated with; Moderately deep, excessively drained, loamy-skeletal soils on steeply sloping side slope of hills very severe erosion hazard and slight stoniness	o Sandy-skeletal, Lithic Udorthents o Loamy-skeletal, Typic Eutrochrepts
07	Very deep, somewhat excessively drained, fine soils on moderately steeply sloping side slope of hills having loamy surface with moderate erosion hazard: associated with; Moderately shallow, excessively drained, clayey soils on steeply sloping side slope of hills with severe erosion hazard.	o Fine, Typic Palehumults o Fine, Typic Haplumbrepts

Mapping Unit	Description	Soil Taxonomy
08	Moderately shallow, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side slope of hills having loamy surface with severe erosion hazard and strong stoniness: associated with; Moderately deep, somewhat excessively drained, fine-loamy soils with moderate erosion hazard.	o Loamy – skeletal, Typic Kanhaplohumults o Fine – loamy, Panchic Haplumbrepts
09	Deep, well drained, fine soils on moderately side slope of hills having clayey surface with moderate erosion hazard: associated with; Very deep, well drained, fine-loamy soils with moderate erosion hazard.	o Fine, Typic Kanhaplohumults o Fine-loamy, Pachic haplumbrepts
10	Very deep, somewhat excessively drained, fine loamy soils on moderately steeply sloping side slope of hill having loamy surface with moderate erosion hazard and slight stoniness: associated with; Very deep, well drained, fine loamy soils with moderate erosion hazard	o Fine-loamy, Umbric Dystrochrepts o Fine-loamy, pachic Haplumbrepts
11	Very deep, well drained, fine-loamy, soils on moderately sloping side slope of hills having loamy surface with moderate erosion hazard and slight stoniness: associated with; Very deep, well drained, fine soils with moderate erosion hazard	o Fine loamy, Pachic Hablumbrepts o Fine Typic Pale Humults
12	Very deep, well drained, fine soils on moderately steeply sloping side slope of hills having clayey surface with moderate erosion hazard: associated with; Deep, somewhat excessively drained, fine soils with erosion hazard	o Fine Typic Kandihumlts o Fine Pachic Haplumbrepts
13	Very deep, poorly drained, fine soils on very gently sloping plain in narrow valley having loamy surface with slight erosion hazard and slight flood hazards: associated with; Very deep, imperfectly drained, fine soils with slight erosion hazards	o Fine Humaqueptic Fluaquents o Fine Humic Haplaquepts
14	Very deep, well drained, fine soils on moderately sloping side-slopes of hills having loamy surface with moderate with moderate erosion hazard: associated with deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side-slopes of hills having loamy surface with severe erosion hazard.	o Fine Typic Kanhaplohumults o Loamy skeletal o Umbric Dystrochrepts
15	Very deep, well drained, fine soils on moderately steeply sloping side-slopes of hills having loamy surface with moderate erosion hazard: associated with; Deep, well drained, fine soils on moderately steeply sloping side-slopes of hills with severe erosion hazard	o Fine Typic Paleudults o Fine Umbric Dystrochrepts
16	Very deep, well drained, fine-loamy soils on moderately sloping side-slopes of dissected low hills having loamy surface with moderate erosion hazard: associated with; Very deep, well drained, fine-loamy soils with moderate erosion hazard	o Fine loamy Typic Dystrochrepts o Fine Loamy Typic Paleudalts

Mapping Unit	Description	Soil Taxonomy
Soils of Siwalik Hills		
17	Deep, excessively drained, loamy-skeletal soils on very steeply sloping summits having loamy surface with severe erosion hazard and strong stoniness: associated with: Moderately deep, excessively drained, fine-loamy soils with severe erosion hazard and slight stoniness	o Loamy skeletal o Umbric Dystrochrepts o Fine loamy Typic Dystrochrepts
18	Very deep, well drained, fine-loamy soils on moderately steeply sloping summits having loamy surface with moderate erosion hazard: associated with: Deep, well drained, loamy-skeletal soils with moderate erosion hazard and slight stoniness	o Fine loamy Typic Dystdrochrepts o Loamy skeletal o Dystric Utrochrepts
19	Deep, somewhat excessively drained, loamy-skeletal soils on steeply sloping summits having loamy surface with severe erosion hazard and moderate stoniness: associated with: Deep, somewhat excessively drained, fine-loamy soils with moderate erosion and strong stoniness	o Loamy skeletal o Typic Udorthents o Fine loamy Typic Dyistrochrepts
20	Deep, somewhat excessively drained, loamy skeletal soils on moderately steeply sloping side-slopes of hills having loamy surface with severe erosion hazard and slight stoniness: associated with: Deep, well drained, fine-loamy soils on gently sloping foot hill slopes with moderate erosion hazard and slight stoniness.	o Loamy skeletal o Typic Udorthents o Fine loamy o Typic Dystrochrepts
21	Deep, somewhat excessively drained, fine-loamy soils on steeply sloping side-slopes of hills having loamy surface with severe erosion hazard and slight stoniness: associated with: Deep, well drained loamy-skeletal soils on moderately sloping side slopes of hills having loamy surface with moderate erosion hazard and slight stoniness	o Fine loamy o Typic Haplaumbrepts o Loamy skeletal o Typic Udorthents
22	Deep, somewhat excessively drained, loamy-skeletal soils on moderately sloping side-slopes of hills having loamy surface with severe erosion hazard and slight stoniness: associated with: Very deep, well drained, fine loamy soils with moderate erosion hazard	o Loamy skeletal o Typic Haplumbrepts o Fine loamy o Umbric Dystrochrepts

- The 16 SMU of Eastern Himalayas cover following different physiographic aspects:
    - o Very steeply sloping hill summits – 1-4 SMU
    - o Steep to very steeply sloping hill side – 6,8 – 9 SMU slopes
    - o Moderately sloping hill side slopes – 5,7,10,11,12,14,15,16 SMU
- The 6 SMU covering Siwalik zone covers different physiographic aspects.
    - o Very steeply summits 17 – SMU
    - o Steeply sloping side slopes 19-21 SMU
    - o Moderately Steep side slopes 18,20,22 SMU

Some Salient Features of the Soil Legend

North Eastern Himalayas

Very steeply sloping hill summits cover 4 SMU namely 1,2,3,4. Overall, it can be generalized that these summits have shallow (25-50 cm) soil depth, loamy skeletal textural family and suffers from severe erosion. Taxonomically, they are Lithic/Typic Udorthents of entisols soil order means immature soils. However, SMU 2 has deep soils and belongs to inseptisols soil order implying inception of profile development, as such, relatively have better productivity.

Steep to very steep hill side slopes cover 3 SMU namely 6,8,9 and shows increasing soil depth viz. shallow, moderately shallow and deep. Former two have sandy skeletal and loamy skeletal severely eroded soils of entisols soil order but have inceptisols in association but SMU 9 soils are fine clayey with moderate erosion and belong to Ultisols soil order implying low base saturation and low CEC. In thin group SMU 9 has a better productivity.

Moderately steep hill side slopes are spread over 7 SMU namely 5,7,10,11,12,15,16 of which, 5,7,12,14,15 belongs to fine textural family belonging to Ultisols soil order associated with inceptisols; whereas, SMU 10,11, and 16 belong to fine loamy textural family and belong to Dyestric group of inceptisols indicating low base saturated immature soils. Overall, these soils are very deep, moderately eroded with slight stoniness in SMU 10 and 11. These slopes are mostly covered with alpine and subalpine, temperate coniferous, semi evergreen and tropical moist deciduous forest.

Narrow valleys are mapped under SMU 13. It has poorly drained very deep fine soils with high ground water table and none to slight water erosion but have slight flood hazards. They are stratified soils of Fluvaquents group of entisols. They are normally used for met paddy cultivation. Hill / terraces are cultivated for rice, maize, millets, peas, beans, potato and vegetables.

In general, soils are strongly to moderately acidic (pH 4.2 to 5.7) with high organic matter content (OC – 1 – 5.2%) and have appreciable amount of exchangeable A1 + ^{3} [1.0 to 5.9 C mol (P+) kg^{-1}], subsurface have low CEC (3.5 – 23.5 c mol (P+) kg^{-1}, poor base status, medium to high available N, low available P, low to high available K and low in Mn and Zn contents.

Soils of Siwalik

Most of the Siwalik soils are deep to very deep with loamy skeletal textural family and are affected by severe soil erosion except SMU 18 and 21, which have dominance of fine loamy textural family and suffer from moderate to severe soil erosion. In soil classification subgroup Umbric / Dystric imply strongly acidic low base status soils. It is worth while to note that most loamy skeletal soils are associated with a minor extent under fine loamy soils.

These soils are moderately to slightly acidic nature (pH 4.6 to 5.8) and moderate to high organic matter content (OC% - 1.3 to 3.7%). The CEC of the soils ranges from 3.7 to 15.2 c mol (p+) kg^{-1}, and they are moderate to poor in base saturation.

2.7 Socio-cultural and religious values

In Arunachal Pradesh, Gumpa Forests, known as Sacred Groves are attached to Buddhist monasteries. There are 101 sacred groves recorded from AP[1]. No monuments/protected monuments in Subansiri Basin have been listed by Archaeological Survey of India[2]. Description of Socio-cultural and religious values in Subansiri Basin is given below.

1 Lower Subansiri District

Eight sacred groves have been recorded in Lower Subansiri District as given in **Table 2.3**[3].

Table 2.3: Sacred groves in Lower Subansiri District

Sr no	Name of Sacred Grove	Location of Sacred Grove	Name of the deity	Area (ha)
1	Dilang Tare Bo / Dilang Posa	-	Dilang Posa, Dilang Tari Bo, Khalo	-
2	Kyong Thervada Gumpa forest	VIP Colony, Vivek Bihar	Buddha	-
3	Pumin Pubiang	-	Pumin Pubiang, Sai, Tajhe	-
4	Siddhartha Vihar Gumpa forest	Bank Tinali	Buddha	1.2
5	Sree Moro Doji Yapung	-	Sree Moro / Doji Yapung	-
6	Suthi Pache Ko	-	Suthi Pache Ko	-
7	Takae	-	Geka	-
8	Yapun Yapyo	-	Yapun Yapyo	-

Ziro is located in Lower Subansiri District is a tourist destination and is known for high altitude fish farm, Pine and bamboo groves, trekking & hiking. Talley valley is sanctuary located in Lower Subansiri District is 30 km from Ziro. It is known for green paddy fields, paddy cum pisciculture and eco-tourism.

Parsi Parlo located in Lower-Subansiri district is known for scenic beauty, Neolithic Site, Historical/Religious Site[4].

Shiva lingam at Kardo forest: It is about 4 Km away from Hapoli township. The height of Shiva Lingam is 25ft. and 22 ft width at Kardo. Million of devotees who offer their prayers, worship and faith of Lord Shiva in the remote Himalayan region of Tribal beliefs and traditions[5].

Fairs & Festivals

Festivals are an essential part of the socio-cultural life of the people. The festivals are connected with agriculture and celebrated with ritualistic gaiety either to thank god for his

[1] *http://www.ecoheritage.cpreec.org*
[2] *http://asi.nic.in/asi_monu_alphalist_arunachal.asp*
[3] *http://www.ecoheritage.cpreec.org*
[4] *http://asi.nic.in/asi_exca_indi_arunachal.asp*
[5] *http://lowersubansiri.nic.in/html/ziro.htm*

providence or to pray for a bumper harvest. The large fairs and festivals are linked with the people and religions. The festivals celebrated by the Arunachalees, mirror the people, culture, their artistic genius and skill in music and dance, which is a vital element in the life of every tribe.

The spring-time festivals are celebrated during the period from January to April by the different groups. Major festivals celebrated in Subansiri basin is given in **Table 2.4**.

Table 2.4: Major festivals celebrated in Subansiri basin

Sr. No.	District	Headquarter	Festivals	Date & Month (Apprx.)
1	Lower Subansiri	Ziro	Boori Boot (Hill Miris) Nyokum (Nishi) Dree (Apatanis)	6 February 26 February 5 July
2	Upper Subansiri	Daporijo	Si-Donyi (Tagins) Boori Boot (Hills Miris) Mopin (Adis)	6 January 6 February 5 April

Lower subansiri district

Myoko Festival: This festival is celebrated during the month of March every year amongst three villages namely Diibo-Hija, Hari-Bulla and Hong of Apatani plateau on rotational basis with traditional gaiety and festivity. The festival is celebrated by the whole villager for well being of society in which people from other villages are invited for local beer 'OHO' and meat, besides, merry making like BUSHII and AYU traditional song).

Murung festival: This festival is celebrated during the month of January by individual in which all the villagers participate. The festival is celebrated for well being of individual and immediate kith and kin. In this, Mithuns and cows are sacrificed that are distributed to the whole villagers of Apatani before "PENII SOLIN DU" traditional festivities in which young and old go to other villages of Apatani plateau by chanting "HO-HO" in a queue.

Dree festival: This Agricultural festival is celebrated during the month of July, centrally on 5th July every year at Nenchaleya, Old Ziro to propitiate the Dree God to protect the agriculture crops from pests and diseases. In this festival traditional songs and dances are also performed. The people of all villages of Apatani take part, besides people from other areas are also invited for community feast at festival ground.

2 Upper Subansiri District

Festivals

1) Si Donyi:- The people of Tagin tribe celebrate this festival invoking the creators, Si and Donyi, to bestow them with good crops and prevent diseases thereby blessing the people with plenty, prosperity and success.
2) Boori-Yullo:- During this festival celebrated by the Nyishi community of the district, people get together to hail the spring season and a successful harvest. The festival also invokes the spirit of Boori Boot to bless the community with prosperity and free them from diseases of any kind.
3) Mopin:-This festival is celebrated by the Galo community for wealth, prosperity, good health and universal happiness.

Religious places

Menga Mandir is located 22 km North of Daporijo towards Taliha near the confluence of River Subansiri and Mengha River. It is a rock cave temple with two tunnels. The tunnels are located at the backside and towards the left side of cave wall. The first one starts from the back wall of the cave at a place about 1.80 metres high from the platform reached by stairs. The opening of the tunnel is big and allows single person to enter. But gradually it becomes so narrow that a person has to crawl for further entry. The interior of the tunnel is extremely dark. There are several niches in the passage where three or four persons can stand together. The second tunnel on the left appears to be an extension of the cave. The ceiling of this tunnel is about 0.90 metres from the floors of the cave[6].

3 Kurung Kumey district

Culture

Nyokum Yullo is the main festival of the district which is celebrated during the month of February. Solung festival is also followed in the upper region of the district i.e. Koloriang, Sarli. Rikam Pada and Buya is the main dance of the region. It is performed to welcome the guest and show the culture of its community. The Nyishi people have rich ornaments called Tassand (Beads), Rurh (Sword), Lakte (Metal Ornament).

Religion

The region belief in Doni-Polo God which is the God of Sun & Moon. The tribe performs different worships for different purpose. Yullo Oyi for the welfare of the family which worship to God of family protector.

[6] http://ardistricts.nic.in/district_profile/travel_and_tourism/tp_details.php?id=1

Chapter 3: Hydropower Development in Subansiri Basin

3.1 Overall Hydropotential & Identified Project

Arunachal Pradesh has been identified as a major state for hydropower development. Central Electricity Authority (CEA) ranking study has identified 89 major hydropower projects in Arunachal Pradesh with total potential of 49,126 MW. Under Prime Minister's 50,000 MW initiatives, Central Government has identified 42 schemes in the state with an installed capacity of 27,293 MW, for preparation of Pre-feasibility Reports (PFRs). At the beginning of the current study, detailed interaction was carried out with the CEA & Department of Power, Government of Arunachal Pradesh to get the updated information about the planned and allotted projects, along with the status of each, in Subansiri Basin. A comprehensive list of all the allotted/potential projects has been prepared along with their present status by compiling all the information and is given in following sections.

3.2 Current Status

CEA had earlier attempted to identify various sites suitable for developing the hydropower potential on Subansiri River and its sub-tributaries through a preliminary study named "Reassessment of Hydroelectric Potential (1978-87)". Based on available data/information and toposheet study, 25 schemes had been identified. The tentative hydropower potential[7] of the basin as per their estimates is given in **Table 3.1**.

Table 3.1: Tentative Assessment of hydropower potential of Subansiri Basin

No. of Identified Schemes	25
Firm Power	4036 MW
Probable Installed Capacity	13767 MW
Potential at 60% Load Factor	6092 MW
Annual Energy for 90% year	56880 MW

The implementation of these schemes in the basin would yield an aggregate of 6092 MW of Power (at 60% load factor). The total installed capacity of these schemes has been projected to be 13,767 MW. Gross head for various schemes range between 40 m to 365 m. Twenty of these schemes were envisaged to be "run of the river" type and the rest were expected to be developed as storage schemes.

Eight of these schemes are proposed on main Subansiri River installed capacity of 8412 MW. These are Oju – I (700 MW), Oju – II (1000 MW), Niare (800 MW), Naba (1000 MW), Subansiri Lower (2000 MW), Subansiri Upper (2000 MW), Nalo (360 MW) and Dengser (552 MW) with expected annual energy generation of 8412 MW respectively in a 90% dependable year.

[7] *CEA*

Five of the schemes are located on Kurung River, an important tributary of Kamla River. These are Kurung I – II (330 MW), Mili (75 MW), Sape (38 MW), Chomi (80 MW) Chela (75 MW).

Two of the schemes are located on Kamla River namely Tamen (175 MW) and Subansiri Middle Kamla HEP (1728 MW).

The rest of the four schemes were proposed on various other sub-tributaries. The Tammu (55 MW) on Siu River, Nyepin (32 MW) and Hiya (41 MW) on Payam River and Tago – I (55 MW) on Kale River, Apart from the projects on the main river, hydropower projects are planned on all major tributaries and sub-tributaries.

In Subansiri Basin, as on 2004, out of total assessed potential of 6092 MW at 60% load factor, hydroelectric schemes with potential of 114.6 MW at 60% L.F. (1.66% of the assessed potential) have already been developed. **Table 3.2** describes the current status of the projects in the basin.

Table 3.2: Name and Number of Hydel Projects and Status of Works and Allotment

Sr. No.	Name of the project	Catchment Area (Sq.km)	Present IC (MW)	Number of Water Sampling Locations	FRL m	Ht. of the dam (m)	Tail Water Level (m)	Present Status	Status of Allotment of Projects
1.	Oju-I	9827	700	2	1950	110	1670	Merged as single Oju Project with IC of 1878 MW. Under S&I. ToR approved by MoEF in Feb., 2014. EIA/EMP pending.	M/s Navyuga Engineering Company Ltd. Delhi
2.	Oju-II	9979	1000	3	1650	90	1300		
3.	Niare	11181	800	2	1280	100	1055	Under S&I. ToR applied.	M/s Coastal Infrastructure Pvt. Ltd., Hyderabad
4.	Naba	11272	1000	3	1035	110	780	Under S&I. ToR issued in July, 2013. EIA/EMP pending.	Abir Infrastructure Private Ltd., Delhi
5.	Mili	-	75	1	1400	-	1200	Information as Per CEA Re-assessment Study. S&I yet to be taken up.	Not Yet allotted
6.	Sape	-	38	1	1155	-	1080	Information as Per CEA Re-assessment Study. S&I yet to be taken up.	Not Yet allotted
7.	Chomi	1194	80	1	1067	-	905	Under S&I.	Adveta Power Pvt Ltd.
8.	Chela	1430	75	1	895	-	750	Under S&I.	Adveta Power Pvt Ltd
9.	Kurang I & II	2302	330	1	745	140	620	PFR Prepared.	North Eastern

Sr. No.	Name of the project	Catchment Area (Sq.km)	Present IC (MW)	Number of Water Sampling Locations	FRL m	Ht. of the dam (m)	Tail Water Level (m)	Present Status	Status of Allotment of Projects
									Electric Power Corporation Limited NEEPCO
10	Tamen	7595	175	1	320	-	250	Information as Per CEA Re-assessment Study. S&I yet to be taken up.	
11	Tago – I	-	55	1	1080	-	790	Information as Per CEA Re-assessment Study. S&I yet to be taken up.	
12	Subansiri Lower	34900	2000	3	205	116	-	Under Construction.	NHPC
13	Subansiri Middle (Kamala HEP)	7213	1800	-	455	275	285.50	DPR under examination in CEA. ToR obtained in Dec., 2010. Extension of ToR granted for 4th year in Feb., 2014. Draft EIA/ EMP under preparation.	Jindal Power Limited, Gurgaon
14	Subansiri Upper	14665	2000	-	460	236.5 Above DFL	278	Under S&I. ToR approved by MoEF in Apr., 2011. Validity extended upto 27.04.2015. EIA/EMP pending.	KSK Energy Ventures Pvt. Ltd., Hyderabad
15	Nalo	-	635	-	765	-	635	Under S&I. ToR Obtained on 21/3/12. Applied for revised ToR. EIA/EMP pending.	M/s Coastal Infrastructure Pvt. Ltd., Hyderabad
16	Dengser	17625	552	2	630	100	490	Under S&I. ToR applied.	M/s Coastal Infrastructure Pvt. Ltd., Hyderabad
17	Tammu	-	55	1	310	-	220	Information as Per CEA Re-assessment Study. S&I yet to be taken up.	Not Yet allotted
18	Nyepin	-	32	1	1060	-	920	Information as Per CEA Re-assessment Study.	M/s Nguffa Developers Pvt. Ltd.
19	Hiya	-	41	1	880	-	745	Information as Per CEA Re-assessment Study.	M/s Sowbhagya Energy Pvt. Ltd.

The details of other existing, proposed small & micro hydel projects and corespondence with Department of Hydropower Development, Government of Arunachal Pradesh is is given in **Annexure 3.1**.

3.3 Projects Description

Efforts have been made to collect the data of all the planned projects in the basin. Data have been sourced from Power Department of Arunachal Pradesh as well as by contacting project promoters so that all the relevant information can be compiled for data analysis. Required information has been collected for all the projects where progress has been made in preparation of PFR/DPR, etc. Information collected is compiled in the form of salient features of each project and is given in **Table 3.4.** These projects are also shown in **Figure 3.1**. For the 10 projects, locations, levels and expected installed capacities are available. This data is used during basin-wise impact assessment.

3.3.1 Oju – 1

Oju-I HE Project is located in upper reaches of Subansiri River near Pare village. It is about 220 km from Daporijo town. Hydropower potential of the River Subansiri is proposed to be harnessed through cascade of several projects, viz., Oju-I, Oju-II, Niare, Naba, Nalo, Dengser, Subansiri Upper Project and Subansiri Lower Project. However, the project beyond Naba is located in a difficult terrain which is not easily accessible as the Daporijo road terminates at Limeking. This road needs to be extended for about 60 km to access the Oju-I project area. **Figure 3.2** depicts location physiography & topography of the project.

3.3.2 Oju – II

Oju-II HE Project is located in upper reaches of Subansiri River near Oju village. It is about 200 km from Daporijo town. The proposed site of Oju- II project is located in a difficult terrain not easily accessible now. The Daporijo- Limeking road needs to be extended to access the Oju-II project area. **Figure 3.2** depicts location physiography & topography of the project.

3.3.3 Niare

Niare HE Project is located in upper reaches of Subansiri River near Orak village. It is about 180 km from Daporijo town. Since, the projects beyond Naba are not easily accessible as the Daporijo road terminates at Limeking. This road needs to be extended for about 20 km to access the Niare project site area. **Figure 3.3** depicts location physiography & topography of the project.

3.3.4 Naba

Naba HE Project is located in upper reaches of Subansiri River near Badok village. It is about 160 km from Daporijo town. The proposed site of Naba project is accessible through Daporijo-Limeking road. Naba Hydroelectric Project comprises of 110 m high dam, with 9.75/9.80 km long HRT, 23 m dia surge shaft, 7.25 m dia steel lined pressure shaft and 1000 MW underground power house. **Figure 3.3** depicts location physiography & topography of the project.

3.3.5 Nalo

Nalo HE Project is located in upper reaches of Subansiri River near Nalo village. It is about 120 km from Daporijo town. The proposed site of Nalo project is accessible through Daporijo-Limeking road. **Figure 3.4** depicts location physiography & topography of the project. As per the toposheet, the study area with in 10 kms of the proposed project site is characterised by presence of dense scrub and dense mixed jungle. Site is located at an elevation of 630 metres. The 10 kms study area of Nalo HEP overlaps with Dengser HEP.

3.3.6 Dengser

Dengser HE Project is located in Upper Subansiri District of Arunachal Pradesh near village Charu on lift bank and Nacho on right bank. It about 100 km from Daporijo town. The proposed site of Dengser project is accessible through Daporijo – Limeking road. **Figure 3.4** depicts location physiography & topography of the project. As per the toposheet, the study area is characterised by presence of dense mixed jungle, fairly dense mixed jungle and open pine. Site is located at an elevation of 560 metres.

3.3.7 Upper Subansiri

With a view to exploit hydro potential and to derive benefits of flood moderation Brahmaputra Board had prepared, Detailed Project Reports (DPR) of Subansiri Dam Project (4800 MW) in April 1983 respectively. **Figure 3.5** depicts location, physiography & topography of the project.

3.3.8 Middle Subansiri (Kamala HEP)

Subansiri Middle (Kamala HEP) Project is proposed on River Kamla, a tributary of Subansiri, 3.5 km u/s of Tamen village in Lower Subansiri district of Arunachal Pradesh. The project envisages construction of 216 m high dam on Kamla River with a gross storage capacity of 2366 MCM (atMWL of 470m) and 1928 MCM (at FRL of 455m). The submergence area is 27.75 sq. km at FRL. **Figure 3.6** depicts location, physiography & topography of the project.

3.3.9 Lower Subansiri

Subansiri Lower HE Project is one the biggest hydroelectric project undertaken in India. The Project is located near North Lakhimpur on the border of Assam and Arunachal Pradesh. The nearest railhead is Nagaon and nearest airport is Lilabari. The estimated annual energy generation from the Project is 7421 MU in a 90% dependable year. **Figure 3.6** depicts location, physiography & topography of the project.

3.3.10 Kurung I&II

Under the ranking studies done by CWC, three schemes with a total capacity addition of 565 MW have been identified on Kurung River. These schemes envisages cascade development of Kurung River viz., Kurung-I, Kurung-II and Hegio. Kurung-I and Kurung-II have been combined because of Techno-Economical considerations and called as Kurung HE project. This project comprises of a 140 m high concrete dam, about 8 km long HRT, a 25 m dia Surge shaft, 7m dia steel lined Pressure shaft and 330MW underground Powerhouse.

3.3.11 Other Projects

There are 9 other projects whose PFR and DPR have not been prepared by any agency. Further, they have not been allotted to any developer / operator. The basic descriptions of these projects are summarized in **Table 3.3** & their tentative location, physiography & topography is shown in **Figure 3.2 to 3.10.**

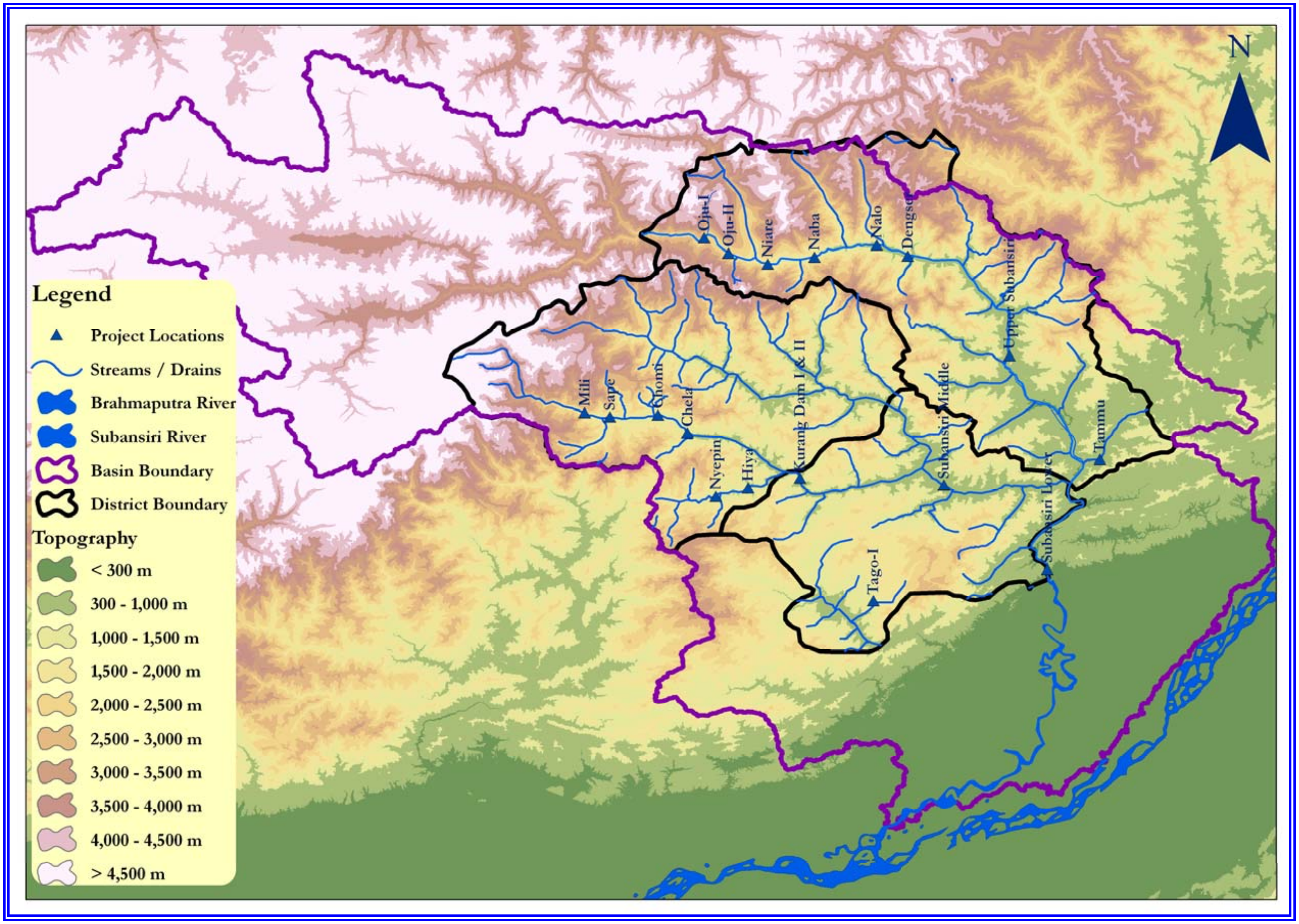


Figure 3.1: Location, Physiography &Topography of the Projects

Table 3.3: Name and Number of Hydel Projects and Status of Works and Allotment*

Sr. No.	Name of the project	Catchment Area (Sq.km)	Present IC (MW)	Number of Sampling Locations	FRL m	Ht. of the dam (m)	Tail Water Level (m)	Status of reports (PFR / FR / DPR / EIA / EMP)	Status of Allotment of Projects
1.	Mili	-	75	1	1400	-	1200	-	CEA identified project, not Yet allotted Information as Per CEA Re-assessment Study. S&I yet to be taken up.
2.	Sape	-	38	1	1155	-	1080	-	CEA identified project, not Yet allotted Information as Per CEA Re-assessment Study. S&I yet to be taken up.
3.	Chomi	1194	80	1	1067	-	905	-	M/s Adveta Power Pvt. Ltd. Under S&I.
4.	Chela	1430	75	1	895	-	750	-	M/s Adveta Power Pvt. Ltd. Under S&I.
5.	Tamen	7595	175	1	320	-	250	-	CEA identified project, not Yet allotted Information as Per CEA Re-assessment Study. S&I yet to be taken up.
6.	Tago – I	-	55	1	1080	-	790	-	CEA identified project, not Yet allotted Information as Per CEA Re-assessment Study. S&I yet to be taken up.
7.	Tammu	-	55	1	310	-	220	-	CEA identified project, not Yet allotted Information as Per CEA Re-assessment Study. S&I yet to be taken up.
8.	Nyepin	-	32	1	1060	-	920	-	M/s Nguffa Developers Pvt. Ltd. (formal MoA is yet to be executed) Information as Per CEA Re-assessment Study. *
9.	Hiya	-	41	1	880	-	745	-	M/s Sowbhagya Energy Pvt. Ltd. (formal MoA is yet to be executed) Information as Per CEA Re-assessment Study.

Note: *Status as on December, 2014

* ➔ Details of Chomi HEP and Chela HEP were provided by the Developers

Table 3.4: Salient Features of Hydro-electric Plants

Features			Projects											
			Kurung I&II	Dengser	Naba	Nalo	Niare	Oju-I	Oju-II	Upper Subansiri	Lower Subansiri	Middle Subansiri (Kamala HEP)	Chomi	Chela
Location	District		Kurung-Kumey	Upper Subansiri	Upper Subansiri	Upper Subansiri	Upper Subansiri	Upper Subansiri	Upper Subansiri	Upper Subansiri	Lower Subansiri / Dhemaji	Lower Subansiri	Kurung-Kumey	Kurung-Kumey
	River		Kurung	Subansiri / Singit	Subansiri/Si Ngit	Subansiri/Si Ngit	Subansiri/Si Ngit	Subansiri/Si Ngit	Subansiri/Si Ngit	Subansiri	Subansiri	Kamla	Kurung	Kurung
Hydrology	Catchment area (sq.km.)		2302	17625	14300	12150	11181	9827	9979	14665	34,900	7,213	1194	1430
	Location of catchment	Latitude	27º35'00", 28º05'00"	27º50' N to 29º00' N	27º00' N to 28º22' N	27º50' N to 29º00' N	27º00' N to 29º00' N	27º00' N to 28º25' N	27º00' N to 28º23' N	27°50'46'' N & 29°00'00" N	27°33'15"N	27°46'18"N	27º55'45.48"N	27º53'45.05"N
		Longitude	92º45'00", 93º55'00"	91º45' E to 93º55' E	91º45' E to 93º34' E	91º45' E to 93º49' E	91º45' E to 93º29' E	91º45' E to 93º21' E	91º45' E to 93º26' E	91°48'00" E & 94°16'48'' E	94°15'30" E	93°59'19"E	93º17'09.21"E	93º22'47.63"E
	Average annual rainfall (mm)		1745.4	2810	2825	2810	2825	2825	2825	2230	2,356			
	Maximum average discharge at dam site (cum)		310	-	-	-	-	-	-	5016	12024			
	Minimum observed discharge (cumec)		35	-	-	-	-	-	-	41	188			
Reservoir	Full reservoir level (FRL)		745 m	630 m	1035 m	765 m	1280 m	1950 m	1650 m	460 m	205.0 m	455.0 m	1067	895
	Min. Draw Down Level (MDDL)		710 m	610 m	1022 m	745 m	1260 m	1930 m	1630 m	420 m	181 m	430.0 m		
	Gross storage	at FRL	1075 Mcum	89.14 mcm	31.9 mcm	163.37 mcm	15.94 mcm	31.8 mcm	12.9 mcm	1755 MCM	1365 mcm	1927.60 mcm		
		at MDDL	501 Mcum	49.48 mcm	23.9 mcm	113 mcm	8 mcm	19.7 mcm	6.55 mcm	1010 MCM	720 mcm	1304.04 mcm		
	Area under submergence at FRL		20.25 sq.km	2.32 sq. km	0.81 sq. km	2.84 sq. km	0.48 sq. km	0.72 sq. km	0.37 sq. km	22.2 sq.km	33.50 sq. km	27.75 sq. km		
	Length of reservoir (km)		31	-	-	-	-	-	-	49.5	-	-	11KM	8.6KM
Diversion Tunnel	Number		1	2	2	2	2	2	2	2	5	3		
	Size		9 m dia.	11.00 m	10.50 m	10.75 m	10.50 m	9.5 m	10 m	11.0 M	9.5 m	13.5 m		
	Shape		horse shoe	Horse shoe	Horse shoe	Horse shoe	Horse shoe	Horse shoe	Horse shoe	Horseshoe	Horse shoe			
	Length (m)		600	650/800 m	700 m each	650/800 m	850/675 m	700/800 m	800/925 m	520 m & 630 m	493 m - 693 m	915 m – 1315 m		
	Diversion capacity (Non-monsoon, 1:25 Year)		900 cum	2700 cumec	2500 cumec	2600 cumec	2300 cumec	2000 cumec	2200 cumec	2750 cumec	4550 m3/s	7520 cumec		
	U/s coffer dam		25 m	28 m	25 m	28 m	25 m	26 m	25 m	33 m	31m	64m		
	D/s coffer dam		10 m	14 m	14 m	14 m	14 m	14 m	14 m	12 m	21m	26m		
Dam	Type		Concrete gravity	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete Gravity	Concrete Gravity	Concrete Gravity		
	Top elevation of dam		750 m	635 m	1040 m	770 m	1285 m	1955 m	1655 m	472 m	210.0 m	475.0 m		
	Height of dam above deepest foundation level		140 m	100 m	110 m	125 m	100 m	110 m	90 m	237 m	116 m	216 m		
	Length of dam at top		322.5 m	383 m	245 m	366 m	269 m	288 m	249 m	533 m	-	628 m		
Spillway	Design flood (cumec)		5500	14900	12000	12300	11500	10500	11000	11000	37,500	17416		
	Type		Orifice type	Orifice Crest type	Orifice Crest	Orifice Crest	Orifice Crest	Orifice Crest	Orifice Crest	Orifice	Orifice	Orifice Crest		
	Crest elevation		670 m	619 m	1025 m (Upper)	753.5 m (Upper)	1270 m (Upper)	1940 m (Upper)	1640 m (Upper)	430 M (Upper)	145 m	446 M (Upper)		
	Number & size of spillway opening	Number	5	2	2 (Upper)	2 (Upper)	2 (Upper)	2	2	2	9	7		
		Size	6.0 m X 7.2 m	10 m x 11 m	8.0 X 10 m	9.75 m x 11.5 m	8.0 x 10 m	8.25 m x 10.0 m	8.25 x 10.00 m	7.0 M x 8.5 M	11.5 m X 14.0 m	6.0 m x 10.5 m		

Features			Projects											
			Kurung I&II	Dengser	Naba	Nalo	Niare	Oju-I	Oju-II	Upper Subansiri	Lower Subansiri	Middle Subansiri (Kamala HEP)	Chomi	Chela
	Energy dissipation		Ski jump with preformed plunge pool	Ski jump with preformed plunge pool	Ski jump with preformed plunge pool	Ski jump with preformed plunge pool	Ski jump with preformed plunge pool	Ski jump with preformed plunge pool	Ski jump with preformed plunge pool	Ski jump with preformed plunge pool	Ski jump with preformed plunge pool	Trajectory Bucket		
	Length of spillway		70 m	140 m	142 m	120 m	126 m	126 m	126 m	112 m	-	-		
	Constructi on Sluice	Number	4	-	-	-	-	-	-	6	-	-		
		Size	3 m X 4 m	-	-	-	-	-	-	4 M x 5 M	-	-		
		Elevation	630 m	-	-	-	-	-	-	272 M	-	-		
Intake	Invert level (m)		690	590	1000	725	1240	1910	1613	390	160	406		
	Number		1	2	2	2	2	2	2	4	8	4		
	Size of gate opening		7.5 m X 8.5 m	8.6 m x 9.8 m	8.60 X 9.8 m	7.5 m x 8.5 m	7.9 x 9.0 m	6.70m x 7.65 m	7.2 x 8.2 m	10 M x 11 M	7.3 m X 9.5 m	6.0 m x 7.0 m		
	Trash rack		17 m X 20 m	26 m x 20 m	25 X 22 m	18 m x 20 m	25 x 20 m	18 m x 20 m	25 x 17 m	-	7.5 m x 23.75 m	-		
Head Race Tunnel	Number		1	2	2	2	2	1	1	4	8	4		
	Size		8.5 m dia.	8.7 m	8.7 m	7.5 m	8 m	9.6 m	10.25 m	11 m	9.5 m	10 m		
	Shape		Horse shoe	Horse shoe	Horse shoe	Horse shoe	Horse shoe	Horse shoe	Horse shoe	Horse shoe	Horse shoe	Circular		
	Length		8 km	8.0 / 7.9 km	9.75/9.80 km	2.5 /2.6 km	2.75/2.60 km	5.25 km	5 km	385 to 575 m	608 m – 1164 m	515 m – 815 m		
	Design discharge		242.1 cum	254.8 cumec	251 cumec	186.4 cumec	216 cumec	302 cumec	344 cumec	368 cumec	322.4 cumec	308.5 cumec		
Surge Shaft	Number		1	2	2	2	2	1	1	-	-	-		
	Size		25 m	25 m	23 m	20 m	18 m	20 m	20 m	-	-	-		
Pressur e Shaft	Number		1	2	2	2	2	1	1	4	8	8		
	Size		7 m dia. steel lined	7.2 m	7.25 m	6.25 m	6.75 m	7.75 m	8 m	7.75 M (D) x136.5 M(H)	9.5 / 8 / 7 m	5.7 m		
Power House	Type		Underground	Under ground	Underground	Surface	Underground	Underground	Underground	Underground	Surface	Underground		
	Installed capacity		330 MW	552 MW	1000 MW	360 MW	800 MW	700 MW	1000 MW	2,000 MW	2000 MW	1728 MW	80MW	75MW
	Number of units		3	4 (138MW each)	4(250 MW each)	4 (90 MW each)	4(200 MW each)	4 (175 MW each)	4 (250 MW each)	8	8	8 x 216 MW		
	Power house cavern size		24m (W) X 100m (L) X 45 m (H)	130 (L)x 24 (W) x 49 (H)	136mX23mX48m	103 (L)x 22 (W) x 47 (H)	136mX25mX51m	122mX22mX48m	124mX22mX48m	24.5 M x 59 M x 270 M	285 m X 61 m X 64 m	302 m x 23 m x 56.5 m		
	Type of turbine		Vertical Francis	Vertical Shaft Francis	Vertical Shaft Francis	Vertical Shaft Francis	Vertical Shaft Francis	Vertical Shaft Francis	Vertical Shaft Francis	Francis	Francis	Vertical Axis Francis		
Cum Transformer	Cavern size		15m (W) X 80m (L) X 25 m (H)	100(L)x 20 (W) x 25 (H) m	100 (L)x 20 (W) x 25 (H) m	-	100 (L)x 20 (W) x 25 (H) m	96m (L)x 20m (W) x 25m (H)	96m (L)x20m (W) x 25m	20 m x 31 m x 225 m	15 m X 62.5 m X 249 m	297 m x 16.5 m x 25.5 m		
	Draft tube opening		9.6 m X 4.6 m with one 2 m wide	2 nos, 5.75 m (W) X 5.2m(H)	4.2m (W) X 6m(H) 2 nos	2 nos , 5 m (W) X 4.3 m (H)	4m (W) X 5.7m(H) 2 nos	6.5m (W) X 5.5m (H)	6.3 m (W) X 5.7m(H)	2 NOS. EACH OF 4.6 M x 9.0 M	12 m X 10m including intermediate Piers of 2 m width	-		
Tail Race Tunnel	Number		1	2	2		2	1	1	4	-	4		
	Size		8.5 m	8.7 m	8.7 m		8 m	9.6 m	10.25 m	11 m	206	10 m		
	Shape		Horse Shoe	Horse Shoe	Horse Shoe		Horse Shoe	Horse Shoe	Horse Shoe	Horse Shoe	Horse shoe	Circular		
	Length		300 m	200/190 m	100 m	50 m	320 m	200 m	200 m	155 m to 185 m	35 m	415 m – 555 m		
	Design discharge		242.1 cum	254.8 cumec	251.00 cumec	372.8 cumec	216 cumec	302 cumec	344 cumec	368 cumec	-	-		

Features		Projects											
		Kurung I&II	Dengser	Naba	Nalo	Niare	Oju-I	Oju-II	Upper Subansiri	Lower Subansiri	Middle Subansiri (Kamala HEP)	Chomi	Chela
Pot Head Yard	Size	25 m (W) X 60 m (L)	50m (W) X 80m(L)	50m (W) X 100m(L)	80m (W) X160m(L)	50m (W) X 80m(L)	50m (W) X 80m (L)	50m (W) X 80m(L)	150 M x 40 M	-	150 m x 55 m		
Power Generated	Installed capacity	3 X 110 MW (330 MW)	552 MW	1000 MW	360 MW	800 MW	700 MW	1000 MW	2000 MW	2000 MW	1728 MW	80MW	75MW
	Annual energy generation in 90% dependable year	1435.43 MU	2666.71 MU	3995.25 MU	1732.99 MU	3356.62 MU	3291.58 MU	4629.93 MU	6768.5 MU	7,421.59 MU	6739.0 MU		

** ➔ Details of Chomi HEP and Chela HEP were provided by the Developers*

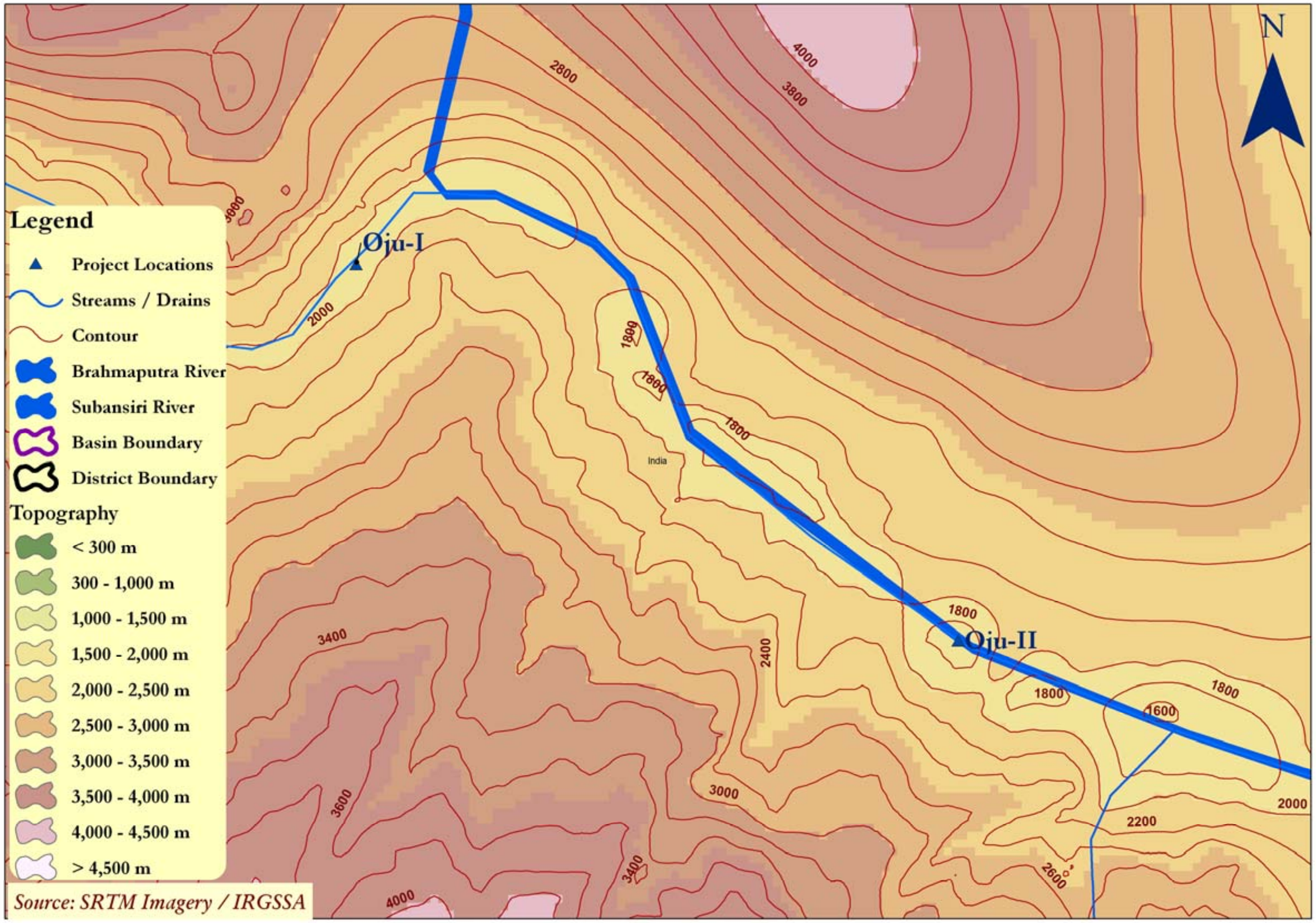


Figure 3.2: Oju – I and Oju II / Location, Physiography &Topography of the Projects

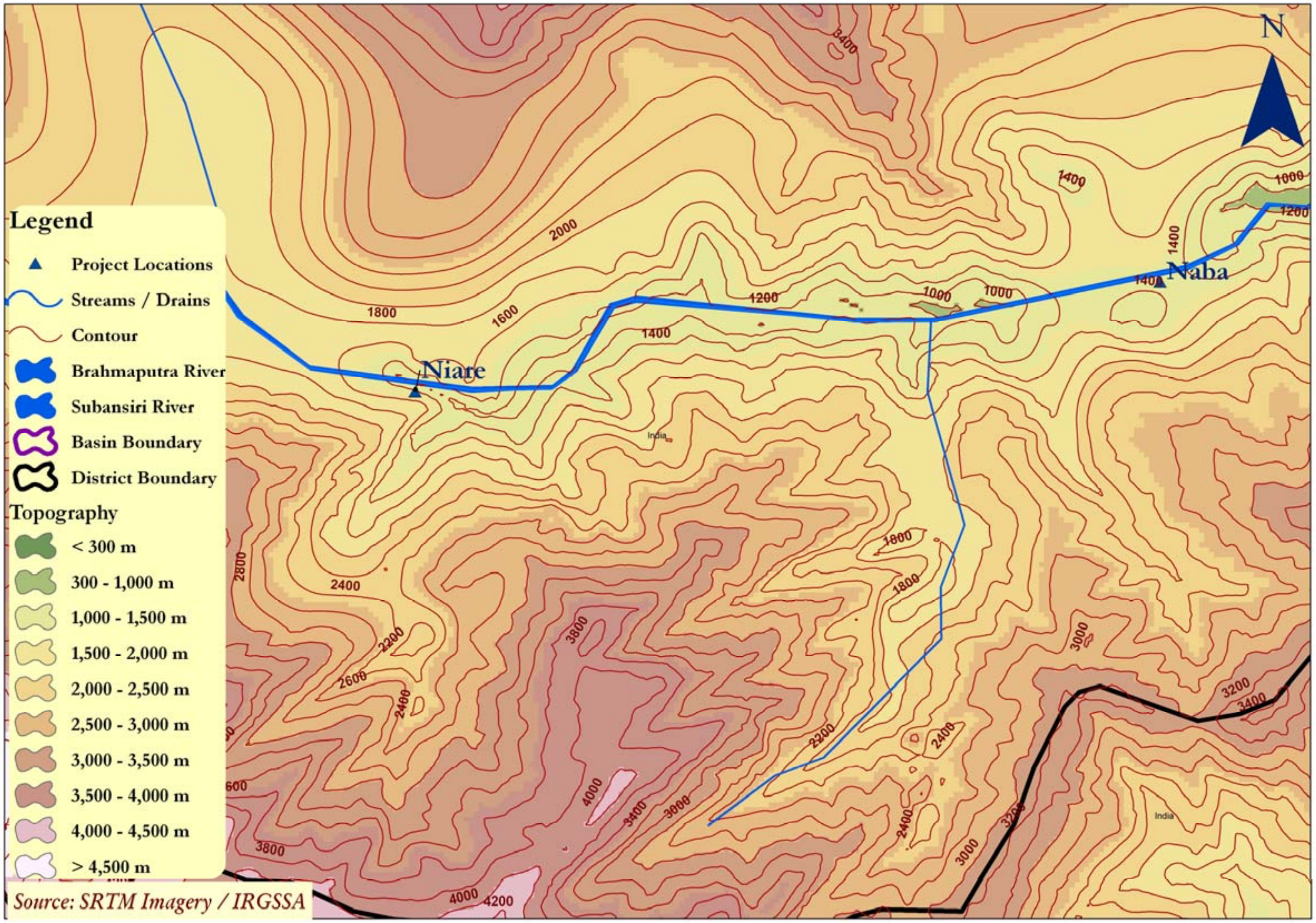


Figure 3.3: Niare and Naba / Location, physiography & Topography of the Projects

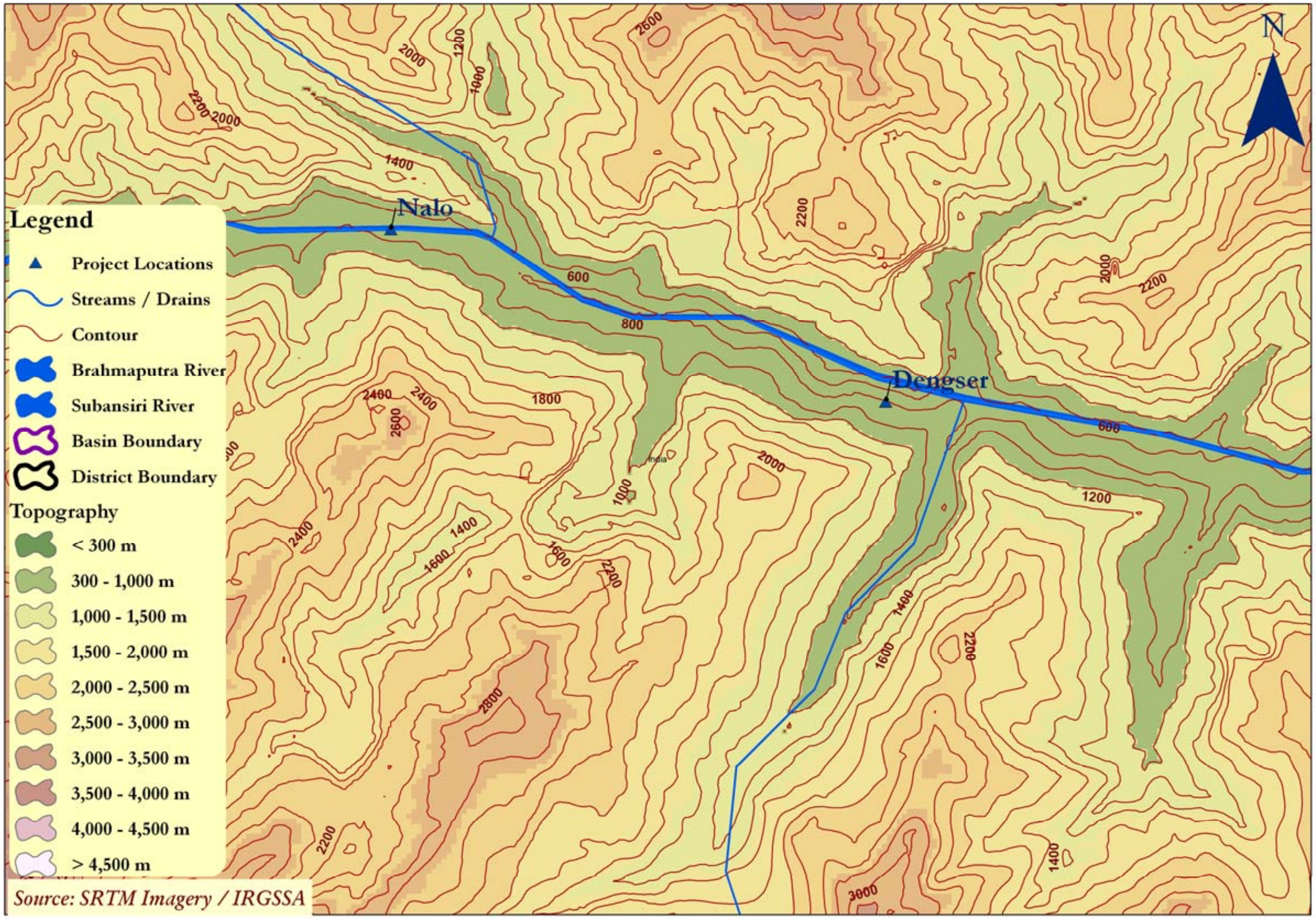


Figure 3.4: Nalo and Dengser / Location, Physiography & Topography of the Projects

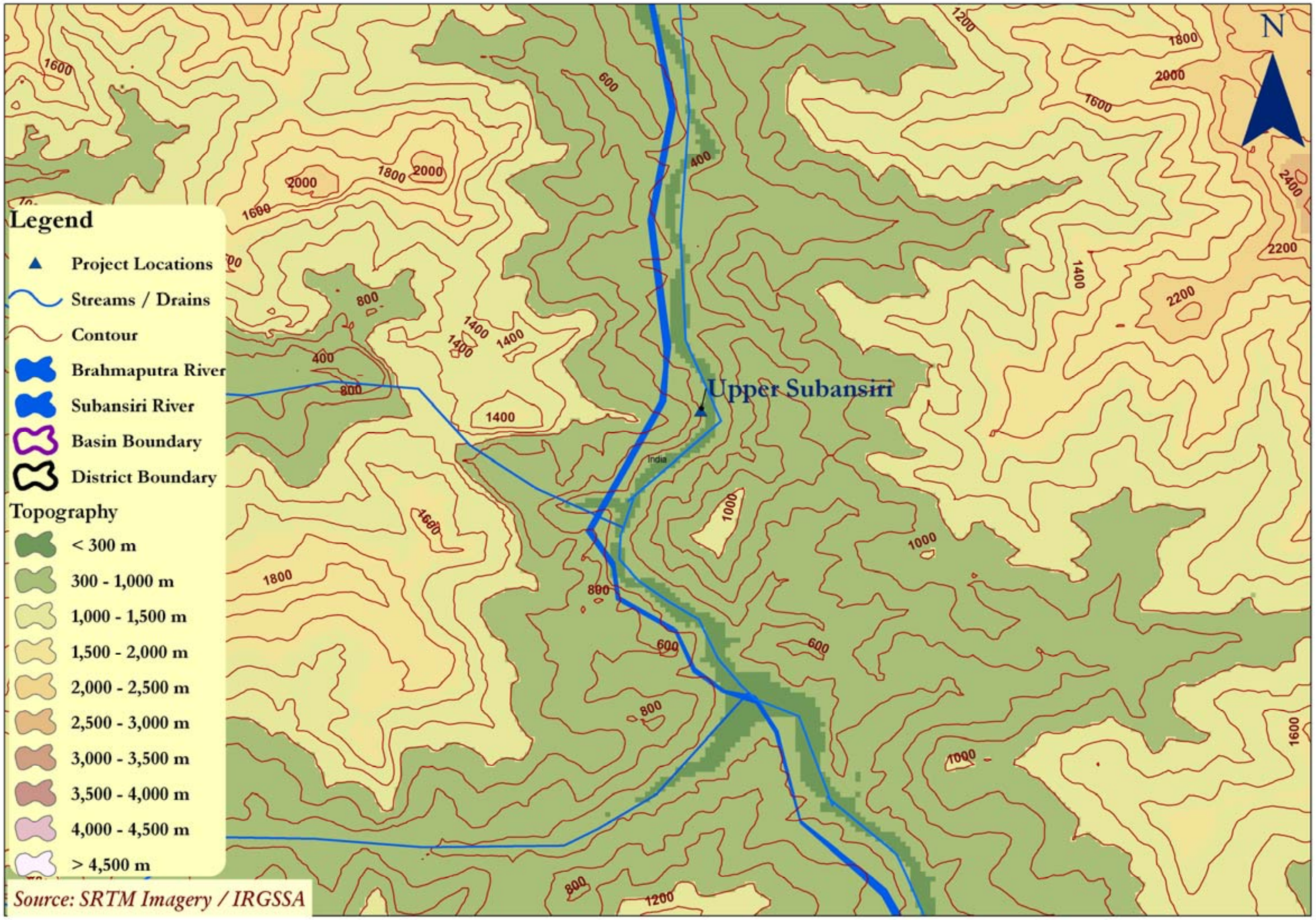


Figure 3.5: Subansiri Upper Location, Physiography & Topography of the Projects

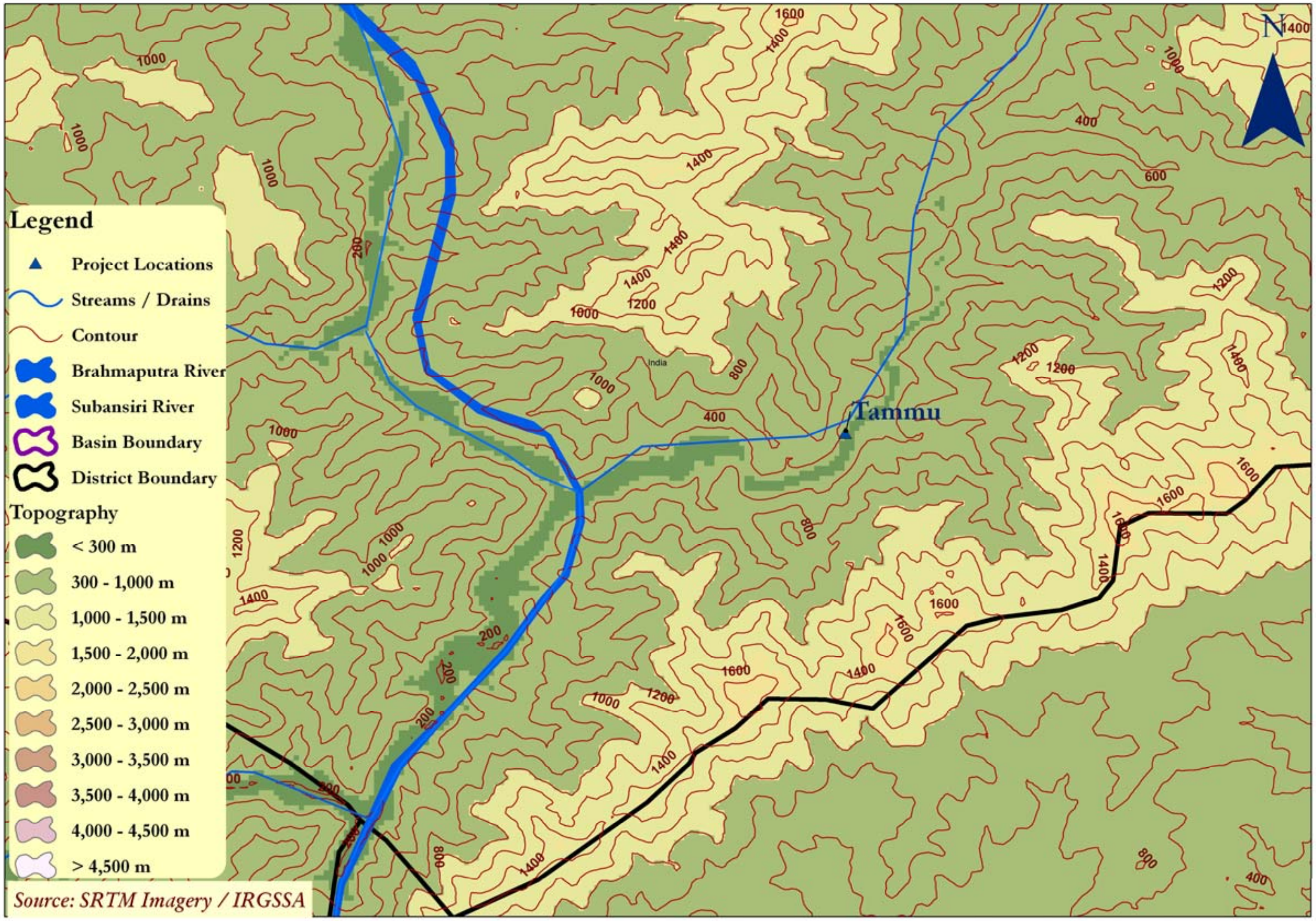


Figure 3.6: Tammu Location, Physiography & Topography of the Projects

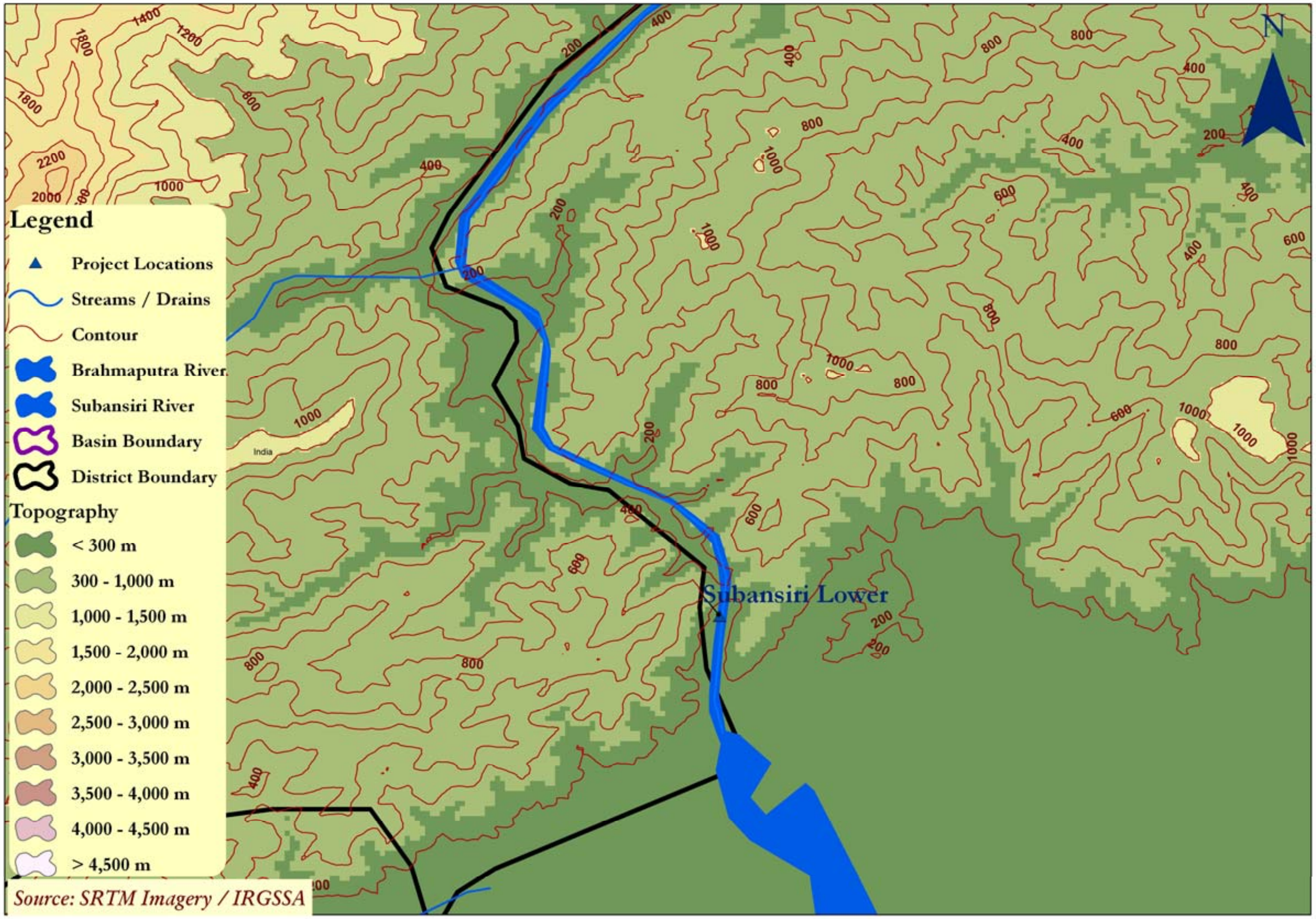


Figure 3.7: Lower Subansiri Location, Physiography & Topography of the Projects

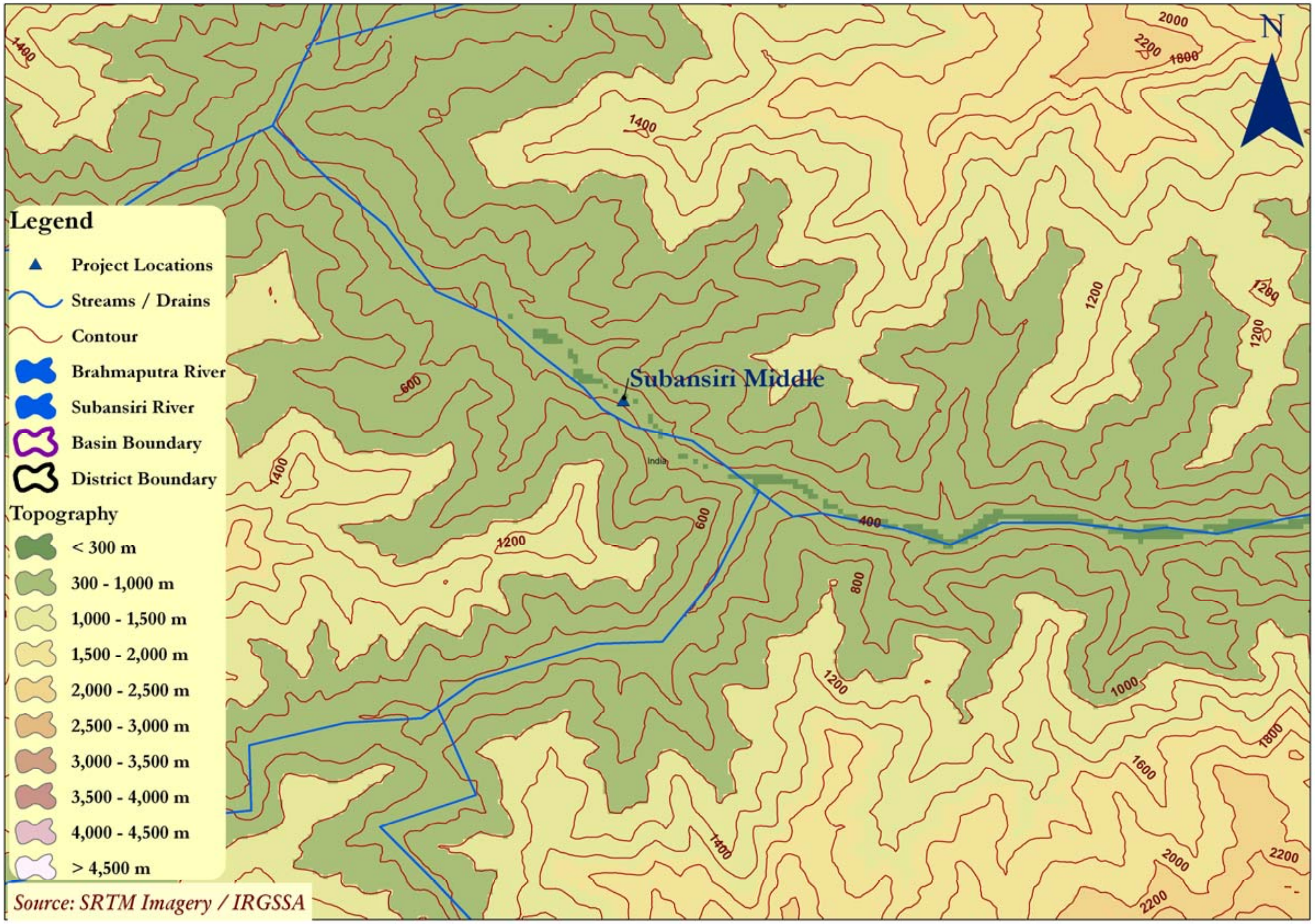


Figure 3.8: Subansiri Middle (Kamala HEP) Location, Physiography & Topography of the Projects

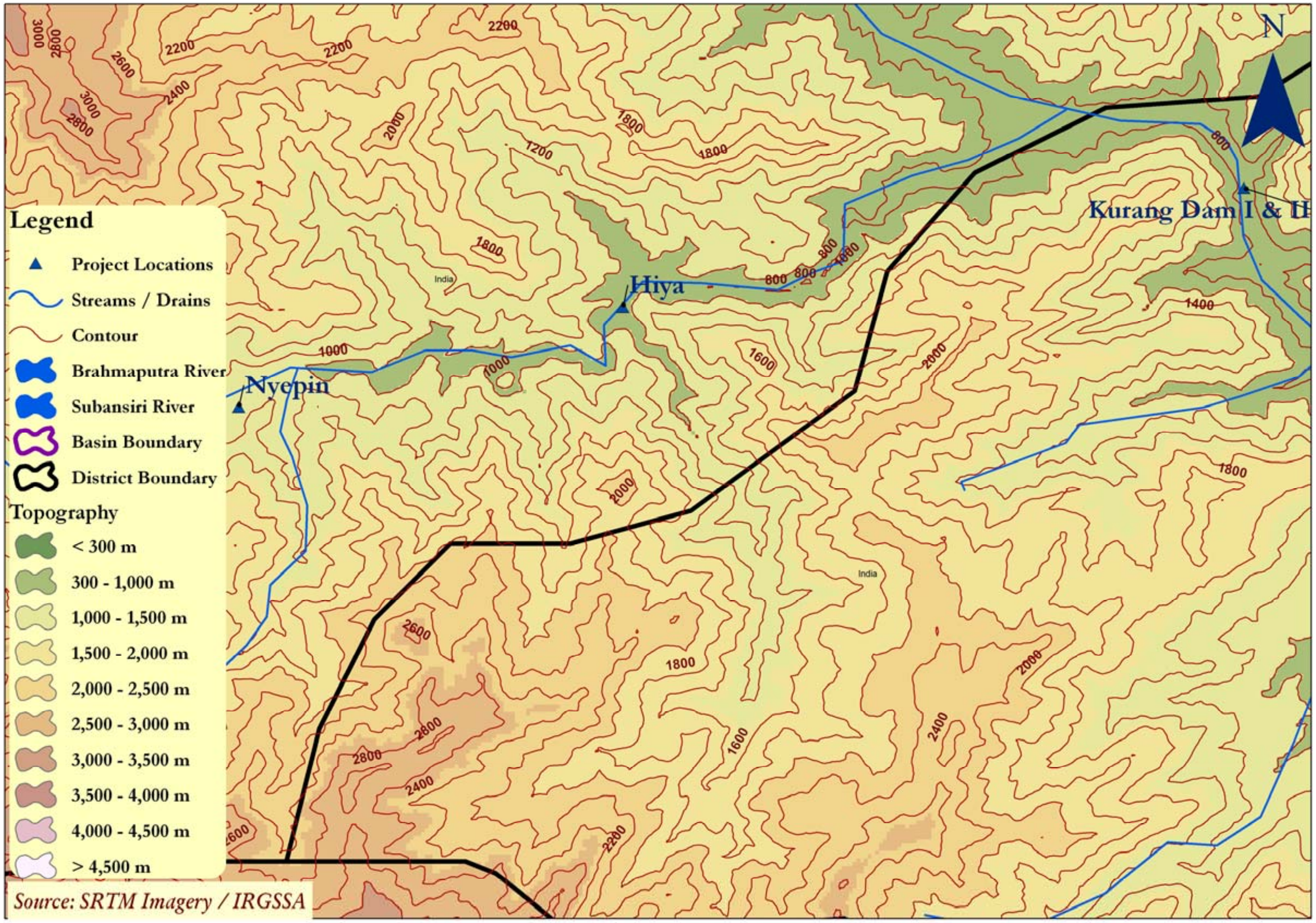


Figure 3.9: Nyepin, Hiya & Kurang I & II Location, Physiography & Topography of the Projects

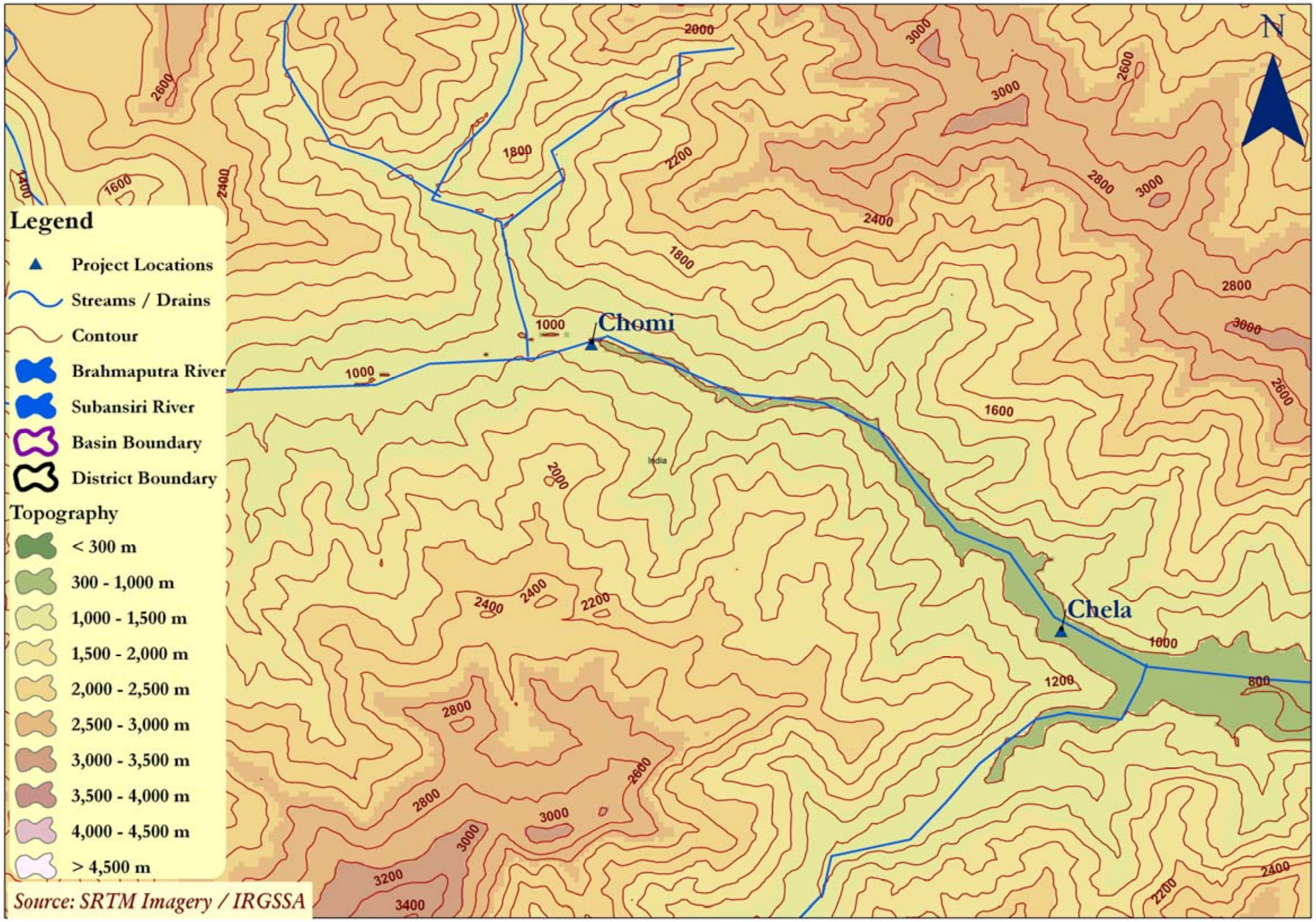


Figure 3.10: Chomi & Chela Location, Physiography & Topography of the Projects

Gradient analysis of the proposed cascade development of nineteen projects has been summarized in **Table 3.5** and depicted in **Figure 3.11, Figure 3.12, Figure 3.13 & Figure 3.14**.

Table 3.5: Gradient Analysis

Sr. No.	HEP Locations - Subansiri			Distance	Cumm Dist	Altitude	Dist Bet. FRL & TWL (Km)
	From	To					
1.	From Entry	Oju-1		19.93		2275	
2.	Oju-1	Oju-2		9.75	0.00	1889	0.35
3.	Oju-2	Niare		10.86	9.75	1560	0.53
4.	Niare	Naba		14.27	20.61	1180	0.64
5.	Naba	Nalo		19.49	34.88	925	2.04
6.	Nalo	Dengser		9.07	54.37	675	3.44
7.	Dengser	Upper Subansiri		51.66	63.44	537	1.54
8.	Subansiri Upper	Subansiri Lower		92.33	115.10	241	48.36
9.	Subansiri Lower				207.43	112	
Sr. No.	HEP Locations - Kamla			Distance	Cumm Dist	Altitude	Dist Bet. FRL & TWL (Km)
	From	To					
1.	From Start	Confluence		142.38	0.00	4000	
2.	Confluence	Subansiri Middle (Kamala HEP)		8.79	142.38	317	
3.	Subansiri Middle (Kamala HEP)	Confluence		36.82	151.17	310	
4.	Confluence				187.99	182	
Sr. No.	HEP Locations - Kurung			Distance	Cumm Dist	Altitude	Dist Bet. FRL & TWL (Km)
	From	To					
1.	From Start	Mili		33.70	0.00	4395	
2.	Mili	Sape		8.59	33.70	1365	1.55
3.	Sape	Chomi		14.48	42.29	1135	2.24
4.	Chomi	Chela		10.50	56.77	1004	2.98
5.	Chela	Kurang Dam I – II		39.17	67.27	840	6.56
6.	Kurang Dam I & II	Confluence		39.14	106.44	693	
7.	Confluence				145.58	317	
Sr. No.	HEP Locations - Payam			Distance	Cumm Dist	Altitude	Dist Bet. FRL & TWL (Km)
	From	To					
	From Start	Nyepin		28.21	0.00	2092	
	Nyepin	Hiya		13.43	28.21	1044	5.17
	Hiya	Confluence		12.45	41.64	883	
	Confluence				54.09	638	

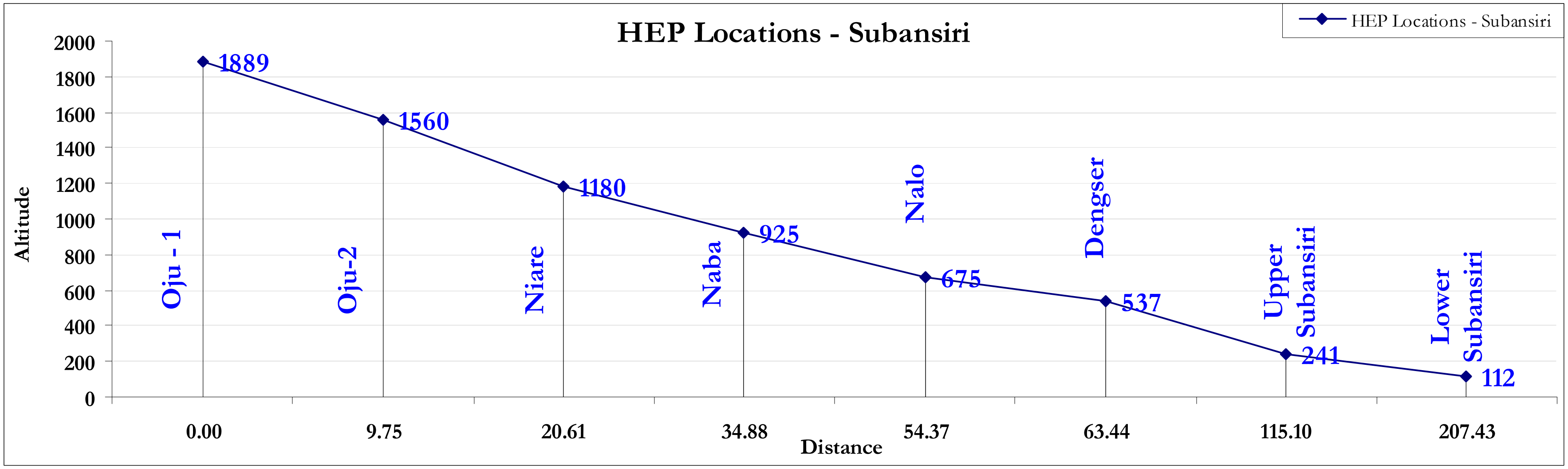


Figure 3.11: Proposed Cascade Development of HEP on Main Stem of Subansiri

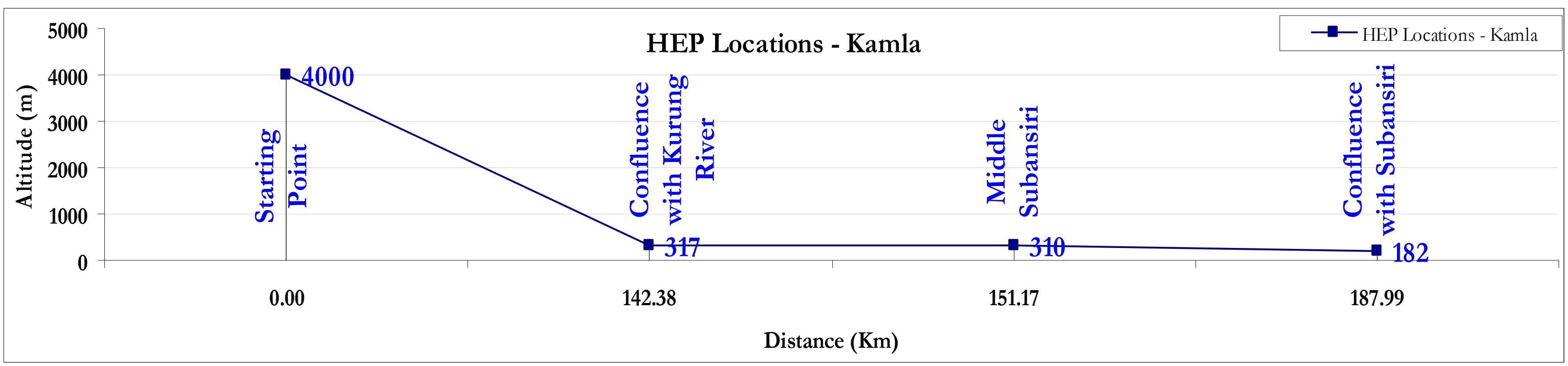


Figure 3.12: Proposed Cascade Development of HEP on Kamla River

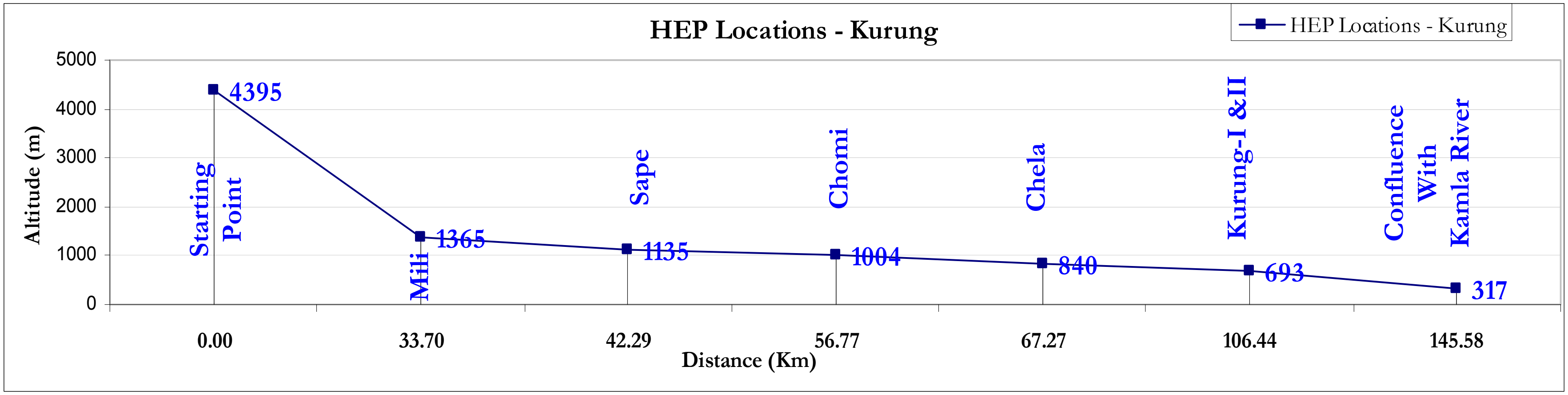


Figure 3.13: Proposed Cascade Development of HEP on Kurung River

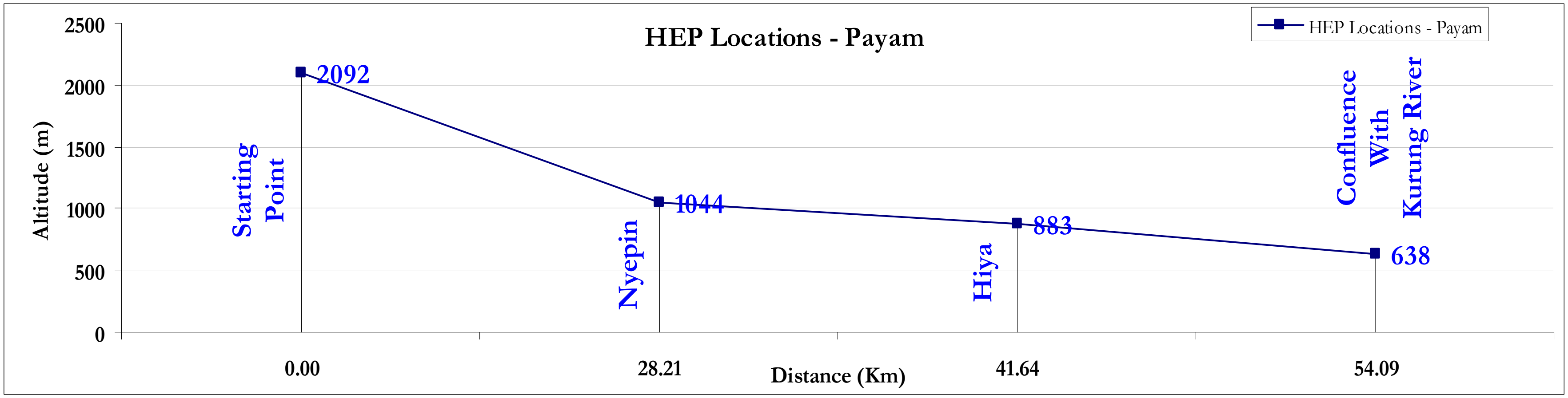


Figure 3.14: Proposed Cascade Development of HEP on Payam River

On analyzing the above data, it can be seen that from the Oju – I to Oju – II the slope is 22.93 m/km, Oju – II to Niare is 37.35 m/km, Niare to Naba is 19.19 m/km, Naba to Nalo is 17.00 m/km, Nalo to Dengser is 6.84 m/km, Dengser to Upper Subansiri Project at Menga is 5.56 m/km and that from Menga to Lower Subansiri is 1.80 m/km which shows that the slope on the main stem of Subansiri River is rather steep.

For the Kamla River, it can be seen that from the start of the river to the point of confluence of Kurung River the slope is 25.86 m/km, from the confluence point to the Middle Subansiri (Kamala HEP)project near Tamen, it is 0.79 m/km, and from Tamen to the confluence point with Subansiri River it is 3.47 m/km, which shows that the slope on the main stem of Kamla River is steep in the beginning of the river but the slope substantially reduces as it reaches the confluence with Subansiri River. For Kurung River, it can be seen that from the start of the river to Mili slope is 89.91 m/km, from Mili to Sape it is 26.77 m/km, from Sape to Chomi is 9.04 m/km, Chomi to Chela is 15.62 m/km, Chela to Kurung 1 & 2 is 3.75 m/km and from Kurung to the confluence point with Kamla River it is 9.60 m/km which shows that the slope on the main stem of Kurung River is extremely steep in the beginning of the river but the slope substantially reduces as it reaches the confluence with Kamla River. For the Payam River, it can be seen that from the start of the River to Nyepin the slope is 37.14 m/km, from Nyepin to Hiya it is 11.99 m/km, and from Hiya to the confluence point with Kurung River it is 19.68 m/km which shows that the slope on the main stem of Payam River is steep in the beginning of the river but the slope substantially reduces as it reaches the confluence with Kurung River.

In the earlier proposal, Oju-I has been proposed on right bank and Oju-II on left bank as necessitated by the topography. The Border Roads Organisation (BRO) alignment runs along the right bank and the left bank has undisturbed forests. It is desirable to have both the schemes on right bank only so as minimize disturbance and impact on the forests. Further, the free stretch between the earlier proposed Oju-I (with installed capacity of 700 MW) and Oju-II (with installed capacity of 1000 MW) works out to be less than 1 km which is not desirable from environmental angle. In view of these factors, the earlier proposed Oju I and Oju II have been recommended to be merged as one project namely Oju (with installed capacity of 1878 MW), at the location of earlier proposed Oju I.

The earlier proposed location of Oju I will be the dam location of the merged Oju project. With this merger, the distance between FRL and TWL of Oju and Niare is 0.88 km and Niare (with proposed installed capacity of 800 MW) and Naba (with proposed installed capacity of 1000 MW) is 0.64 km. Since the distance between these projects is less than 1 km, it is recommended that detailed surveys and investigations should be carried out to ascertain the distance between FRL and TWL of Niare and Naba. It is recommended that the distance between FRL and TWL should be made in accordance with MoEF guideline of maintaining the distance of at least 1 km.

Chapter 4: Hydrometeorology

4.1 General Climatic Conditions in Subansiri Basin

Arunachal Pradesh has different climatic zones, which experience varied climatic conditions. Major parts of the state have humid sub tropical climate with wet summer & winters. Similarly, the climatic condition of the Subansiri basin varies from place to place as well as season to season. The climate is largely influenced by the nature of terrain depending upon altitude and location of place in the basin. It may broadly be divided into four seasons in a year:

(1) The cold weather (December to February)
(2) The pre-monsoon season (March to May) followed by,
(3) The South –West monsoon (June to about the middle of October)
(4) Post monsoon or the retreating monsoon (second half of October to November).

In the foot hills area, the climatic condition is moderate in comparison to high altitude areas, where the winter is very cold and chilly, and the summer is pleasant. December and January are generally the coldest months, while June & July are warmest months.

4.2 Rainfall

Rainfall in the Subansiri basin districts has been compiled and analyzed from 1901 till 2010 based on IMD data given in **Annexure 4.1**. The list of rainfall stations in Subansiri Basin, their class coordinates and elevation[8] are given in **Annexure 4.1**. Mean monthly rainfall in the basin districts during this period has been summarized in Table 4.1 & Table 4.2 and depicted in Figure 4.1 & Figure 4.2. Analysis of this data indicates that minimum recorded mean monthly rainfall ranges from 0.02 mm to 169.40 mm, while maximum recorded mean monthly rainfall ranges from 60.50 mm to 615.79 mm. January is the leanest month while July is the wettest month. The monthly and annual rainfall at Ziro, Daporijo, Koloriang, Taliha and Limeking measured by NHPC is given in **Annexure 4.2**. There is some variability in rainfall as seen from the rainfall data of different places in the basin. The average annual rainfall in Subansiri lower sub basin is about 1885 mm while the same in Subansiri upper sub basin is about 1665 mm. The average annual rainfall at Ziro, Daporijo, Koloriang, Taliha and Limeking is about 1220 mm, 1750 mm, 2860 mm, 2440 mm and 2275 mm respectively[9].

Annual rainfall in the Southern part of basin is heavier than the Northern areas. During the monsoon period, more than 70 % of the rain is over the Southern half while in the Northern portions, it is about 60 %. Variability of rainfall for the monsoon and the year, as a whole, are relatively small.

Climatic conditions indicates that the study area experiences prolonged monsoon i.e. from June to Middle of October. As per “State’s Action Plan on Climate Change” during monsoon, average number of days having light rainfall in the basin districts is above 80.

[8] *Indian Meteorological Department (http://www.imdpune.gov.in/research/ndc/ndc_index.html)*
[9] *(These figures are based on historical data of 1901 – 2010 from IMD.)*

Days when rainfall is high, range from 1 to 5 days, while extreme rainfall days range from 1 to 2 days. During post monsoon, average number of rainy days in the state ranges from 12 days to 17 days.

Table 4.1: Mean Monthly Rainfall in Lower Subansiri from 1901 to 2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average (mm)	12.20	22.74	48.97	133.83	226.24	353.39	383.37	299.62	218.67	96.83	15.73	9.73
Min. (mm)	0.02	0.86	5.38	37.05	58.03	46.10	104.00	68.60	53.00	0.40	0.17	0.13
Max .(mm)	60.50	88.20	121.89	299.87	553.68	588.69	615.79	470.75	401.25	226.60	90.19	61.58

Source: IMD

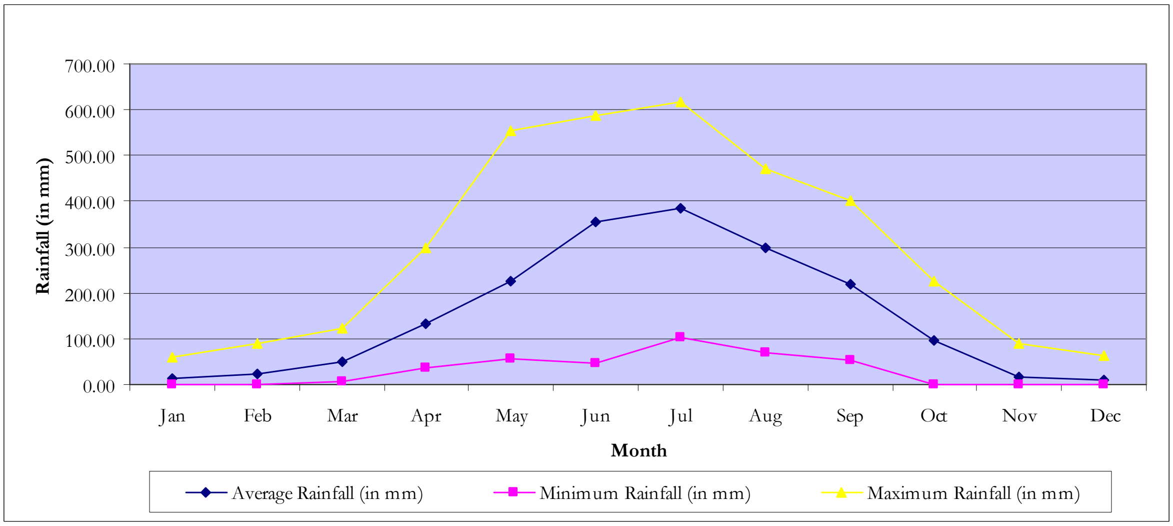


Figure 4.1: Mean Monthly Rainfall in Lower Subansiri from 1901 to 2010

Table 4.2: Mean Monthly Rainfall in Upper Subansiri from 1901 to 2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average (mm)	11.48	22.83	46.41	119.70	188.72	322.26	359.46	277.28	205.60	85.58	14.86	8.99
Min. (mm)	0.03	1.19	6.57	32.80	47.52	131.75	169.40	127.37	91.90	5.56	0.14	0.03
Max. (mm)	79.80	123.80	181.00	315.40	457.65	552.84	580.45	454.40	362.08	195.39	87.65	54.66

Source: IMD

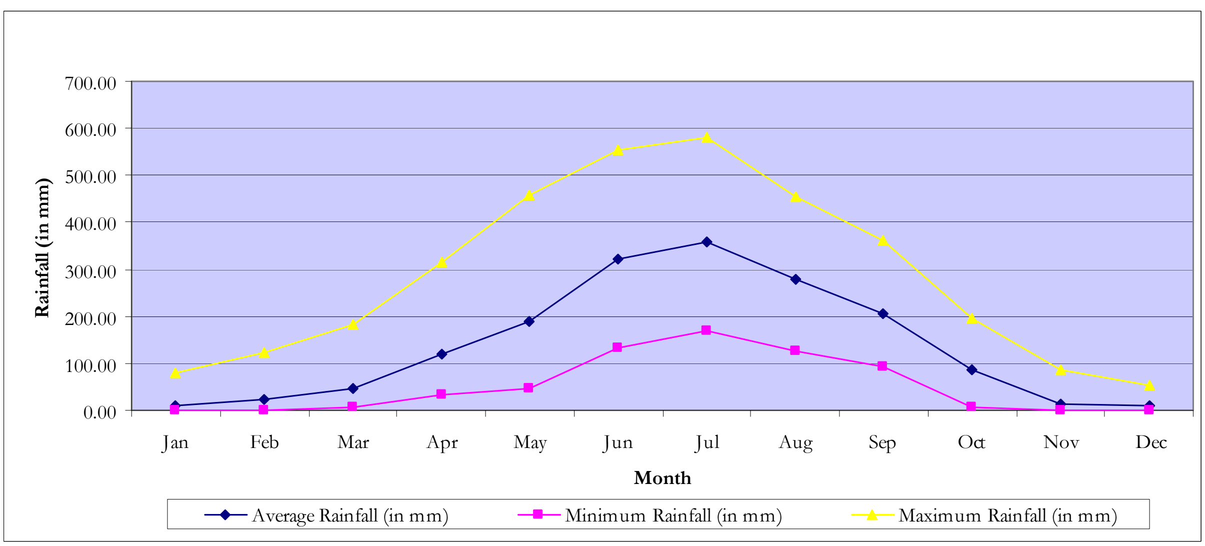


Figure 4.2: Mean Monthly Rainfall in Upper Subansiri from 1901 to 2010

In addition, the rainfall scenario of Subansiri basin has been studied and analyzed using TRMM data which is shown in **Figure 4.3**. The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to measure rainfall for weather and climate research. TRMM is designed to measure tropical precipitation and its variation from a low-inclination orbit combining a suite of sensors to overcome many of the limitations of remote sensors previously used for such measurements from space. TRMM is a comprehensive and systematic program designed to increase the extent and accuracy of tropical rainfall measurement. The TRMM science program consists of a broad research effort which includes development of cloud models, rain retrieval algorithms for the space sensors, use of TRMM measurements with other satellite data to improve sampling, a surface-based verification system, and a TRMM science data and information system (TSDIS).

The average annual rainfall for the period 1998-2009 is available for the tropic region in Geotiff format which gives a fairly good assessment of hypsometric variation in rainfall in Himalayan region and same has been presented as **Figure 4.3** below, which shows that in Subansiri basin area, rainfall variation is approximately of the order of 500 - 2900 mm in Subansiri catchment while in Kamla catchment it is between 500 – 2000 mm and between 750 – 2000 mm in Kurung catchments, rainfall variation is approximately of the order of 500 - 3000 mm. This rainfall data was assessed for comparative estimation of yields during environment flow assessment.

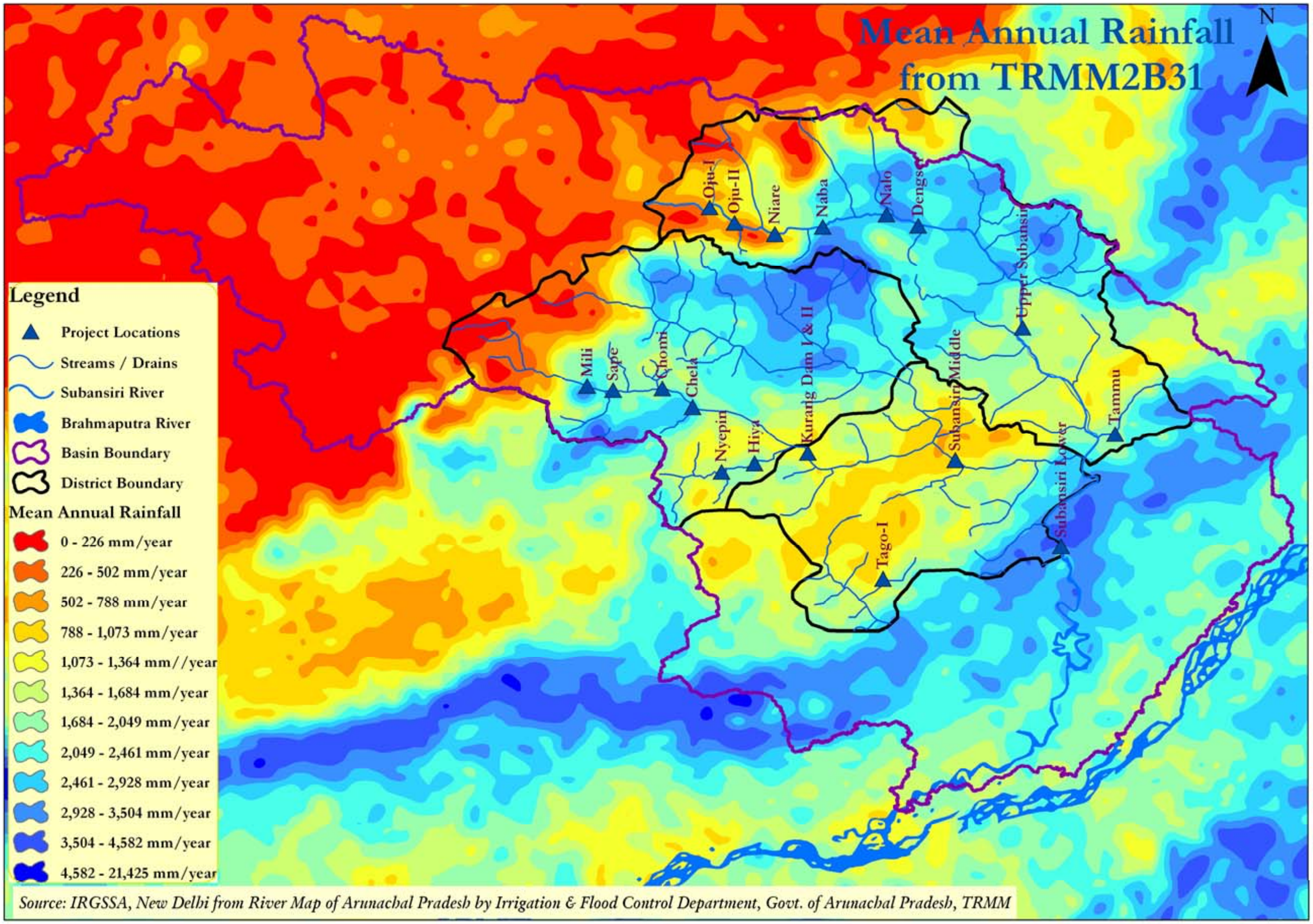


Figure 4.3: Rainfall Scenario in Subansiri from TRMM

4.3 Temperature and Humidity

Temperature profile in the Subansiri basin districts has been compiled and analyzed from 1901 to 2002 based on IMD data given in **Annexure 4.3**. Mean Monthly Minimum & Mean Monthly Maximum temperature during this period have been summarized in **Table 4.3** & **Table 4.4** and depicted in **Figure 4.4** & **Figure 4.5**.

Table 4.3: Mean Monthly Temperature in Lower Subansiri from 1901 to 2002

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum (ºC)	8.95	10.03	13.68	16.01	18.75	21.12	21.82	22.08	20.99	17.84	13.55	9.66
Maximum (ºC)	12.70	16.14	18.37	21.32	22.71	24.49	24.46	24.32	23.65	21.74	17.42	13.55

Source: IMD

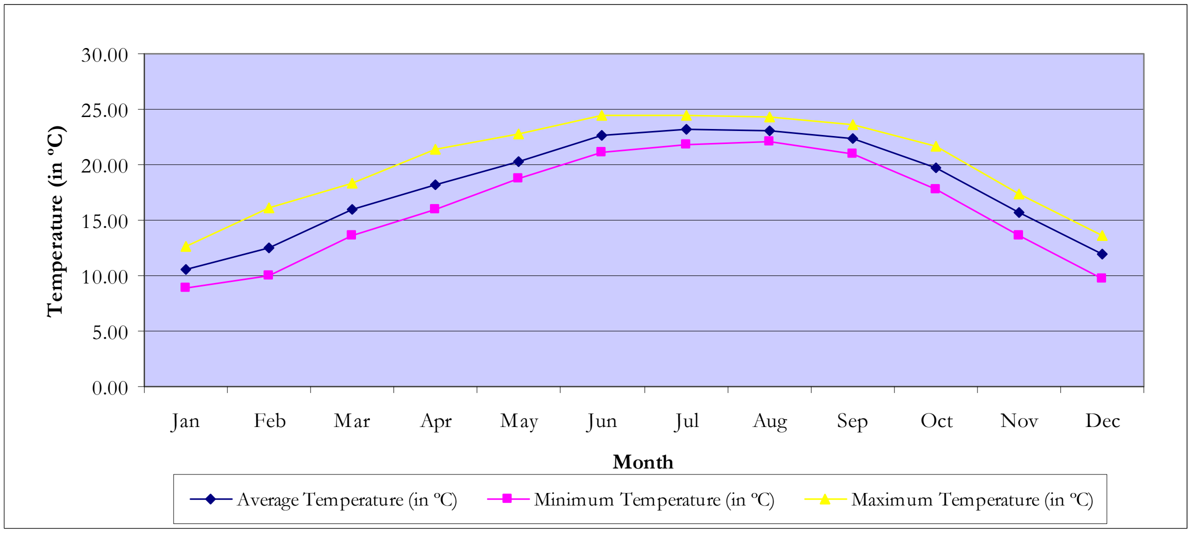


Figure 4.4: Mean Monthly Temperature in Lower Subansiri from 1901 to 2002

Table 4.4: Mean Monthly Temperature in Upper Subansiri 1901 to 2002

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min (ºC)	5.39	6.71	10.07	12.68	15.96	18.55	19.29	19.59	18.33	14.90	10.01	6.29
Max (ºC)	9.46	12.53	15.01	17.99	19.92	22.14	22.12	21.97	21.03	18.76	14.23	10.25

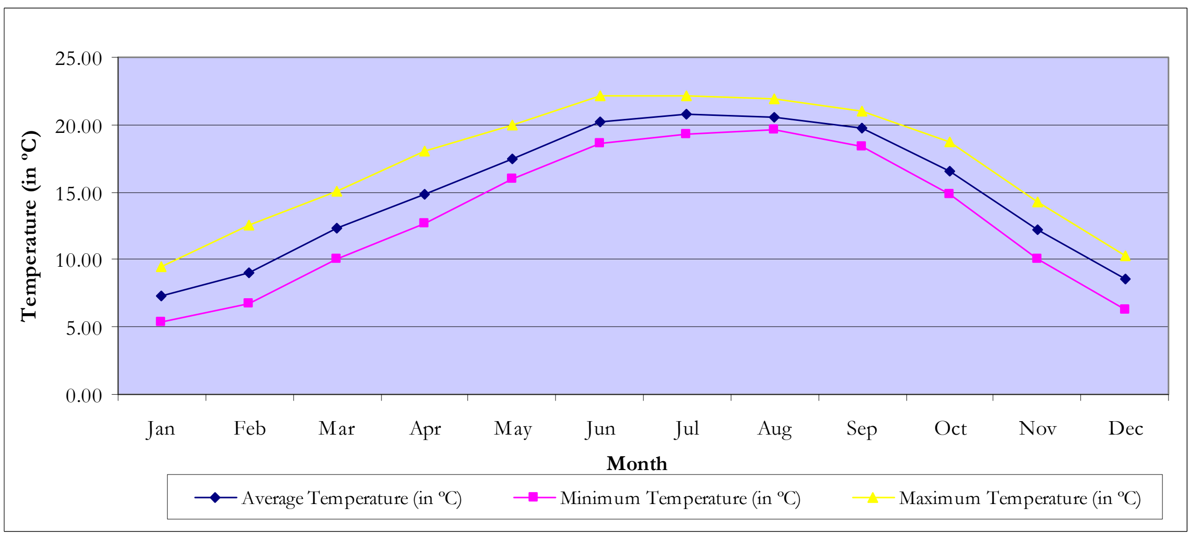


Figure 4.5: Mean Monthly Temperature in Upper Subansiri from 1901 to 2002

Mean monthly minimum temperature in the basin ranges from 5.39 ºC to 22.08 ºC while mean monthly maximum temperature ranges from 9.46 ºC to 24.49 ºC, January is the coldest month, while June & July are the warmest months.

Relative humidity is always high throughout the year except winter months being slightly less humid. In the cold season, the sky is obscured on many mornings due to lifted fog which clears with the advance of the day. Generally, the study area is moderately clouded during March to May, heavily clouded to overcast in the monsoon season and clear or slightly clouded during the post monsoon season. Winds are generally light. Strong winds down the valleys are experienced as local effect produced due to terrain.

Relative humidity in Subansiri basin based on observations from 1965 to 1980 at Ziro Observatory is summarized in **Table 4.5**. It shows that relative humidity ranges from maximum 82% in March, April, July, August, October and November and minimum 75% in January[10].

Table 4.5: Relative humidity in Subansiri Basin

Month		Relative Humidity (%)
January	I	75
	II	75
February	I	81
	II	76
March	I	82
	II	78
April	I	82
	II	79
May	I	79
	II	75
June	I	81
	II	77
July	I	82
	II	76
August	I	82
	II	77
September	I	81
	II	77
October	I	82
	II	81
November	I	82
	II	79
December	I	76
	II	75
Annual total or Mean	I	82
	II	77
Number of Years	I	11
	II	11

Source: IMD

[10] *I- Annual total or Mean and II- Number of Years*
Source: Climatological tables (1951-1980), India Meteorological Department, New Delhi 1999.

4.4 Water Availability

Rainfall records for different years within Subansiri Basin are available at about 28 ordinary and one observatory stations of India Meteorological Department. NHPC is also maintaining around 22 ordinary and 15 self-recording rain gauges within Subansiri basin since 2001. Discharge data of Subansiri are available at Chouldhowaghat (CD Ghat), Gerukamukh, Menga G&D sites. This data has been observed by CWC, Brahmaputra Board and NHPC at different points of time. Discharge data of Kamla River is available at Tamen. At present CWC is gauging River Subansiri at three locations viz CD Ghat at Gerukamukh, Limeking and Bataudi Ghat sites. In all there are 16 existing gauging sites within the Subansiri basin as given in **Table 4.6**.

Table 4.6: Available records of the gauge and discharge sites in Subansiri Basin

S. No	G&D/ Gauge Site	Period of Data Availability	Type of Data
1.	Menga (NHPC)	2003-2008	G&D
2.	Daporijo (BB)	1978 to 1987	G&D
3.	Tamen (BB)	1980 to 1998, July 2002 till date	G&D
4.	Gerukamukh (BB)	1973 to 2008 (with gaps)	G&D
5.	Chouldhowaghat (BB + CWC)	1956 to 1997, Dec 2000 till date	G&D
6.	Tamen Bridge (Kamla-NHPC)	Jun 2000 till date	G&D,HG
7.	Tamen (Pein-NHPC)	Jun 2000 till date	G&D,HG
8.	Deo-Nallah (NHPC)	Oct 2000 till date	G&D,HG
9.	Suspension Bridge (NHPC)	Apr 2002 till date	G&D, HG
10.	PH Site (Subansiri Upper – NHPC)	Jun 2000 till date	Hourly Gauge
11.	PH Site (Subansiri Middle (Kamla) – NHPC)	Jun 2000 to Aug 2002	Hourly Gauge
12.	Ferryghat (Subansiri Lower –NHPC)	Jun 2000 to Oct 2002	Hourly Gauge
13.	Chouldhowaghat	1974-Sept 2000	Hourly Gauge
14.	Tamen	1981 to 1985	Hourly Gauge
15.	Daporijo	1981 to 1985	Hourly Gauge
16.	Gorgemouth	1981,1984	Hourly Gauge

Source: DPR of Subansiri Upper Project, NHPC, Vol-3, Hydrology / 06 CH-03 Water Availability Study

Water availability series for the hydro electric projects in the Subansiri basin has been finalized by Central Water Commission (CWC) based on the observed discharge data of Chouldhowaghat, Gerukamukh, Menga and Tamen Gauge & Discharge (G&D) sites. The observed discharge data of these G&D sites has been checked for its consistency using the appropriate statistical test. So far CWC has approved the water availability series for Subansiri lower, Subansiri middle (Kamla), Subansiri upper, Nalo and Oju-I HE Projects. The water availability series for Subansiri lower HE Project was worked out on the basis of observed discharge data of Chouldhowaghat and Gerukamukh G&D sites using the yield correction factor and catchment area proportioning. The water availability series of Subansiri middle (Kamla HE Project) had been worked out on the basis of observed discharge data at Tamen G&D site. The water availability series for Subansiri upper, Nalo and Oju-I HE Projects were estimated on the basis of observed discharge data of Menga, Chouldhowaghat and Gerukamukh G&D sites using the catchment area proportion and yield correction factor. While finalizing the water availability series, the yield correction factor apart from catchment area proportioning has been applied by CWC in order to take into account the hypsometric variability of rainfall in the Subansiri basin.

Though the approved water availability series are available for the above mentioned 5 projects only, however for the present study of the basin, CWC has also provided the 90% dependable flow series for Naba, Dengser, Niare and Oju-II HE projects.

The 90% dependable flow series for Kurang-I, Kurang-II, Nyepin, Hiya, Mili and Sape HE Projects has been estimated by catchment area proportion on the basis of 90% dependable flow series of Subansiri middle (Kamla HE Project).

The flow scenario of 90% dependable year for the hydro electric projects in the basin is given in **Table 4.7** & the flow series of 90% dependable year of projects (season-wise) is given in **Table 4.8**. The same has been used for detailed hydrodynamic modeling, for estimating the environmental flow releases for the planned hydro electric projects in the Subansiri basin.

Table 4.7: Flow Series of 90% Dependable Year of Projects

Unit: Cumec

90% dependable Year		1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	2006-07	Synthetic Series	1981-82	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07
Months		Oju-I (CA-9827 sq.km)	Oju-II (CA-9979 sq. km)	Niare (CA-11181 sq.km)	Naba (CA-11272 sq.km)	Nalo (CA-12150 sq.km)	Dengser CA-12581 sq.km)	Subansiri Upper (CA-14665 sq.km)	Tammu (CA-952 sq.km)	Subansiri Lower	Subansiri Middle (CA-7213 sq.km)	Kurang-I & II (CA-2680 sq.km)	Mili (CA-723 sq.km)	Sape (CA-990 sq.km)	Chomi (CA-1335 sq.km)	Chela (CA-1446 sq.km)	Nyepin (CA-318 sq.km)	Hiya (CA-607 sq.km)
June	I	290.13	296.15	338.20	341.88	377.04	394.41	478.36	163.33	1484.56	1237.47	459.78	124.04	169.85	204.84	248.08	54.56	104.14
	II	291.94	298.01	340.32	344.02	379.40	396.88	481.36	205.80	1505.55	1559.3	579.36	156.30	214.02	258.12	312.60	68.74	131.22
	III	487.09	497.21	567.81	573.99	633.02	662.17	803.12	154.87	2692.18	1173.38	435.97	117.61	161.05	194.23	235.23	51.73	98.74
July	I	725.67	740.75	845.92	855.13	943.07	986.50	1196.49	146.21	2315.28	1107.79	411.6	111.04	152.05	183.38	222.08	48.84	93.22
	II	863.46	881.4	1006.54	1017.50	1122.14	1173.82	1423.68	155.55	3082.95	1178.58	437.9	118.14	161.76	195.10	236.27	51.96	99.18
	III	606.68	619.29	707.22	714.92	788.44	824.75	1000.31	111.02	2447.4	841.18	312.54	84.32	115.45	139.24	168.63	37.09	70.79
August	I	412.89	421.47	481.31	486.55	536.59	561.30	680.78	73.03	3405.57	553.29	205.58	55.46	75.94	91.59	110.92	24.39	46.56
	II	359.71	367.18	419.31	423.88	467.47	489.00	593.09	56.08	4408.61	424.92	157.88	42.59	58.32	70.34	85.18	18.73	35.76
	III	474.82	484.68	553.50	559.53	617.07	645.49	782.89	144.51	3059.18	1094.91	406.82	109.75	150.28	181.25	219.50	48.27	92.14
Sept	I	423.55	432.35	493.73	499.11	550.44	575.79	698.35	111.09	1726.11	841.68	312.73	84.37	115.52	139.33	168.73	37.11	70.83
	II	359.71	367.18	419.31	423.88	467.47	489.00	593.09	185.47	1635.85	1405.25	522.12	140.86	192.87	232.62	281.71	61.95	118.26
	III	304.48	310.8	354.93	358.79	395.69	413.92	502.02	92.49	1370.38	700.78	260.38	70.24	96.18	116.00	140.49	30.9	58.97
Oct	I	349.24	356.49	407.11	411.54	453.86	474.77	575.82	99.28	2250.03	752.2	279.48	75.40	103.24	124.52	150.79	33.16	63.30
	II	205.79	210.07	239.90	242.51	267.45	279.76	339.31	88.85	1106.97	673.17	250.12	67.48	92.39	111.43	134.95	29.68	56.65
	III	141.18	144.11	164.57	166.36	183.47	191.92	232.77	55.04	988.83	417.03	154.95	41.80	57.24	69.03	83.60	18.39	35.09
Nov	I	100.27	102.35	116.88	118.16	130.31	136.31	165.32	43.67	777.53	330.91	122.95	33.17	45.42	54.78	66.34	14.59	27.85
	II	78.9	80.54	91.97	92.98	102.54	107.26	130.09	38.80	739.28	293.99	109.23	29.47	40.35	48.67	58.94	12.96	24.74
	III	65.38	66.74	76.22	77.05	84.97	88.89	107.8	40.31	538.4	305.44	113.49	30.62	41.92	50.56	61.23	13.47	25.70
Dec	I	51.61	52.69	60.17	60.82	67.08	70.17	85.1	35.76	400.15	270.92	100.66	27.16	37.18	44.85	54.31	11.94	22.80
	II	44.34	45.26	51.68	52.25	57.62	60.27	73.1	33.38	410.23	252.92	93.97	25.35	34.71	41.87	50.70	11.15	21.28
	III	47.36	48.34	55.20	55.80	61.54	64.38	78.08	26.44	393.49	200.32	74.43	20.08	27.49	33.16	40.16	8.83	16.86
Jan	I	38.85	39.66	45.29	45.79	50.49	52.82	64.06	25.16	315.89	190.62	70.83	19.11	26.16	31.55	38.21	8.4	16.04
	II	38.42	39.22	44.79	45.27	49.93	52.23	63.35	24.76	260.82	187.62	69.71	18.81	25.75	31.06	37.61	8.27	15.79
	III	40.99	41.84	47.78	48.30	53.27	55.72	67.58	23.70	241.33	179.53	66.7	18.00	24.64	29.72	35.99	7.91	15.11

																Unit:		Cumec
90% dependable Year		1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	2006-07	Synthetic Series	1981-82	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07
Months		Oju-I (CA-9827 sq.km)	Oju-II (CA-9979 sq. km)	Niare (CA-11181 sq.km)	Naba (CA-11272 sq.km)	Nalo (CA-12150 sq.km)	Dengser CA-12581 sq.km)	Subansiri Upper (CA-14665 sq.km)	Tammu (CA-952 sq.km)	Subansiri Lower	Subansiri Middle (CA-7213 sq.km)	Kurang-I & II (CA-2680 sq.km)	Mili (CA-723 sq.km)	Sape (CA-990 sq.km)	Chomi (CA-1335 sq.km)	Chela (CA-1446 sq.km)	Nyepin (CA-318 sq.km)	Hiya (CA-607 sq.km)
Feb	I	38.78	39.58	45.20	45.69	50.39	52.71	63.93	27.65	328.8	209.52	77.85	21.00	28.76	34.68	42.00	9.24	17.63
	II	46.26	47.23	53.93	54.52	60.13	62.89	76.28	28.25	272.99	214.07	79.54	21.46	29.38	35.44	42.91	9.44	18.01
	III	41.61	42.48	48.51	49.03	54.08	56.57	68.61	29.43	340.35	222.96	82.84	22.35	30.60	36.91	44.70	9.83	18.76
March	I	53.68	54.79	62.57	63.25	69.76	72.97	88.5	40.65	502.41	308	114.44	30.87	42.27	50.98	61.75	13.58	25.92
	II	92.24	94.16	107.53	108.70	119.88	125.40	152.09	43.89	733.12	332.54	123.56	33.33	45.64	55.05	66.66	14.66	27.98
	III	147.86	150.93	172.36	174.23	192.15	201.00	243.78	45.52	604.08	344.92	128.16	34.57	47.34	57.10	69.15	15.21	29.03
April	I	110.2	112.49	128.46	129.86	143.22	149.81	181.7	68.40	734.85	518.27	192.56	51.95	71.13	85.79	103.90	22.85	43.61
	II	128.63	131.3	149.94	151.57	167.16	174.86	212.08	67.00	967.02	507.65	188.62	50.88	69.68	84.03	101.77	22.38	42.72
	III	159.72	163.04	186.19	188.22	207.57	217.13	263.35	115.10	922.79	872.04	324.01	87.41	119.69	144.35	174.82	38.45	73.39
May	I	192.85	196.85	224.80	227.25	250.62	262.16	317.97	60.86	1070.87	461.09	171.32	46.22	63.29	76.33	92.44	20.33	38.80
	II	463.77	473.41	540.62	546.51	602.71	630.47	764.67	75.88	1119.67	574.9	213.6	57.63	78.91	95.17	115.25	25.35	48.38
	III	205.47	209.74	239.52	242.12	267.03	279.32	338.78	117.05	1273.96	886.87	329.52	88.90	121.72	146.81	177.79	39.1	74.63

Table 4.8: Flow Series of 90% Dependable Year of Projects (season-wise)

Unit: Cumec

90% dependable Year	1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	2006-07	1981-82	1981-82	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07
Months	Oju-I (CA-9827 sq.km)	Oju-II (CA-9979 sq. km)	Niare (CA-11181 sq.km)	Naba (CA-11272 sq.km)	Nalo (CA-12150 sq.km)	Dengser CA-12581 sq.km)	Subansiri Upper (CA-14665 sq.km)	Tammu (CA-952 sq.km)	Subansiri Lower	Subansiri Middle (CA-7213 sq.km)	Kurang-I & II (CA -2680 sq.km)	Mili (CA-723 sq.km)	Sape (CA-990 sq.km)	Chomi (CA-1335 sq.km)	Chela (CA-1446 sq.km)	Nyepin (CA-318 sq.km)	Hiya (CA-607 sq.km)
Monsoon Discharge																	
Mon-Avg-Jun to Sep-cumec	466.68	476.37	544.01		606.49	634.42	769.46	133.29		1009.88	410.92	101.23	138.61	167.17	202.45	44.52	84.98
10 % of avg -cumec	46.67	47.64	54.40		60.65	63.44	76.95	13.33		100.99	41.09	10.12	13.86	16.72	20.25	4.45	8.50
15 % of avg -cumec	70	71.46	81.60		90.97	95.16	115.42	19.99		151.48	61.64	15.18	20.79	25.08	30.37	6.68	12.75
20 % of avg -cumec	93.34	95.27	108.80		121.30	126.88	153.89	26.66		201.98	82.18	20.25	27.72	33.43	40.49	8.90	17.00
30 % of avg -cumec	140	142.91	163.20		181.95	190.33	230.84	39.99		302.96	123.28	30.37	41.58	50.15	60.74	13.36	25.50
40 % of avg -cumec	186.67	190.55	217.60		242.60	253.77	307.78	53.32		403.95	164.37	40.49	55.44	66.87	80.98	17.81	33.99
50 % of avg -cumec	233.34	238.19	272.00		303.24	317.21	384.73	66.64		504.94	205.46	50.61	69.30	83.58	101.23	22.26	42.49
100 % of avg -cumec	466.68	476.37	544.01		606.49	634.42	769.46	133.29		1,009.88	410.92	101.23	138.61	167.17	202.45	44.52	84.98
Lean Months Discharge																	
Lean-Avg-Dec to Mar-cumec	52.73	53.83	61.47		68.53	71.68	86.94	31.44		238.24	96.94	23.88	32.70	39.44	47.76	10.50	20.05
10 % of avg -cumec	5.27	5.38	6.15		6.85	7.17	8.69	3.14		23.82	9.69	2.39	3.27	3.94	4.78	1.05	2.00
15 % of avg -cumec	7.91	8.07	9.22		10.28	10.75	13.04	4.72		35.74	14.54	3.58	4.90	5.92	7.16	1.58	3.01
20 % of avg -cumec	10.55	10.77	12.29		13.71	14.34	17.39	6.29		47.65	19.39	4.78	6.54	7.89	9.55	2.10	4.01
30 % of avg -cumec	15.82	16.15	12.29		20.56	21.51	26.08	9.43		71.47	29.08	7.16	9.81	11.83	14.33	3.15	6.01
40 % of avg -cumec	21.09	21.53	24.59		27.41	28.67	34.78	12.58		95.29	38.78	9.55	13.08	15.77	19.10	4.20	8.02
50 % of avg -cumec	26.37	26.91	30.73		34.26	35.84	43.47	15.72		119.12	48.47	11.94	16.35	19.72	23.88	5.25	10.02
100 % of avg -cumec	52.73	53.83	61.47		68.53	71.68	86.94	31.44		238.24	96.94	23.88	32.70	39.44	47.76	10.50	20.05
Other 4 Months Discharge																	
Avg-Oct-Nov-Apr-May-cumec	187.55	191.45	218.63		243.74	254.97	309.24	73.13		554.06	225.45	55.54	76.05	91.72	111.07	24.43	46.63
10 % of avg -cumec	18.76	19.14	21.86		24.37	25.50	30.92	7.31		55.41	22.54	5.55	7.60	9.17	11.11	2.44	4.66
15 % of avg -cumec	28.13	28.72	32.79		36.56	38.24	46.39	10.97		83.11	33.82	8.33	11.41	13.76	16.66	3.66	6.99
20 % of avg -cumec	37.51	38.29	43.73		48.75	50.99	61.85	14.63		110.81	45.09	11.11	15.21	18.34	22.21	4.89	9.33
30 % of avg -cumec	56.27	57.43	65.59		73.12	76.49	92.77	21.94		166.22	67.63	16.66	22.81	27.51	33.32	7.33	13.99
40 % of avg -cumec	75.02	76.58	87.45		97.50	101.99	123.69	29.25		221.62	90.18	22.21	30.42	36.69	44.43	9.77	18.65
50 % of avg -cumec	93.78	95.72	109.32		121.87	127.48	154.62	36.56		277.03	112.72	27.77	38.02	45.86	55.54	12.21	23.31
100 % of avg -cumec	187.55	191.45	218.63		243.74	254.97	309.24	73.13		554.06	225.45	55.54	76.05	91.72	111.07	24.43	46.63

Chapter 5: Approach and Methodology

5.1 Approach & Methodology

A work plan and a detailed approach & methodology to complete the activities mentioned in SoW was submitted to CWC. This included primary and secondary data collection from different sources. Further, approach & methodology was customized after midcourse correction suggested by TAC during presentation on 1st May 2012 as well as the minutes on the presentation received on 7th May 2012 which are summarized in section 3.5. As per the Terms of Reference (ToR) following major tasks were conducted to complete the work.

5.1.1 Meteorology

Information on various meteorological aspects was collected from India Meteorological Department (IMD) for meteorological stations located within the Subansiri basin area or in vicinity to the basin boundary. This included various aspects such as rainfall, temperature, wind, humidity etc.

5.1.2 Water Resources

Information on following aspects was collected and included:

- Review of drainage characteristics of the basin, including various surface water bodies like rivers and lakes.
- Data collection and review of past studies/reports/data, etc.
- Review of existing water sharing agreements for meeting various need-based existing and future demands viz. municipal, irrigation, power generation and industrial.
- Analysis of all, past assessment of the water availability and assessing the water availability, as per updated data for the system as a whole and at existing ongoing / proposed project locations on annual / monsoon / non – monsoon and monthly basis.
- Estimation of sediment load at various points in the basin based on available secondary data.
- Identification of perennial sources of water and their designated usages.

The above data was collected from the Central Water Commission (CWC), State water resources department, IMD and project implementing agency.

5.1.3 Water Quality

Water sampling and analysis of water sampling has been done in accordance with Uniform Protocol on Water Quality Monitoring Order 2005, vide notification dated 17th June 2005, Ministry of Environment and Forests, Government of India and National Drinking Water Standard (IS:10500), 1991.

As a part of the study, primary data for water quality was collected in the study area. As per ToR, water quality monitoring was proposed at 19 HEP's by CWC which includes 32 water sampling locations in the study area. Two additional existing G&D stations of CWC downstream of Lower Subansiri HEP namely Chauldhuaghat and

Badodighat in Assam, were considered for water quality monitoring. The frequency of sampling was once per month for 12 months including one rainy season. The various parameters considered for water quality include pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Alkalinity, Total Hardness, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrates, Chlorides, Sulphates, Phosphates, Sodium, Calcium, Magnesium, Potassium, Iron, Manganese, Zinc, Cadmium, Lead, Copper, Mercury, Total Chromium and Total Coliform.

The water quality monitoring was proposed at 21 sites (19 HEPs+2 existing G&D stations of CWC) as per the ToR. Out of 21 sites, water sampling data of 13 sites (11 HEPs +2 G&D stations), and totaling 23 water sampling locations is presented in this report. Water samples were collected during each sampling season for physico-chemical as well as biological parameters. The sampling sites were located near the area where major project components are proposed like dam site, powerhouse, muck dumping sites, working area, near the confluence of major tributaries with the main channel and near settlements. The composite water samples from the river were taken in triplicates at each site and average values were computed for the results. The details of sampling sites and their location along with coordinates are given in **Figure 5.1.**

Name and number of HEPs and sampling locations[11] are given in **Table 5.1**. The details of monitoring results are summarized in Chapter 7.

Table 5.1: Name and number of proposed HEPs and sampling locations

Sr. No.	Name of the project	Number of sampling locations (As per ToR)
1.	Oju – I	2
2.	Oju – II	3
3.	Niare	2
4	Naba	3
5.	Mili	1
6	Sape	1
7	Chomi	1
8	Chela	1
9	Kurang I & II	1
10	Tamen	1
11	Tago – I	1
12	Subansiri Lower	3
13	Subansiri Middle (Kamala HEP)	3
14	Subansiri Upper	3
15	Nalo	1
16	Dengser	2
17	Tammu	1
18	Nyepin	1
19	Hiya	1
20	Chauldua Ghat*	1
21	Badodighat*	1
Total		32*+2= 34 locations

Water Quality Monitored

[11] *Note:*
**2 additional locations of CWC's G&D stations namely Chauldhuaghat and Batodighat located in Assam, downstream of Lower Subansiri HEP (under construction).*

In order to assess the water quality of Subansiri River and its tributary streams a Water Quality Index (WQI) was used which has been developed at Washington State Department of Ecology, Environmental Assessment Programme. WQI used in the report is a unit less number ranging from 1 to 100. A higher number is indicative of better water quality. For temperature, pH, faecal coliform bacteria and dissolved oxygen, the index expresses results relative to levels required to maintain beneficial uses (based on criteria in Washington's Water Quality Standards, WAC 173-201A).

WQI is a 100 point scale that summarizes results from a total of eight different measurements viz. pH, Dissolved Oxygen, Turbidity, Faecal Coliform, Biochemical Oxygen Demand, Total Phosphates, Nitrates, and Total Suspended Solids. The analysis of water quality, therefore, is based upon 8 parameters as defined for WQI.

Water Quality Index	
Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very Bad

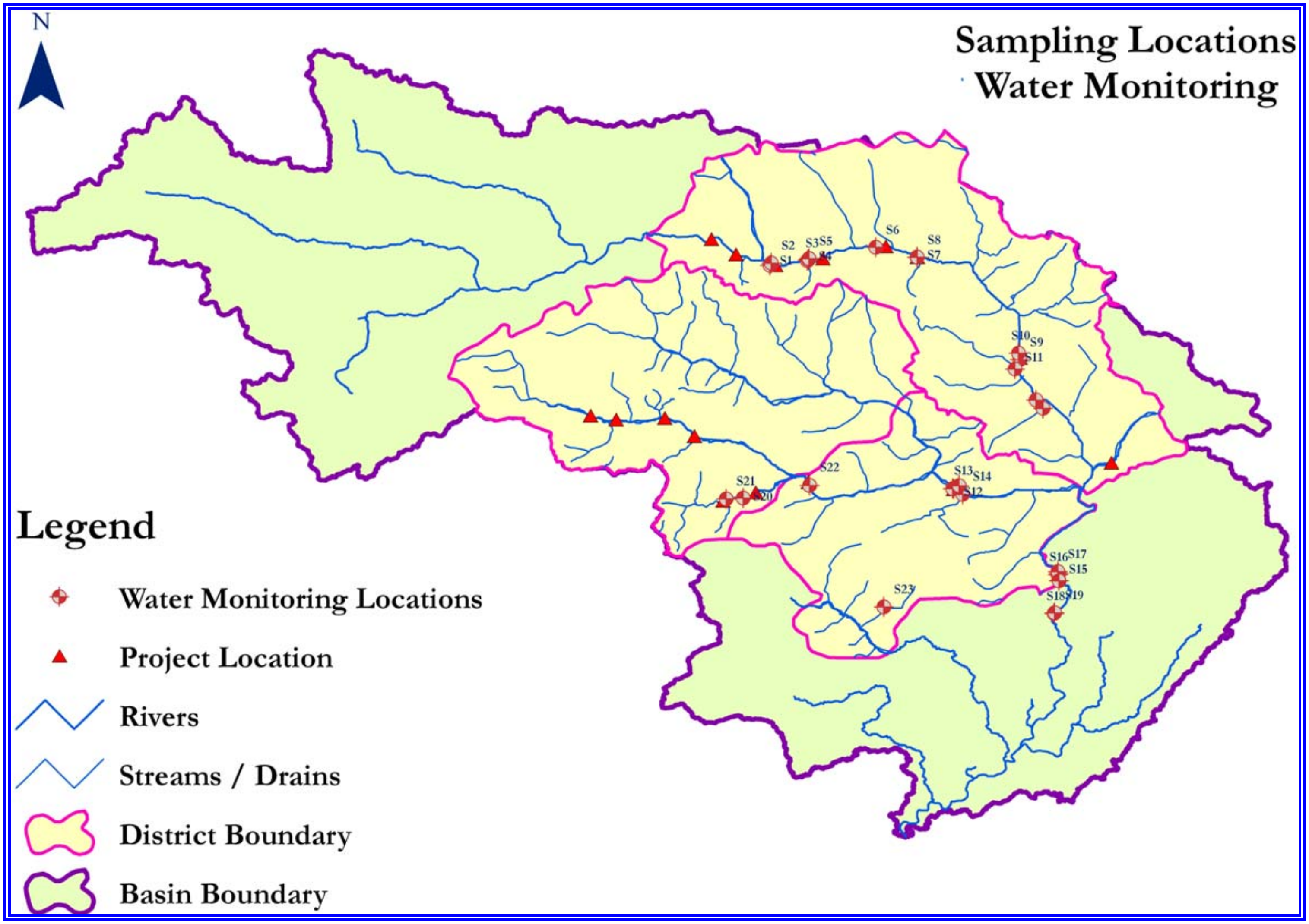


Figure 5.1: Water Sampling Locations

5.2 Assessment of Aquatic and Terrestrial biodiversity

Land use/Land Cover

Land use involves the mapping of natural environment into built environment such as settlements and semi-natural habitats such as arable fields, pastures and managed woods. The representative secondary data of the study area was collected from National Remote Sensing Centre (NRSC) which has been analyzed and described in Chapter 6.

Terrestrial flora

Data was collected from various secondary sources related to Upper Subansiri, Lower Subansiri and Kurung Kumey districts falling in the Subansiri basin as per the ToR. These include:

- Identification of forest type and density, bio-diversity in the study area.
- Preparation of comprehensive checklist of flora (Angiosperms, Gymnosperms, Lichens, Pteridophytes, Bryophytes, Fungi, Algae etc.) with Botanical and local name.
- Importance Value Index of the dominant vegetation at various sampling locations.
- Frequency, Abundance and density of each species of Trees, Shrubs and Herbs at representative sampling sites.
- Identification and listing of plants genetically, biologically, economical and medicinal importance.
- Major forest product, if any and dependence of locals on the same in the forests observed in the study area.

As per the ToR, characterization of forest types in the study area and extent of each forest type was done as per Champion and Seth, 1968 classification of forest types in the study area. Extent of each forest type was identified as per the Forest Working Plan of the study area, namely working plan of Hapoli Forest Division and Daporijo Forest Division. Information on general vegetation pattern and floral diversity was collected from the Materials for the flora of Arunachal Pradesh (in three volumes), Botanical Survey of India and Forest Working Plan of the study area. Presence of economically important species in the basin area was recorded as per the Materials for the flora of Arunachal Pradesh (in three volumes), Botanical Survey of India, working plan of the study area, etc. Presence of endemic floral species was recorded in the basin area as per the Materials for the flora of Arunachal Pradesh (in three volumes), of Botanical Survey of India (BSI), Working Plan of the study area and Red data Book of Indian Plants and the IUCN Red List of Threatened Species etc. Flora under Rare, Endangered and Threatened Plants categories was listed using International criteria and Botanical Survey of India's Red Data list. Information was collected on location of wildlife sanctuaries, national parks, biosphere reserves, etc. from ENVIS Centre on Wildlife & Protected Areas, Wildlife Institute of India, Botanical Survey of India and Zoological Survey of India.

Methodology for collection of primary flora data

To understand the community composition and structure of vegetation of the study area, stratified random sampling method was used to obtain baseline data. The size and number of quadrats needed were determined using the species-area curve method (Mishra, 1968). The sampling was conducted by placing quadrats of 10 x 10 m^2 for trees, 5 x 5 m^2 for shrubs and 1 x 1 m^2 for herbs. Quadrats used for shrubs and herbs were nested within the quadrats laid for trees. All the quadrats were spatially distributed so as to minimize the autocorrelation among the vegetation. The data on vegetation were quantitatively analyzed for density, frequency and abundance as per Curtis & McIntosh (1950). The Importance Value Index (IVI) for trees was determined as the sum of relative density, relative frequency and relative dominance (Curtis, 1959). Tree individuals with > 31.5 cm CBH (circumference at breast height i.e., 1.37 m from the ground) were individually measured for CBH. Data were collected for all the three seasons in case of herb and shrub species and once in case of tree species.

For the calculation of dominance, the basal area was determined by using following formula (Mishra, 1968).

Basal area (BA) = $(CBH)^2 / 4\pi$

The index of diversity was computed by using Shannon Wiener Diversity Index (Shannon Wiener, 1963) as:

$H = - \Sigma (ni/n) \times \ln (ni/n)$
Where, ni is individual density of a species and n is total density of all the species.

The Evenness Index (E) is calculated by using Shannon's Evenness formula (Magurran, 2004).

Evenness Index (E) = $H / \ln (S)$
Where, H is Shannon Wiener Diversity index; S is number of species.

Margalef Species Richness (SR) = $S-1/\ln(N)$
Where, S is total number of species and N is total number of individuals

Plant sampling was carried out in three seasons in 35 locations covering 10 HEPs (proposed dam sites, upstream areas, submergence areas, downstream areas, etc. to understand characteristics of vegetation in the proposed project area including catchment area up to the dam site, probable loss of vegetation due to submergence, activities during construction phase, muck disposal, etc.). The sampling locations and their coordinates are given in **Table 5.2.**

Table 5.2: Plant sampling locations in Subansiri Basin

Sr. no.	Sampling Site	Degree	Min	Sec	Lat	Degree	Min	Sec	Long
1.	Tago-S1	27	27	25.25	27.4570	93	48	4.31	93.8012
2.	Tago-S2	27	27	26.74	27.4574	93	48	19.44	93.8054
3.	Tago-S3	27	28	8.88	27.4691	93	48	26.46	93.8074
4.	Tago-S4	27	27	54.91	27.4653	93	49	7.66	93.8188
5.	Nyepin-S1	27	44	27.93	27.7411	93	22	53.7	93.3816
6.	Nyepin -S2	27	43	57.5	27.7326	93	22	34.42	93.3762
7.	Nyepin S3	27	45	21.18	27.7559	93	23	0.07	93.3834
8.	Nyepin -S4	27	44	50.79	27.7474	93	22	55.31	93.3820
9.	Hiya-S1	27	45	57.05	27.7658	93	27	53.78	93.4649
10.	Hiya-S2	27	45	46.61	27.7629	93	27	15.18	93.4542

Sr. no.	Sampling Site	Degree	Min	Sec	Lat	Degree	Min	Sec	Long
11.	Hiya-S3	27	45	19.51	27.7554	93	26	51.69	93.4477
12.	Dengser-S1	28	23	47.73	28.3966	93	52	43.16	93.8787
13.	Dengser-S2	28	24	51.09	28.4142	93	50	34.92	93.8430
14.	Dengser-S3	28	22	3.92	28.3678	93	51	33.48	93.8593
15.	Subansiri U-S1	28	4	7.02	28.0686	94	10	58.96	94.1830
16.	Subansiri U-S2	28	7	0.66	28.1169	94	8	39.37	94.1443
17.	Subansiri U-S3	28	7	40.95	28.1280	94	8	52.12	94.1478
18.	Subansiri U-S4	28	8	14.62	28.1374	94	8	56.43	94.1490
19.	Subansiri L-S1	27	32	54.83	27.5486	94	15	37.51	94.2604
20.	Subansiri L-S2	27	32	41.3	27.5448	94	15	17.3	94.2548
21.	Subansiri L-S3	27	33	33.26	27.5592	94	15	7.55	94.2521
22.	Subansiri L-S4	27	33	58.67	27.5663	94	14	7.72	94.2355
23.	Nalo-S1	28	24	34.26	28.4095	93	48	27.18	93.8076
24.	Nalo-S2	28	24	56.8	28.4158	93	47	49.9	93.7972
25.	Nalo-S3	28	24	24.11	28.4067	93	48	41.89	93.8116
26.	Naba-S1	28	22	37.31	28.3770	93	38	37.88	93.6439
27.	Naba-S2	28	22	34.17	28.3762	93	38	2.8	93.6341
28.	Naba-S3	28	23	3.12	28.3842	93	39	9.85	93.6527
29.	Niare-S1	28	21	32.51	28.3590	93	31	6.93	93.5186
30.	Niare-S2	28	21	45.91	28.3628	93	30	32.28	93.5090
31.	Niare-S3	28	21	16.94	28.3547	93	31	39.89	93.5277
32.	Middle Subansiri -S1	27	46	39	27.7775	93	58	54.97	93.9819
33.	Middle Subansiri --S2	27	46	43.19	27.7787	93	58	53.88	93.9816
34.	Middle Subansiri --S3	27	46	29.31	27.7748	93	58	53.88	93.9816
35.	Middle Subansiri --S4	27	46	19.65	27.7721	93	59	3.84	93.9844

The map showing HEPs and Terrestrial ecology sampling locations is given in **Figure 5.2**.

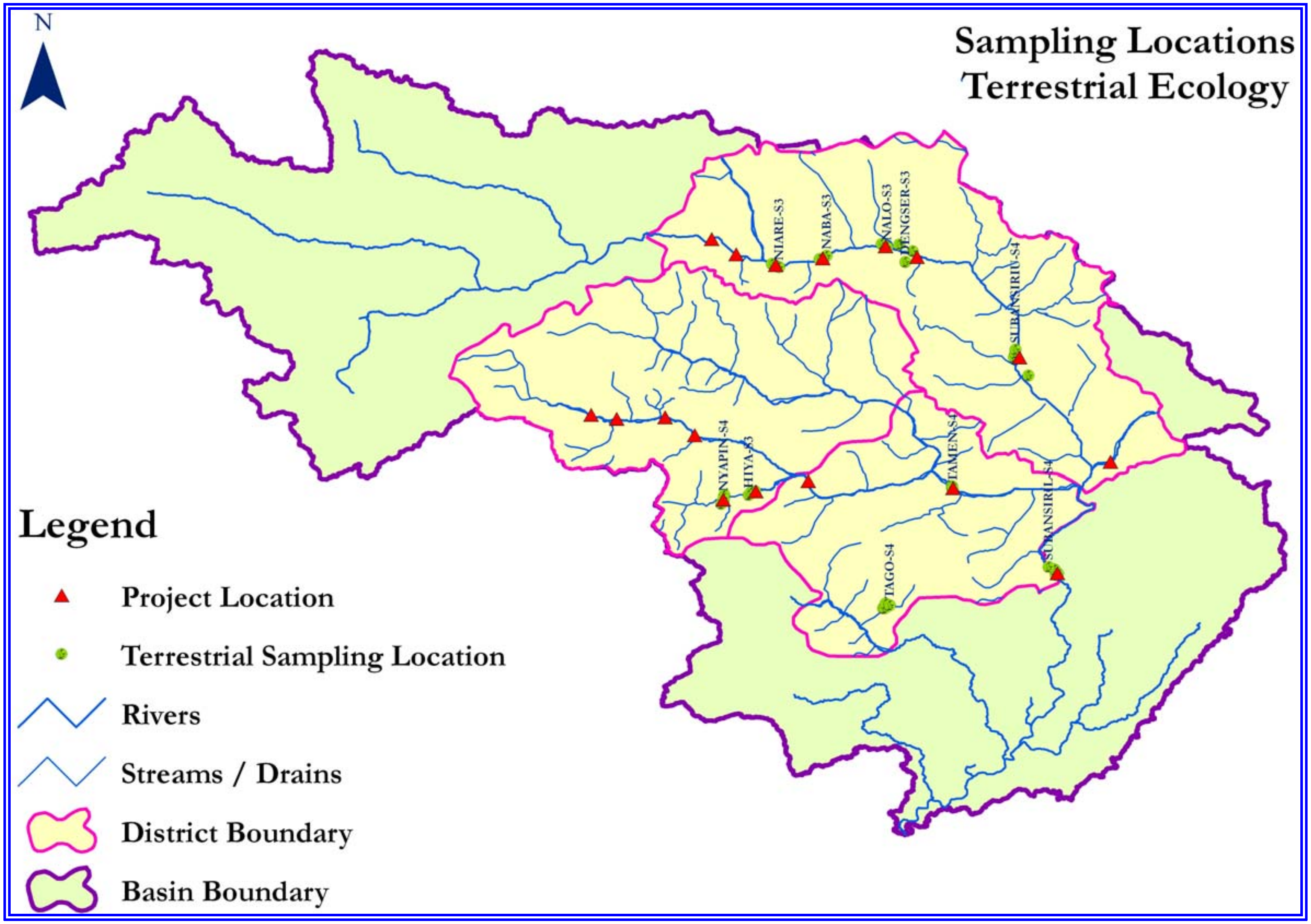


Figure 5.2: HEPs and Terrestrial ecology sampling locations

Terrestrial Fauna

During ecological survey, identification of faunal species has been carried out simultaneously. Indirect observations of mammals were made by identification of tracks, droppings (scat), claw marks and calls, etc. The listing of faunal species by direct observation techniques was carried out. The detailed list of faunal species has been formulated based on forest record and published literature. The following data on fauna has been collected through primary survey at HEP locations and various secondary sources for the study area:

- Information on Birds (resident, migratory), land animals including mammals, reptiles, amphibians, fishes etc has been collected & surveyed in the basin area.
- Presence of RET faunal species as per the categorization of IUCN Red Data list as per different schedules of Indian Wildlife Protection Act, 1972 in the basin area have been recorded.
- Presence of endemic faunal species found in the basin area (if any) has been assessed as a part of the Basin Study.
- Existence of barriers and corridors for wild animals (if any) has been covered as a part of the study.
- Identification of threats to wildlife in the region.
- Information has been collected on location of wild life sanctuaries, national parks, biosphere reserves (if any) from ENVIS Centre on Wildlife & Protected Areas and Wildlife Institute of India.

The fauna has been assessed using standard methods in different seasons from sampling sites identified during the initial reconnaissance survey. Methodologies were suitably modified wherever the field conditions so demanded and linear transect of 1 km each was chosen for identification of fauna. Each transect was trekked for 1 hour for sampling for animals. The sampling methods used are described below.

Taxa	Sampling Methods
Butterflies	Pollard Walk (Random Walk), Opportunistic observations
Amphibians	Visual Encounter Survey (search)
Reptiles	Visual Encounter Survey (search)
Birds	Random Walk, Opportunistic observations
Mammals	Tracks and signs, and Visual Encounter Survey
Fish	Sampling using appropriate fishing nets

Butterflies: The butterflies of the area have been documented using direct observations during Random Walks, Opportunistic Observations and Standardized Transect Counts during morning hours (9:00 to 11:00 hrs) Butterfly surveys have been carried out by searching 5 m distance on either side of transect. Various standard reference texts (Haribal, 1992; Gunathilagaraj *et.al,* 1998; Kunte & Gadgil, 2000; Kehimkar, 2008) have been referred for the identification of butterflies.

Avifauna: The avifauna of the study site has been documented through Direct Observations, Random Walks and Opportunistic Observations, during early morning (6:00 to 10:00 hrs.) and evening 17:00 to 19:00 hrs) using a pair of binoculars (10x50). Line transect method was applied for recording the birdlife communities in the study area (Bibby & Buckland, 1987; Bibby *et.al,* 2000; Thompson, 2002). The length and numbers of transects have been decoded based on local topography and conditions. Standard books have been followed for identification and nomenclature (Ali & Ripley, 1981; Grimmett *et.al,* 1999).

Visual Encounter Method (all out search) has been followed during the survey for amphibians and reptiles. Visual Encounter Survey (VES) is one in which field personnel walk through a chosen area for a prescribed time period systematically searching for animals. This is an appropriate technique for inventory and monitoring studies. During the search leaf litter, fallen logs and trees (bark, buttress, root, shrubs, boulders, rocks and rock crevices) is examined. The identification of herpetofauna has been done with the help of keys given by Boulenger (1890), Daniel and Sekar, 1989; Daniel, 2002; Daniel, 2005; Indraneil Das, 2002; Whitaker and Captain, 2004.

Mammals: Both direct and indirect methods have been applied to sample mammals present in the study area. Indirect evidences like tracks and signs (e.g. footprints/pugmarks, calls, signs and scats) along with Visual Encounter Surveys have been used and a Night survey was conducted for sampling nocturnal mammals and chiropterans (Moreno & Halffter, 2000).

3 Aquatic flora and fauna

Phytobenthos and Plankton

Samples of periphyton were obtained by scraping of 3 cm^2 area of the boulders and preserved in 1 ml of Lugol's solution. The upper surfaces of boulders have been scraped with the help of sharp razor. The keys of Trivedy and Goel (1984) and Ward and Whipple (1959) have been used for identifying the filamentous and non-filamentous algae. Plankton (phyto & zooplankton) samples have been collected using plankton net. The samples were preserved in Lugol's solution and carried to the laboratory for their study. Identification of planktons, their density & diversity have been estimated using different indices (MargalefIndex, Simpson's Index).

Benthic Macro-Invertebrates

Benthic macro-invertebrates was collected from the designated sampling sites in river using Surber's Square Foot Sampler device adopting random sampling (Welch, 1948).

A simple hand net was used as kick net to collect aquatic insects from running water. The organisms collected were immediately preserved in 5% buffered formalin. All the samples were segregated in the laboratory and examined under a Stereo zoom binocular microscope (Nikon SMZ-U model) and identified with the aid of standard manuals.

Ichthyofauna (Fish Fauna)

A diverse array of active as well as passive gears including cast net, scoop net, drag net, gill net traps were used in various standardized combinations for sampling the fishes from different areas.

Sections of the streams, river and associated aquatic systems representing a wide range of habitat conditions were sampled. At each sampling site, fishes visually counted as, much as possible and then sampled using gill nets (different 8-22mm), cast net and dip nets depending upon the depth. Most of the fish measured in the field to the nearest millimeter and released after live photography. The habitat specific coefficient is calculated for individual fish species using the Electivity Index given by Lvlev, 1961 based on Schlosser, 1991.

Duration of the sampling time (netting time) determined by plotting a species area curve. Netting time is fixed as a point beyond which the number of the species (richness) would no longer increase with reasonable sampling efforts. Sampling time was standardized 'across the study sites after preliminary reconnaissance surveys.

Different fishing gears like cast net was used for sampling fish diversity at identified sites. Fish was preserved in 10% formalin solution and brought to the laboratory for their identification. Fish including their spawns, fry and fingerlings caught from the different selected sites in river and identified up to genera/species level with the help of keys given by Day-Fauna, Jayaram (1981), Menon (1987) and Talwar and Jhingran (1997). Identification of breeding and spawning season was done based on maturity status of dominant fish species and sampling/observations of larvae and eggs. Information was collected on geo-morphological changes and its impact on fish habitat. Assessment of water nutrient levels was also done following standard methods of APHA.

A detailed list of the literature referred to develop list of rare, endangered and threatened fauna has been prepared and described in respective chapter 6 on Terrestrial Ecology and chapter 7 on Aquatic Ecology.

5.3 Identification of Impacts

The diversion of water for hydropower generation leads to reduction in flow downstream to the dam site upto disposal of tail race outfall. This leads to diverse impacts on riverine ecology. The dam could also act as a barrier for migration of fishes. The possible impacts on terrestrial and aquatic ecology have been identified due to hydro-power projects. The key aspects which have been covered for assessment of impact are listed below:

- Modification in hydrologic regime due to diversion of water for hydropower generation.
- Depth of water available in river stretches during lean season and its assessment of its adequacy vis-à-vis various fish species.
- Length of river stretches with normal flow due to commissioning of various hydroelectric projects due to diversion of flow for hydropower generation.
- An impact on discharge in river stretches during monsoon and lean seasons due to diversion of flow for hydropower generation.
- Impacts on water users in terms of water availability and quality.
- Impacts on aquatic ecology including riverine fisheries as a result of diversion of flow for hydropower generation.
- Assessment of maintaining minimum releases of water during lean season to sustain riverine ecology, maintain water quality and meet water requirement of downstream users.
- Impact due to loss of forests.
- Impact on RET species & impacts on economically important plant species.
- Impacts due to increased human interferences
- Impacts due to agricultural practices.
- Downstream impact on Assam due to hydropower development in Subansiri basin and release from Lower Subansiri Dam.

Dependability Analysis

The dependability analysis has been carried out on the basis of water availability series of the projects by arranging the annual flow series in descending order and using Weibull formula.

5.4 Assessment of Environmental Flows

Environmental flow has been estimated by HEC-RAS which has been proposed to model the following flow scenarios for environmental flow considerations.

The flow scenario of 90% dependable year series of the each hydro electric project has been used and the average discharge of leanest four months, monsoon four months and non lean non monsoon four months have been computed. The flow parameters i.e. water depth, velocity of flow and top flow width has been assessed for 10%, 15%, 20%, 30%, 40%, 50% and 100% release of respective average of the three season's flows of each hydroelectric project to estimate the environmental flow release during the lean, monsoon and non lean non monsoon periods.

In general the hydraulic model set up for steady flow water surface profile computation with HEC-RAS consist of a river reach and upstream/ downstream boundary. Based on the approach, methodology and input data discussed above, the HEC-RAS model has been used for steady flow water surface profile computations of HE projects.

The release computations and flow parameters i.e. flow depth, flow velocity, flow top width corresponding to different release conditions from HE Project as computed by hydraulic model set up with HEC-RAS which is described in Chapter 8.

Downstream Impact

Downstream impacts are dependant on the water availability and positions of HEP in the basin. Therefore, in a cascade scenario, flow series e.g. from 0 to 18 hours, 18 to 22 hours and 22 to 24 have been was determined and cumulative discharge at downstream has been computed. The same is arrived at by hydrodynamic routing. Therefore, downstream impacts have been assessed based on peaking flow series under similar scenarios which is described in Chapter 4, 8 and 9.

5.5 Mid course corrections (as per comments of TAC in the meeting on May 01, 2012 and field visit in April, 2012) & Actions taken

The following mid course corrections were proposed to be incorporated, as per the valuable suggestions given by members of the Technical Advisory Committee during the field visit undertaken in April, 2012 and the TAC meeting on May 01, 2012.

1. The number of quadrats per location should be taken as per the standard methodology and members, EAC on River Valley & HE Projects, of MOEF.
2. The river cross-section at each location should be adopted either from the PFRs and other sources or by actual observation.
3. A suitable Mathematical Model should be adopted for the study in consultation with the Director (Hydrology), CWC.
4. The places of religious/social importance should be suitably covered in the report

5. Suitable management measures should be suggested to mitigate the adverse environmental and social impacts.

The Final Report addresses the comments and suggestions received vide Minutes of 68th Minutes of Meeting of EAC-River Valley and Hydroelectric Projects held on 24th September 2013, comments and suggestions made in Minutes of the Meeting of TAC's meeting held on June 11, 2014 and December 10, 2014. Compliance to EAC's observations is given in **Annexure 5.1, Volume II.**

Chapter 6: Terrestrial Ecology

6.1 Introduction

India is recognized as one of the 12 mega biodiversity centers in the world comprising two “Hot spots” regions viz; Western Ghats and Eastern Himalayas. Arunachal Pradesh with an area of 83,743 Sq. km., is located in the Eastern Himalayas, and is particularly representative of all characteristics of the region. The State has the resources in abundance with the highest forest cover in the country and is least populated. It is a nature’s laboratory unto it. As in the region, it has many endemics and vast areas are still unexplored. It is in this state that one can still hope to find new species and records hitherto unknown to the world.

An estimated number of 5000 flowering plants, 600 orchids, 400 ferns, 48 gymnosperms and an equally high number of unexplored algae, fungi, lichens and bryophytes inhabit the diverse habitats that occur in at least six broad forest types of Arunachal Pradesh. The eastern Himalayan state contains more than 33% of the total Indian flora out of which about 30% are endemic to the state. Besides, the flora of the state is considered to be the representative of the entire Indo – Malayan region. The floristic feature of Arunachal Pradesh is unique in many ways and has maximum diversity in comparison to the other states of north eastern region. This region has been considered by many as the cradle of speciation and center of origin for some of our useful plants which are a basic source for crop improvement. All the facts have contributed to consider the north eastern region of India – Arunachal Pradesh in particular as one of the eighteen “Biodiversity Hotspots” in the world.

The different habitat and ecosystem types of Arunachal Pradesh in particular described above are home to more than 100 species of mammal, 650 birds, 83 snakes/reptiles, 213 fishes and 7 non-human primates and innumerable species of insects and other life forms. This rich flora and fauna form rich genetic resources which are highly useful for the human population.[12]

6.2 Land Use

The total geographical area of the state is about 83,743 sq km (approx), out of which 70% constitutes broad and narrow valleys, 10% foothills and flat area and 20% constitutes wooded peak area. The total land area of three districts of Subansiri basin was 17166.99 sq.km. Land use of districts can be categorized as cultivable, uncultivable and wetlands. Uncultivable land includes Gullied/Ravinous and Land with or without scrub. The representative secondary data collected from National Remote Sensing Centre (NRSC) and analyzed which is given in **Table 6.1** and shown in **Figure 6.1**.

[12] State Biodiversity Strategy and Action Plan, Arunachal Pradesh

Sl. No	Class Desception	Symbol
1	Builtup,Urban	
2	Builtup,Rural	
3	Builtup,Mining	
4	Agriculture,Crop land	
5	Agriculture,Plantation	
6	Agriculture,Fallow	
7	Agriculture,Current Shifting Cultivation	
8	Forest,Evergreen/Semi evergreen	
9	Forest,Deciduous	
10	Forest,Forest Plantation	
11	Forest,Scrub Forest	
12	Forest,Swamp/Mangroves	
13	Grass/Grazing	
14	Barren/unculturable/Wastelands,Salt Affected land	
15	Barren/unculturable/Wastelands,Gullied/Ravinous Land	
16	Barren/unculturable/Wastelands,Scrub land	
17	Barren/unculturable/Wastelands,Sandy area	
18	Barren/unculturable/Wastelands,Barren rocky	
19	Barren/unculturable/Wastelands,Rann	
20	Wetlands/Water Bodies,Inland Wetland	
21	Wetlands/Water Bodies,CoastalWetland	
22	Wetlands/Water Bodies,River/Stream/canals	
23	Wetlands/Water Bodies,Reservoir/Lakes/Ponds	
24	Snow and Glacier	

Source: NRSC. Compiled by IRG System South Asia Pvt. Ltd.

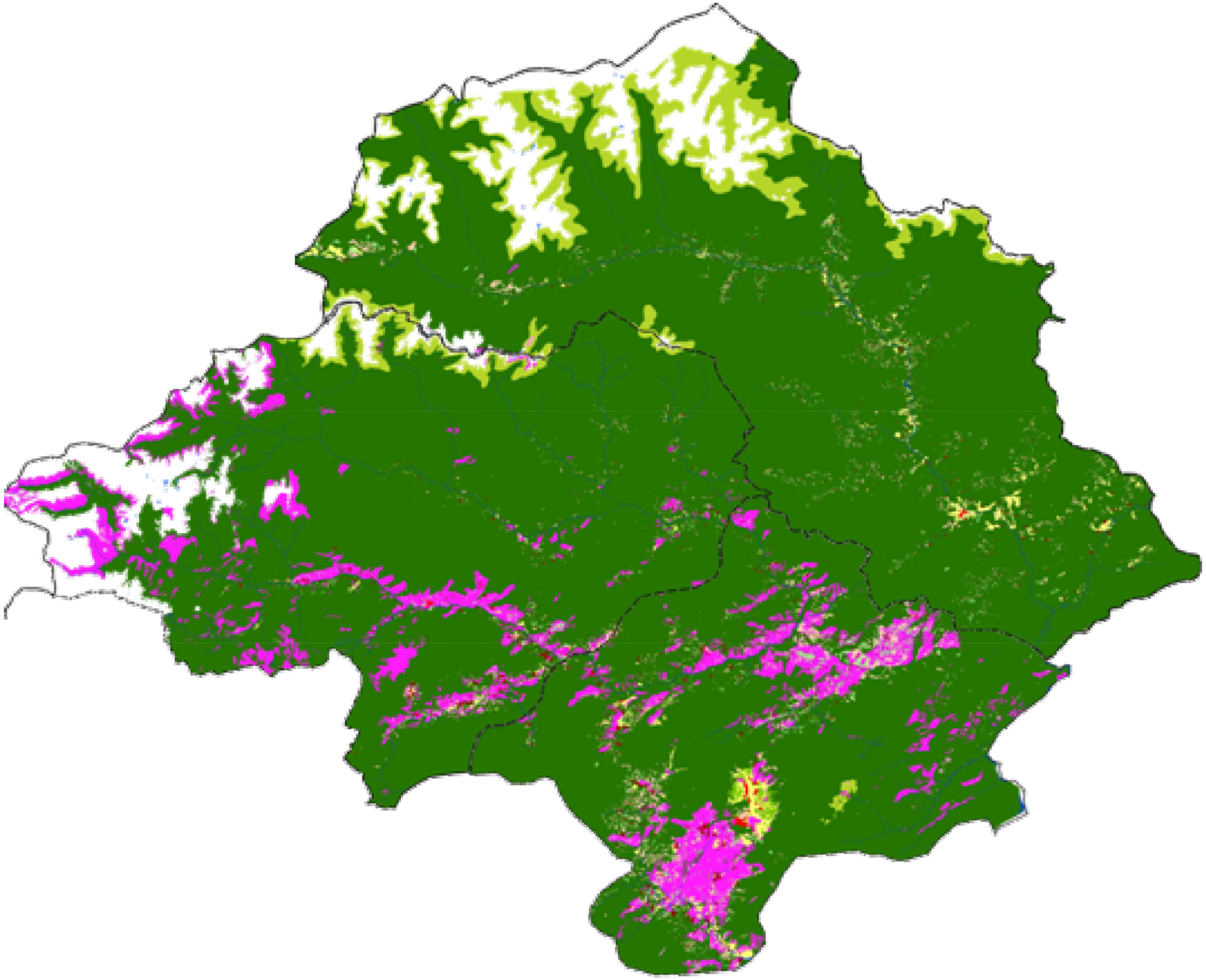


Figure 6.1: Land Use / Land Cover Map of Subansiri Basin, Arunachal Pradesh

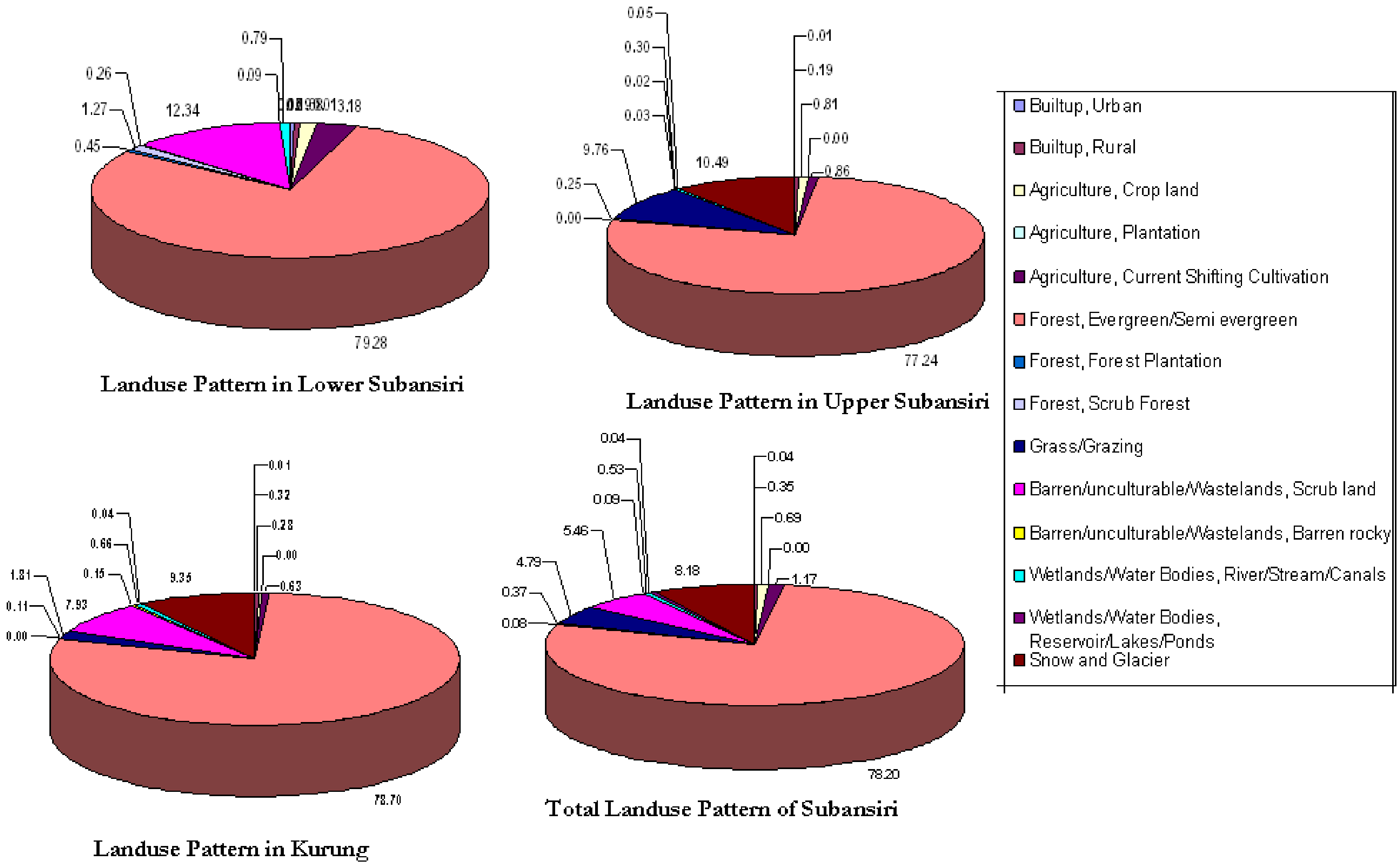


Figure 6.2: District wise Land use Pattern in Subansiri-2008

Figure 6.2 indicates that a total of 13425.35 sq. km i.e. 78.20 % area was under forest out of total geographical area of 17166.99 sq. km of Subansiri basin. The Highest forest area was reported in the Lower Subansiri (79.28%) district followed by Kurung Kumey (78.70%) and Upper Subansiri (77.24%). River channel contribute 0.53% in the Subansiri, whereas lake water without vegetation covers 0.04% of the total geographical area (TGA) of Subansiri districts.

During 2008, 118.43 sq. km (0.69% of TGA) area was under agricultural cop land, whereas agriculture, plantation covers 0.21 sq. km only in Lower Subansiri. The built-up area was reported 66.73 sq. km (0.38%) of TGA of Subansiri districts. The maximum built-up area was found in Lower Subansiri district followed by Kurung Kumey and Upper Subansiri.

Land under the snow and glacier constitute 8.18% of the total area. The highest snow and glacier area was reported in Upper Subansiri and Kurung Kumey while it does not exist in Lower Subansiri district.

Wastelands constitute 5.55% (5.46% Barren/unculturable/Wastelands, Scrub land and 0.09% Barren rocky) of total area, the maximum wasteland was observed in Kurung Kumey followed by Lower Subansiri and Upper Subansiri[13].

Table 6.1: Landuse Pattern in Subansiri Basin-2008

Land use Classes	Lower Subansiri	Upper Subansiri	Kurung Kumey	Total
	Area (sq. km)			
Builtup, Urban	4.47	0.94	1.04	6.45
Builtup, Rural	23.73	13.45	23.1	60.28
Agriculture, Crop land	41.43	56.88	20.12	118.43
Agriculture, Plantation	0.21	-	-	0.21
Agriculture, Current Shifting Cultivation	95.28	60.17	44.86	200.31
Forest, Evergreen/Semi evergreen	2373.67	5431.66	5620.02	13425.35
Forest, Forest Plantation	13.34	-	-	13.34
Forest, Scrub Forest	38.17	17.31	7.66	63.14
Grass/Grazing	7.67	686.06	129.27	823
Barren/unculturable/Wastelands, Scrub land	369.38	2.25	566.25	937.88
Barren/unculturable/Wastelands, Barren rocky	2.56	1.18	10.99	14.73
Wetlands/Water Bodies, River/Stream/Canals	23.51	20.97	47.05	91.53
Wetlands/Water Bodies, Reservoir/Lakes/Ponds	0.56	3.67	3.04	7.27
Snow and Glacier	-	737.47	667.6	1405.07
Total Geographical Area	2993.98	7032.01	7141	17166.99

6.3 Forest Cover

The State of Arunachal Pradesh lies within coordinates 26°28' N and 29°30' N latitudes and 91°30' E and 97°30' E longitudes. Its geographical area is 83, 743 sq.kms., which constitutes 2.54% of the total area of India. The state has a very wide altitudinal variation ranging from flood plains of Brahmaputra to more than 7600 m high mountain peaks. The elevational variation, associated variability in climatic and edaphic factors, phytogeographical position, and undulating topography of the state have led to formation of varied ecological diversity, with a rich gene pool of wild and domesticated plant species. The mountainous topography of the state presents an ideal condition for the development of hydro-electric projects. Based on the size and

[13] *NRSC, Compiled by IRGSSA*

volume of water drained, there are five major river basins in the state, namely, Kameng River Basin, Subansiri River Basin, Siang River Basin, Dibang River Basin and Lohit River Basin. The above mentioned major rivers of the state either constitute or finally drain into the Brahmaputra River. Each of these rivers has very high potential of hydro-power generation. Besides, there are many tributaries and distributaries of these rivers which also offer suitable locations for the development of hydro-electric power projects. The recorded forest area in the State is 51,541 sq.kms. which is 61.55% of State's geographical area. Reserved forests is spread in an area of 10,723 sq.km (20.80% of recorded forest area), protected forests in 9,779 sq.km. area (18.97%) and unclassed forests in 31,039 sq.km. area (60.22%) in Arunachal Pradesh[14]

Total area of the Subansiri Basin

The Subansiri basin is positioned in three districts namely Lower Subansiri District (3508 sq.kms), Kurung Kumey (6040 sq.kms) and Upper Subansiri District (7032 sq.kms) and thereby covering a total geographical area of 16580 sq.kms. Subansiri basin constitutes 19.79% of the total geographical area of Arunachal Pradesh.

Forest Cover

On the basis of interpretation of the satellite data of 2010-2011, total forest and tree cover in the State is 67, 981 sq. kms. which works out as 81.18 of the State's geographical area (83, 743 sq.kms.). In terms of the forest cover within green wash, the area covered by very dense forests is 13,182, sq.kms., moderately dense forests is 20, 674 sq. kms and open forests are 5,381 sq.kms. Forest cover outside green wash comprises very dense forests 7,646, sq.kms., moderately dense forests is 10, 740 sq. kms and open forests are 5,381 sq.kms. Tree cover comprise 660 sq.km. The forest and tree cover totals 67, 981 sq. kms. Forest cover of the State is shown in **Figure 6.3**.

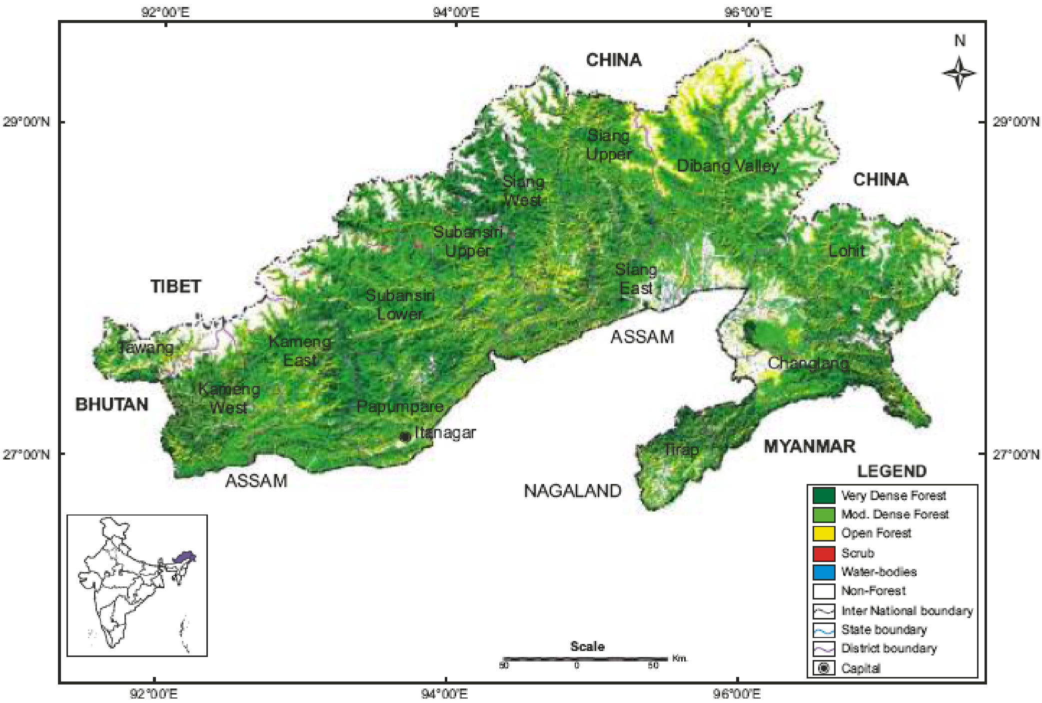


Figure 6.3: Forest Cover of Arunachal Pradesh (as per SFR, 2013)

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[14] Arunachal Pradesh: India State of Forest Report, 2013.

Proportion of different forest cover classes is depicted in the pie diagram in percentage terms is shown in **Figure 6.4.**

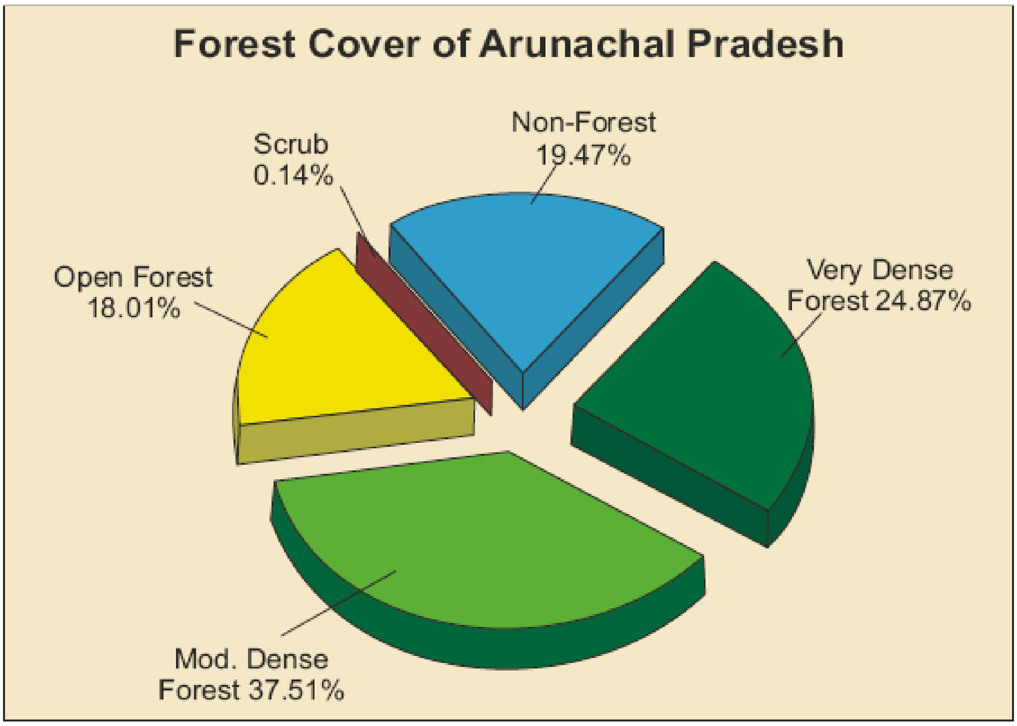


Figure 6.4: Proportion of different forest cover classes in Arunachal Pradesh (as per SFR, 2013)

Forest cover in different canopy density classes, scrub and change in forest cover in comparison to 2009 assessment in the Subansiri Basin is given in **Table 6.2**.

Table 6.2: Forest Cover in Subansiri Basin

District	Geographical area in sq.kms	2013 Assessment				% of GA	Change*	Scrub
		Very dense forest	Moderate dense forest	Open forest	Total			
Lower Subansiri*	9548	3004	4245	1427	8676	90.87	3	28
Upper Subansiri	7032	1876	2746	1192	5814	82.68	-7	25

*The total geographical area of Lower Subansiri (9548 sq.kms.) used in the assessment of Forest Cover in Subansiri Basin, SFR 2013 is a sum total of geographical area of Lower Subansiri District (3508 sq.kms.) and geographical area of Kurung Kumey district (6040 sq.kms.), as per geographical area given in Census, 2011 for the said two districts.

The change figures are based on comparison of 2008 (SFR, 2011) assessment with that of 2010-11 (SFR 2013) The total forest cover in Lower and Upper Subansri district is 90.87 and 82.68% of the geographical area of the said districts. The total forest cover of the Subansiri Basin is 14490 sq.kms. which is 21.31% of the total forest cover of the State.

Reasons for change detected in 2013 assessment: Reasons for the negative change in forest cover is due to shifting cultivation practices and biotic pressure.

6.4 Forest Types in Arunachal Pradesh

As per Champion and Seth Classification, the State has 16 forest types which belong to 10 forest type groups viz. 1.Tropical Wet Evergreen, 2. Tropical semi Evergreen, 3.Tropical Moist Deciduous, 4.Subtropical Broadleaved Hill, 5.Subtropical Pine, 6.Himalayan Moist Temperate, 7.Himalayan Dry Temperate, 8.Sub Alpine forests, 9.Moist Alpine scrub and 10. Dry Alpine Scrub. Distribution of forest cover in different forest type groups found in the State is given in the pie diagram **Figure 6.5**.

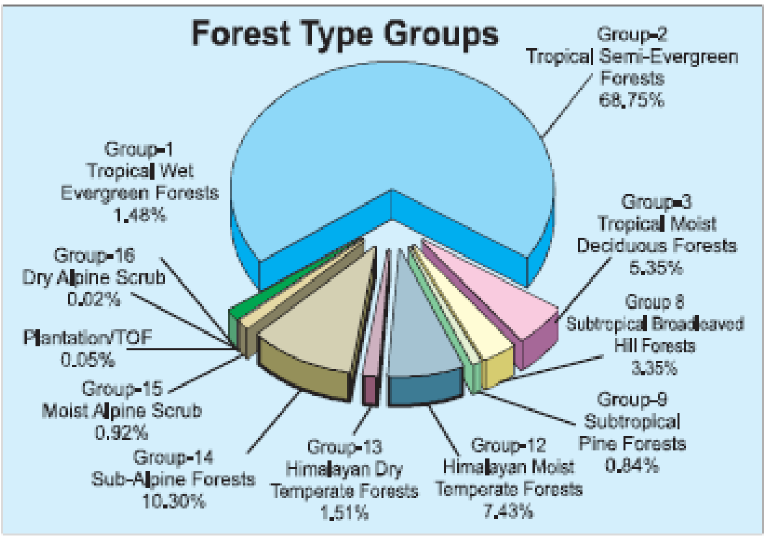


Figure 6.5: Distribution of forest cover in different forest type groups in Arunachal Pradesh

The state is unique in having traditional rights of various tribes over land, water and forests within their jurisdiction. Each tribe as a community exercises control over the natural resources within their surroundings inhabited traditionally by them and sustainability use the resources for shelter, cultivation, food and other day to day multifarious uses.

There are no written land records of ownerships throughout the state. However, traditional boundary demarcation of land lines between the villages, tribes and clans are maintained through natural features of streams, hills and other land marks which is honoured by everyone. Should there be any dispute arising between the clans, villages and tribes, the same is settled amicably by the village elders through the system of Kebong in Adi, Buliang in Apatani, Male in Aka, Ngothun in Nocte, Khapong in Tangsa, Wangsu Wangsa in Wanchu and Yullung in Nishi.

State Government exercises control over the natural resources in the notified areas of forests and wildlife. In the remaining areas the communities concerned exercise their traditional rights in the state. Details of district wise legal status of forests, Protected Areas, Important Bird Area, Elephant reserve (ER)/Elephant Corridor (EC) and proposed and under construction HEPs in Subansiri Basin[15][16] is given in **Table 6.3**.

[15] *State Biodiversity Strategy and Action Plan, Arunachal Pradesh*

As can be seen from the Table 6.3, the proposed HEPs namely Oju I, Oju II, Niare, Naba, Nalo, Dengser, Subansiri Upper and Tammu are proposed in Upper Subansiri District which has 504.00 sq.kms Reserved Forest and 2.00 sq.kms Anchal Reserved Forests (ARF). Kurung I and II, Middle Subansiri (Kamala HEP), Middle Subansiri (Kamala HEP), Tamen and Tago I are located in Lower Subansiri district which has 347.07 sq.kms Reserved Forest and 337 sq.kms area under Talley Wildlife Sanctuary. Mili, Sape, Chomu, Chela, Nyapin, Hiya and Kurung I&II are located in Kurung Kumey district which has no RF, PF, ARF, VRF, NP and WLS. However, it has unclassed forest area of 5964.60 sq. kms.

[16] Principal Chief Conservator of Forests, Arunachal Pradesh, Itanagar

Table 6.3: Proposed / under construction HEPs and District-wise and Legal status-wise forest area in Subansiri Basin, Arunachal Pradesh

Proposed/ under construction HEPs	District	Total Forest Cover (in sq. km.) *	Reserved forests (in sq. km.)	Protected Forest (PF) (in sq. km.)	Anchal Reserved Forest (ARF) (in sq. km.)	Village Reserved Forest (VRF) (in sq. km.)	Biosphere Reserve (in sq. km.)	Wildlife Sanctuary (WLS) (in sq. km.)	National Park NP (in sq. km.)	Important Bird Area (in sq. km.)	Elephant reserve (ER)/Elephant Corridor (EC) (in sq. km.)	Unclassed State Forest (USF) (in sq. km.)	Total Forest Area Affected (in sq. km)	Total Forest Area Affected (in %)
1.Oju 1	Upper Subansiri	5814	504	-	2	-	-	-	-	Nacho-Limeking-Taksing-Majha Site Code: IN-AR-16 (Upper Subansiri District)	-	3076.00	3.55	0.06
2.Oju II													4.05	0.07
3.Niare													5	0.09
4.Naba													3.75	0.06
5.Nalo													4.55	0.08
6.Dengser													1.32	0.02
7.Subansiri Upper													21.7	0.37
8.Tammu														
9.Middle Subansiri (Kamala HEP)	Lower Subansiri	8676	347.07	-	-	-	-	337	-	Taley Valley wildlife Sanctuary Site Code: IN-AR-24 (Lower Subansiri District) is in the project impact area	No ER / EC but known elephant habitat	2064.00	13.3	0.15
10.Lower Subansiri (under construction)													31.87	0.37
11.Tamen														
12.Tago I														
13.Mili	Kurung Kumey**	5620.02	-	-	-	-	-	-	-	Koloriang-Sarli-Damin Areas Site code: IN-AR-10 (Lower Subansiri District) IBA Site Code: IN-AR-24	-	5964.60		
14.Sape														
15.Chomu														
16.Chela														
17.Nyepin														
18 Hiya														
19. Kurung I & II													16.45	0.29

Source: PCCF – Arunachal Pradesh as on 31/03/2011, Statistical Abstract of Arunachal Pradesh, 2011

Note: Area is expressed in square kilometers.

* ➔ Statistics on forest area is as per SFR, Arunachal Pradesh, 2013.

** ➔ Figures of Kurung Kumey district has been taken from NRSC, 2005-2006

6.5 Forest types in Subansiri Basin

Forest types found in Subansiri basin falling under Lower Subansiri District, Upper Subansiri and Kurung Kumey districts as given in the working plans of concerned forest divisions is described below:

Hapoli Forest Division: Hapoli Forest Division encompasses Lower Subansiri District. There are two Reserved Forests of Hapoli Forest Division namely Tale and Kamala. The forests under Hapoli forest Division are located in a zone of high rainfall, short dry season and relatively high average humidity. They are evergreen in nature and comprise large number of tree species occurring in varying proportions at different location. The main features of these forests are the heterogeneous mixture of species, a clear description of which is difficult. Structurally these forests can not be differentiated into distinct storeys. However at places especially on hills two storeys is rather open composed of a mixture of evergreen, semi evergreen and deciduous species. Pure patches of bamboos are very common and are scattered all over the area.

As per Champion & Seth revised classification of forest types of India, the forest under Hapoli Forest Division can be grouped into the following forest sub types:

1) 2B/CI (b) : Eastern Sub-Montane Semi-Evergreen Forests.
2) 2B/CI/ISI : Sub-Himalayan High Alluvial Semi-Evergreen Forests.
3) 2B/2ISI : Secondary Moist Bamboo Brakes
4) 13/C6 : Eastern Himalayan Dry Temperate Coniferous Forest.

The forest are composed of a large number of evergreen as well as deciduous species like Hollock (*Terminalia myriocarpa*) Jutoli (*Altingia excelsa*), amari (*Amoora wallichii*), Tita Sopa (*Michelia champaca*), Gonsorai (*Cinnamomum cecidodaphne*), Makrisal (*Schima wallichlli*), Bogipoma (*Chukrasia tabularis*), Khokan (*Duabanga grandiflora*), Hillika (*Terminalia chebula*), Dhuna (*Canarium resiniferum*), Bahera (*Terminalia bellirica*). Borpat (*Ailanthus grandis*), Simul (*Bombax ceiba*), Nahar (*Mesua ferrea*), Urium (*Bischofia javanica*), Moj (*Albizia lucida*) and Udal (*Sterculia villosa*). The proportion of evergreen species are more than that of the deciduous species mainly due to favourable climate conditions in the area. The middle storey in these forests is mainly composed of evergreen species like Nahar (*Mesua ferrea*), Hinguri (*Castanopsis indica*), Urium (*Bischofia javanica*), Seleng (*Sapium baccatum*) etc., with a little mixture of deciduous species like Paroli (*Stereospermum chelonoides*), Pichola (*Kydia calycina*) etc.

Forest types in Subansiri Basin, Arunachal Pradesh is described below:

Eastern Sub-Montane Semi Evergreen forest – 2B/CI (b): This type of forest is generally found in the Sub-Himalayan Tract and lower slopes of the hills in the division. Makri Sal (*Schima wallichii*), Hingori (*Castanopsis indica*) and Hollock (*Terminalia myriocarpa*) are dominant in this type of forest. The floristic composition is given below in **Table 6.4**.

Table 6.4: Floristic Composition

Top storey	Makri Sal (*Schima wallichii*), Hollock (*Terminalia myriocarpa*) Hingori (*Castanopsis indica*), Jutuli (*Altingia excelsa*) Dhuna (*Canarium resiniferum=C. strictum*) Poma (*Cedrela toona*), Sopa (*Magnolia* spp.), Hatipoila (*Pterospermum acerifolium*), Borpat (*Ailanthus grandis*), Siris (*Albizia procera*), etc.

Middle storey	Banderdima (*Dysoxlyum procerum*), Jamun (*Syzygium cumini*), Pichola (*Kydia glabrescens*), Selleng (*Sapium baccatum*) Paroli (*Pterospermum chelonoides*), Gahari Sopa (*Elaeocarpus aristatus*) etc.
Lower Storey	Baramthuri (*Talauma hodgsonii*) Poreng (*Olea dioica*), Morhal (*Vatica lanceaefolia*), Tejpat (*Cinnamomum tamala*), Thekera (*Garcinia* sp.), Morolia (*Mallotus tetracoccus = M.albus*) etc.
Ground floor	Kaupat (*Phrynium imbricatum*), ban posala (*Saurauia punduana*), Kolgoch (*Musa* spp.) Tora tenga (*Citrus* spp.), Bogitora (*Alpinia* malaccensis), Bihlougoni *(Pteris quadriaurita*), Dhopat tita (*Clerodendrum viscosum = C. infortunatum*), etc.
Bamboo	Kako bans (*Dendrocalamus hamiltonii*) and Bijuli bans (*Bambusa pallida*).
Cane	Lejai bet (*Calamus floribundus*), Jati bet (*Calamus tenuis*)
Palm	Toko palm (*Livistona jenkinsiana*)
Climber	Kuchai (*Acacia pennata*), panilata (*Vitis planicaulis*), Ghila lata (*Bauhinia vahlii*), Gowalia lata (*Vitis latifolia*), Dhekia lata (*Dioscorea indica*) etc.

Sub-Himalayan high alluvial Semi-Evergreen forests 2B/CI/ISI: This type of forest is found in the Zone of Higher Himalayan in the division. Under this type of forests, evergreen species are dominant though deciduous species are also present in significant proportion and the forest is a mixture of both the species. Middle storey is prominent and consists of mixture of evergreen and deciduous species with abundantly shrubby under growth. Hollock (*Terminalia myriocarpa*) and Jutuli (*Altingia excelsa*) are common / dominant species in this type of forest. The floristic composition is given below in **Table 6.5**.

Table 6.5: Floristic Composition

Top storey	Hollock (*Terminalia myriocarpa*), Jutuli (*Altingia excelsa*), Bonsum (*Phoebe goalparensis*), Sopa (*Magnolia* sp.), Hingori (*Castanopsis indica*), Dhuna (*Canarium strictum = C. resiniferum*), Poma (*Toona ciliata*), Behera (*Terminalia bellirica*), Khokan (*Duabanga grandiflora*).
Middle storey	Jamun (*Syzygium cumini*), Nahar (*Mesua ferrea*), Banderdima (*Dysoxylum procerum*), Sam (*Artocarpus chaplasha*), Pichola (*Kydia glabrescenes*), Moj (*Albizia lucida*), Sia Nahar (*Kayea assamica*), Selleng (*Sapium baccatum*), etc.
Lower Storey	Bual (*Ehretia acuminata*), Boromthuri (*Talauma hodgsonii*), Gahari sopa (*Magnolia griffithii*), Bon Am (*Mangifera sylvatica*), Surat (*Laportea crenulata*), etc.
Ground floor	Hati bhekuri (*Solanum subtruncatum*), Banposala (*Saurauia punduana*), Kaupat (*Phrynium imbricatum*). Tora (*Alpinia allughas*), Dhopat tita (*Clerodendrum viscosum*), Kolgoch (*Musa* spp.), Bogitora (*Alpinia malaccensis*).
Cane	Lejai bet (*Calamus floribundus*), Raidang bet (*Calamus flagellum*)
Palm	Toko palm (*Livistona jenkinsiana*), Jeng (*Calamus erectus*).
Climber	Ghila lata (*Entada scandens*), Pani lata (*Vitis latifolia*), Dimorulata (*Ficus scandens*), Mermeri lata (*Gnetum scandens*), etc.

Secondary Moist Bamboo Brakes 2B/2SI: Secondary moist bamboo brakes occur in scattered patches throughout all the tropical semi-evergreen forests in the division. When bamboo brakes have overhead trees, they form thinner clump. Where bamboo patches are pure, the clumps are thick and there is no possibility of regeneration of any other tree species in these bamboo patches. At places, shrubby and grassy under growth is found. The bamboo species found in the forest are given below.

Kako bans	*Dendrocalamus hamiltonii*
Bijuli bans	*Bambusa pallida*
Bojal bans	*Pseudostachyum polymorphum*
Jati bans	*Bambusa tulda*
	Chimonobambusa callosa
	Cephalostachyum capitatum
	Dendrocalamus giganteus

Neohouzeaua helferii

Eastern Himalayan Dry Temperate Coniferous Forest 13/C6: This forest type is characterized by the predominance of conifers, the principal species being Blue Pine (*Pinus wallichiana*). The pure crop of tall and elegant blue pine in various stages of growth is more or less open in nature, which has undergrowth of broad leaved associates along with grasses typical of conifer forest. The top and middle storey are composed of only blue pine, where as, the lower storey and ground vegetation are the typical coniferous associates. The floristic composition is given below.

Top storey	Blue Pine (*Pinus wallichiana*)
Middle storey	Blue Pine (*Pinus wallichiana*)
Lower storey	Oaks, Rhododendrons
Ground cover	Jetelu Poka (*Rubus ellipticus*), Berbery (*Berberis asiatica*), *Imperata cylindrica* etc.

Daporijo Forest Division

Forest types: The Forests under Daporijo Forest Division are located in a zone of high rainfall short dry season and relatively high average humidity. They are evergreen in nature and comprise large number of tree species, occurring in varying proportions at different locations. The main feature of these forests is the heterogenous mixture of species, a clear description of which is difficult. Structurally, these forests can not be clearly differentiated into distinct storeys. However, at place especially on hills two storeys can be identified depending upon species composition. In general, the top storey is rather open composed of a mixture of evergreen, semi evergreen and deciduous species. Pure patches of bamboos are very common and are scattered all over the area.

The forests are composed of a large number of evergreen as well as deciduous species like Hollock (*Terminalia myriocarpa*), Jutuli (*Altingia excelsa*), Amari (*Amoora wallichii*), Tita Sopa (*Michelia champaca*), Gonsoroi (*Cinnamomum cecidodaphne*), Makrisal (*Schima wallichii*), Bogipoma (*Chukrasia tabularis*), Khokan (*Duabanga grandiflora*), Hillika (*Terminalia chebula*), Dhuna (*Canarium resiniferum*), Bahera (*Terminalia bellirica*), Borpat (*Ailanthus grandis*), Simul (*Bombax ceiba*), nahar (*Mesua ferrea*), Urium (*Bischofia javanica*), Moj (*Albizia lucida*), Udal (*Sterculia villosa*), siris (*Albizia procera*), Sam (*Artocarpus chaplasha*) etc. in the Semi-evergreen forests. The proportion of evergreen species is moer than that of the deciduous species mainly due to favourable climatic conditions in the area. The middle storey in these forests is mainly composed of evergreen species like Nahar (*Mesua ferrea*), Hinguri (*Castanopsis indica*), urium (*Bischofia javanica*), Selleng (*Sapium baccatum*) etc. with a little mixture of deciduous species like Paroli (*Stereospermum chelonoides*), Pichola (*Kydia calycina*) etc.

As per Champion and Seth's revised classification of forest types of India, the forests under this division can be grouped into following forest types:

Eastern sub Montane Semi Evergreen Forest – 2B/C1 (b): This type of forests is generally found in the Sub-Himalayan Tract and lower slopes of the hills in various Reserve Forests of the division. Makrisal (*Schima wallichii*), Hingori (*Castanopsis indica*) and Hollock (*Terminalia myriocarpa*) are dominant in this type of forest. The floristic composition is given below in **Table 6.6**.

Table 6.6: Floristic Composition

Top Storey	Makrisal (*Schima wallichii*), Hollock (*Terminalia myriocarpa*), Hingori (*Castanopsis indica*), Jutuli (*Altingia excelsa*), Dhuna (*Canarium resiniferum*), Poma (*Toona ciliata*), Sopa (*Magnolia* sp.), Hatipoila (*Pterospermum acerifolium*), Borpat (*Alianthus grandis*), siris (*Albizia procera*), etc.
Middle Storey	Banderdima (*Dysoxylum procerum*) Jamun (*Syzygium cumini*), Pichda (*Kydia calycina*) Selleng (*Sapium baccatum*) Paroli (*Pterospermum chelonoides*), Gahori sopa (*Elaceocarpus aristatus*),etc
Lower Storey	Baramthuri (*Talauma hodgsonii*), Poreng (*Olea dioica*), Morhal (*Vatica lanceifolia*), Tejpat (*Cinnamomum tamala*), Thekera (*Garcinia* sp.), Morolia (*Mallotus tetracoccus*), etc.

Banderdewa Forest Division: By and large the forests dealt with may be classified broadly, as Assam valley tropical semievergreen forests 2B/C according to Champion and Seth's revised classification of Forest Types of India. The forest is in a zone of high rainfall, temperature and humidity and with almost same type of soil formation all over. The main feature of these forests is the heterogenous mixture of the species. However, a very thin strip of forest (hardly few hectares) in between Kokila Nallah and Chengmara Nallah where scattered occurrence of natural Sal is observed. It is also observed that evergreen and semievergreen forests merge into one another. Pure patches of bamboos are also common almost all over.

Structurally these forests cannot exactly be differentiated into distinct stories. However at places, especially on the hills two stories can be identified depending on the existence of different species including middle sized trees of the top storey. On the whole the top storey is rather open and is composed of an admixture of evergreen, deciduous and semi-ever-green species. The lower belt of Doimukh proposed reserve is by and large covered by bamboo forests with a small percentage of tree species except the area falling in between Singra and Ranga River.

This broad forest type i.e. 2B/Ca may be divided into the following sub-types, taking into consideration the condition of the crop resulting from various local factors:

1. Miscellaneous forests	2. Open forests	3. Mixed bamboo forests	4. Savanah forests

Miscellaneous forests: The very name suggests that no single tree species is dominant in these forests. There are a number of species in the top storey and in varying percentages. This can be taken as conforming to Champion and Seth's revised class 2B/C1/1 S1.

The main species in order of frequency of their occurrence in the top and the middle storeys are:

Top Storey: Amari (*Amoora wallichii*), Hatipoila (*Pterospermum acerifolium*), Paroli (*Stereospermum chelonoides*), Jutuli (*Altingia excelsa*), Khokan (*Duabanga sonneratioides*), Uriam (*Bischofia javanica*), Dhuna (*Canarium bengalense*), Gamari (*Gmelina arborea*), Jatipoma (*Toona ciliata*, (Udal (*Sterculia villosa*), Borpat (*Ailanthus grandis*), Hillika (*Terminalia chebula*), Sam (*Artocarpus chaplasha*), Bopipoma (*Chukrassia tabularis*), Gonsoroi (*Cinnamomum cecidodaphne*), Hingori (*Castanopsis* sp.), Hollock (*Terminalia myriocarpa*) etc.

Middle Storey: Outenga (*Dillenia indica*), Bola (*Morus laevigata*), Banderdima (*Dysoxylum binectariferum*), Baram thuri (*Talauma hodgsonii*), Morolia (*Macaranga* *denticulata*), Pichola (*Kydia calycina*), Kadam (*Anthocephalus cadamba*), Dalmugra (*Gynocordia odorata*), Phulgamari (*Litsea chinensis*), Thekera (*Garcinia* sp.), etc.

The following are the main species comprising the under growth.

Leea sp., Assam lota (*Eupatorium odoratum*), *Coffea bengalensis*, Bhattita (*Clerodendrum viscosum*), *Clerodendrum wallichii, Clerodendrum* sp, *Borreria hispida*, *Alpinia* sp., *Indigofera* sp, *Ageratum conyzoides*, *Sida acuta*, *Cymbopogon* spp., *Solanum torvum*, *Moghania macrophylla*, *Phyllanthus* sp., *Cistus* sp., *Croton* sp., *Urena lobata, Rhynchotechum* sp., *Hibiscus cannabinus,*, *Psychotria erratica*, *Oxyspora paniculata*, *Osbekia nutans*, *Tephrosia candida*, *Impatiens trilobata*, *Polygonum barbatum*, *Desmodium* sp., *Sambucus* sp., *Polygonum chinensis, Begonia barbata*, *Torenia vagans* etc.

Climbers: *Bauhinia vahlii*, *Spatholobus roxburghii*, *Abrus precatorious*, *Acacia* sp., *Tinospora* sp., *Vitis* sp., *Entada scandens*, *Bauhinia* sp., *Rosa* sp. *Milletia* sp. *Acacia pinnata,* etc.

Open Forests: This type occurs as scattered patches of varying sizes. There is hardly any difference in the soils compared to adjoining areas. The open nature of the conopy is probably due to Jhumming in the not too distant past or due to cyclonic storms which probably destroyed the top conopy. Such types of forests are generally covered with bamboos, canes and different shrubs and climbers giving the appearance of a scrub jungle. The trees are seen dotted here and there only. Taking into consideration the scattered taller trees as top storey and shorter scattered trees as middle storey the common species will be the following. This more or less conforms to Champion and Seth's revised type 2B/C1/262.

Top Storey: Kokan (*Duabanga sonneratioides*), Borpat (*Ailanthus grandis*), Hilika (*Terminalia chebula*), Hingori (*Castanopsis* sp.), Hatipoila (*Pterospermum acerifolium)* Udal (*Sterculia villosa*), Simul (*Bombax ceiba*) etc.

Middle Storey: Banderdima (*Dysoxylum binectariferum*), Pichola (*Kydia calycina*), Moralia (*Macaranga denticulata*), etc.

The under growth is quite dense. Tokopat and Kaupat are common shrubs in addition to many other species of the miscellaneous forests.

Mixed Bamboo Forests: Considerable areas are under this sub type. Steepness of the slopes and dryness of the soil may be the two factors mainly attributable to the occurrence of this sub type. Bamboos also occur in some of the low lying areas where soil and water conditions do not permit other species to grow.

The most common bamboos found in these forest area Bijuli (*Bambusa pallida*) and Kako Bans (*Dendrocalamus hamiltonii*). Bojal bans (*Pseudostachyum polymorphum*) is found occasionally.

Miscellaneous species like Khokan (*Duabanga sonneratioides*), Amari (*Amoora wallichii*), Poma (*Toona ciliata*) Sopa (*Magnolia* sp.) makrisal (*Schima wallichii*). Ningori (*Castanopsis indica*) etc occur separately in such areas.

The under growth is very light as the dense bamboo growth inhibiting other growth. This type conforms to Champion and Seth's revised type 2B/251.

Savanah Forest: This sub type is confined to the Southern boundary of Drupong RF extending from near about Dafflagarh Range headquarters upto Changmara beat. Plantations of Hollock and other species in thin strips have already been raised along the boundary leaving patches of this sub type here and there.

Management regime of Forests in Subansiri Basin:

The forests in Subansiri basin is managed under Western circle, Banderewa and Central Circle, Pasighat. The Basin lies in three territorial forest divisions. The details of forest divisions, no. of ranges, no. of beat offices in Subansiri Basin is given in **Table 6.7**.

Table 6.7: District-wise number of forest circles, divisions, ranges and beat offices in Subansiri Basin (as on 31-03-2011)[17]

District	Name of forest Circles Covering the district	No. of Forest Division		No. of ranges	No. of beat offices.	
		Territorial	Survey/WP/SF Research & Wildlife		Accounts beat	Non- accounts beat.
L/Subansiri	Western Circle (Banderdewa)	1	-	4	-	-
Kurung Kumey	-do-	1	-	2	-	-
U/Subansiri	Central Circle. (Pasighat)	1	-	3	-	1

Principal Chief Conservator of Forests, Arunachal Pradesh, Itanagar

In Subansiri Basin, the Lower Subansiri and Upper Subansiri district is characterized by presence of Reserve forest and Anchal Reserved Forest/VRF, while Kurung Kumey has presence of Unclassified State Forest. Talley Valley Wildlife sanctuary (WLS) is within the project impact area of Lower Subansiri HEP in Lower Subansiri District. The details are given in **Table 6.8**.

Table 6.8: Classification of forest area management under reservation, protection etc. in Subansiri Basin [area in sq.kms (as on 31-03-2011)][18]

District	No. of Forest Divisions	Reserved Forest	Anchal Reserved Forest/VRF	Protected Forest	Forest Under		Other purpose	Proposed Reserves Forest	Unclassified State Forest
					WLS	NPS			
L/Subansiri	1	347.07	-	-	337.00	-	-	-	2064.66
Kurung Kumey	1	-	-	-	-	-	-	-	5964.60
U/Subansiri	1	504.00	2.00	-	-	-	-	-	3076.00

6.6 Floristic Diversity of Arunachal Pradesh

Arunachal Pradesh is one of the world's "Ecological Hotspots" presenting a vast range of species and ecosystem diversity in this Eastern Himalayas. It is also considered as one of the thirty four "Biodiversity Hotspots" in the world. The fragile

[17] *Principal Chief Conservator of Forests, Arunachal Pradesh, Itanagar*
[18] *Source: Principal Chief Conservator of Forests, Arunachal Pradesh, Itanagar*

nature of these hills is prone to the loss of species which are under pressure. It is estimated that over 5000 species of flowering plants occur in this territory. The total plant wealth of the territory includes not only the usually large showy- flowered vascular plants but also large number of good non flowering plants viz., ferns, liverworts, lichens, algae etc. The territory has rich tribal cultures and has undergone considerable period of natural and human selection. The richness could also be attributed to different environmental factors like physiography, geology, soil, climate etc. prevailing in the widest possible variations. These plants contain vast treasures of genes for restraining of pests and adaptation to stress conditions.

The vegetation/ forests are classified under 6 major categories i.e. tropical, subtropical, temperate, sub-alpine and alpine vegetation, secondary forests and aquatic vegetation; each comprising subtypes primarily based on altitude and climatic factors. Broad classification of forest types and in comparison with that of the Champion and Seth's classification (1968)[19] as given in **Table 6.9**[20].

Table 6.9: General Forest types of Arunachal Pradesh

Sr. No.	Broad forest Type	As per Champion and Seth,1968	Altitudinal Range	Important species
1.	Tropical semi evergreen	2/B/C1/Ia 2/B/C1b/ISI 1/B/C1, 1/B/C2 8/B/C1	Near Alluvial plains	*Amoora wallichii, Pterospermum acerifolium, Stereospermum chelonoides, Altingia excelsa*
2.	Sub tropical broad leaved	3C3/Bb, 3C/IS2	Up to 900 –1800 meters	*Michelia* spp., *Castanoposis* spp., *Quercus* spp., *Rhododendron* spp., *Alnus nepalensis, Acer* spp., *Albizia* spp., *Photinia* spp.
3.	Sub tropical pine	III/9/DS/1	1000-1800 meters	*Pinus roxburghii* , *Pinus wallichiana* and *Pinus merkusii*
4.	Temperate Broad leaved forests	IV/11/IIB/CI, IV/11/IIB/C2	1800-2750 meters	*Quercus lamellosa, Quercus* spp, *Castanopsis indica, Acer hookeri*
5.	Alpine	V/C2, VI/1SC3, VI/16/C1, E1	3000 –5500	*Rhododendron* spp, *Primula* spp, *Saussaurea* spp, *Saxifraga* spp.
6.	Secondary forests Bamboo brakes	1B/2S		*Bambusa pallida, Schizostachyum polymorphum, Bambusa tulda, Dendrocalamus hamiltonii*

Tropical vegetation: These forests are confined up to 900 m above sea level and spread over the foothill areas and outer valleys in all the districts and represent one of the major ecological types in the state with maximum species diversity and very high rainfall. The vegetation can be divided into two subtypes.

Tropical evergreen forests: The common species represented in this area are tall trees like *Altingia excelsa, Dipterocarpus gracilis, D. retusus, Castanopsis indica, Duabanga grandiflora, Knema angustifolia, Mesua ferrea, Terminalia myriocarpa, etc. along* with medium to small trees and shrubs namely *Actephila excelsa, Ardisia crispa, Bauhinia purpurea, Grewia disperma, Gynocardia odorata, Leea robusta, Michelia doltsopa, Mussaenda roxburghii, etc.* Trees are heavily plastered with lichens and festooned with climbers and numerous lianas like *Pericampylus glaucus, Stephania elegans, Parabaena sagittata*, species of *Bauhinia, Derris, Entada,*

[19] *Champion H.G. & S.K. Seth (1968). A Revised Survey of the Forest Types of India. The Manager of Publications. Government of India, New Delhi, 404pp*

[20] *Arunachal Pradesh, State Biodiversity Strategy and Action Plan.*

Hodgsonia, Piper, Raphidophora, etc. Calamus erectus, C. leptospadix and various other species of similar plants occurring along the swamp areas and form extensive thickets. The epiphytic flora is also very rich. Some common epiphytes are the species of *Aerides, Dendrobium, Cymbidium, Coelogyne, Eria, Pholidota, etc.* Several terrestrial orchids *e.g. Calanthe, Goodyera, Habenaria, Malaxis, Phaius* are common. Species belonging to *Asplenium, Nephrolepis, Drymoglossum, Colysis*, etc. are a few of the common ferns. Along the hill slopes wild species of *Musa* comprising of *Musa acuminata, M. balbisiana* and *M. rosacea* form extensive thicket, which is a prominent feature of the vegetation

Tropical semi evergreen forests: These forests occur along the foothills and riverbank up to an elevation of 600 m. The upper storey consists of deciduous trees while evergreen trees, shrubs, climbers and lianas constitute the rest. Depending on its species contents these forests are further divided into two subtypes.

Low hills and plains semi evergreen forests: In these forests the upper storey is dominated by tall trees like *Terminalia myriocarpa, Altingia excelsa, Anthocephalus chaplasha, Bombax ceiba, Canarium strictum, Elaeocarpus aristatus, Elaeocarpus rugosus, Gmelina arborea, Phoebe goalperensis, etc*. Other common trees are *Gynocardia odorata, Meliosma simplicifolia, Turpinia nepalensis, Lagerstroemia parviflora, Quercus rex, Croton roxburghii* and various species of *Ficus* etc. *Ardisia virens, Coffea khasiana, Debregeasia longifolia, Maesa indica, Saurauia armata*, etc are few common shrubs. Among the climbers and lianas *Argyreia argentea, Dioscorea alata, Gouania tiliaefolia, Mastersia assamica, Porana paniculata Thunbergia coccinea, Thunbergia grandiflora, etc* are common. Epiphytic species of *Dendrobium, Pholidota, Eria, Hoya* and several species of ferns also occur in these forests.

Riverine semi evergreen Forests: Common species like *Bombax ceiba, Bischofia javanica, Canarium strictum, Dillenia indica, Trewia nudiflora, Dalbergia sissoo, Duabanga grandiflora, Lagerstroemia parviflora* forms the top storey whereas the next storey is represented by the species of *Casearia, Micromelum, Ficus, Meliosma, Murraya, Randia* and *Villebrunea, etc*. These species are associated with dense clumps of *Phragmites, Saccharum, Alpinia* and *Hedychium* spp. etc. The epiphytic flora is rather insignificant as compared to the other forest.

Subtropical vegetation: The subtropical forests occur at the elevation from 900-1800 m and are basically of evergreen and dense in nature. These forests are also rich in species diversity and can broadly be divided into two subtypes.

Subtropical Broad Leaved Forests: The dominant trees in these forests are *Castanopsis armata, Castanopsis indica, Ficus gasparriniana, Kydia glabrescens, Magnolia pterocarpa, Michelia oblonga, Quercus semecarpifolia, Ulmus lanceifolia, etc*. Among the small trees and shrubs, *Actinidia callosa, Berberis wallichiana, Camellia caudata, Lasianthus longicaudus, Mahonia acanthifolia, Myrsine semiserrata, Photinia integrifolia, Rubus moluccanus, Saurauia punduana, Stachyurus himalaicus*, *Sterculia hamiltonii, Triumfetta pilosa, Viburnum foetidum,* and various species of *Clerodendrum, Symplocos*, etc. are common. *Argyreia wallichii, Clematis gouriana, Holboellia latifolia, Crawfordia speciosa, etc*. are some common climbers. Epiphytic orchid's *e.g. Bulbophyllum, Coelogyne, Dendrobium, Octochilus, etc* along with some terrestrial ones like *Goodyera, Habenaria, Malaxis, etc.* frequently occur in these forests. *Equisetum ramosissimum, Lycopodium clavatum* flourish along the roadside slopes. Epiphytic ferns like *Asplenium* *ensiforme, Drynaria propinqua, Huperzia serrata, Huperzia hamiltonii, etc.* are also common besides several species of *Lepisorus, Pyrrosia, Vittaria, etc.*

-Subtropical Pine Forests: These forests occur between 1200-1800 m. The dominant species are represented by *Pinus merkusii, Pinus roxburghii,* and *Pinus wallichiana* in association with other tree species like *Alnus nepalensis, Betula alnoides,* etc. The herbaceous species of *Ajuga, Elsholtzia, Pogostemon, and Potentilla* are of common occurrence whereas ferns like *Pteridium aquilinum, Gleichenia glauca* form thickets along forest margins. Epiphytes are not common here.

Temperate vegetation: These forests occur in the form of a continuous belt between 1800-3500 m altitudes. The forests are open and lax storeyed. Based on the constituent species and moisture availability, these forests can be divided into two sub-types:

Temperate Broad Leaved Forest: These forests occur in between 1800-2800 m. Trees like *Acer pectinatum, A.oblongum, Alnus nepalensis, Exbucklandia populnea, Rhododendron* spp., *Castanopsis indica, Populus gamblei, P. ciliata etc*. form the top storey where as the middle storey is represented by species of *Prunus, Rubus, Spiraea, Symplocos, Rhododendron* etc. The lower storey is composed of small trees *e.g Caryopteris odorata, Debregeasia longifolia, Illicium griffithii, Lyonia ovalifolia,* and shrubs like *Mahonia acanthifolia, Myrsine semiserrata, Vaccinium sprengelii*, etc. Climbers are rare whereas various epiphytic species of *Agapetes, Rhododendron, Vaccinium* are common along with several orchids, ferns and lichens. *Plagiogyria scandens,* a dimorphic fern, is very common in these forests.

Temperate Conifer Forest: These forests are confined to 2800-3500 m altitude and experience regular snowfall during winter months. The top canopy is dominated by mixed coniferous types that include *Abies densa, Tsuga dumosa, and Taxus wallichiana*. Sometimes broad-leaved species of *Rhododendron, Photinia, Betula, Ilex*, etc. are also seen associated with those conifers. Pure stand of *Cupressus torulosa* are also present. Shrubs like *Agapetes, Hypericum, Mahonia, Rosa, Sambucus*, etc dominate the lower storey. The climbers are very rare and represented by species of *Crawfurdia, Potentilla, Streptalirion,* etc. Lichens, bryophytes, fungi and ferns dominate the epiphytic flora in these forests.

Sub alpine and Alpine Forest: These forests occupy the highest altitude, 3500-5500 m and generally lack of tree species. Subalpine forests are characterized by tree species like *Abies spectabilis, Cupressus torulosa, Juniperus recurva, Larix griffithiana* and *Rhododendron* spp. The common shrubs are *Berberis asiatica, Berberis wallichiana, Eurya acuminata, Gaultheria fragrantissima* and *Vaccinium venosum, etc*. Epiphytic orchids are represented by *Pleione hookeriana* and *Bulbophyllum* spp., and among the terrestrials *Gymnadaenia orchidis, Herminium longilobatum, Spathoglottis irioides, etc.* are commonly associated with other herbaceous plants namely *Aconitum lethale, Aconitum novoluridum, Primula boothi, Primula gracillipes, Gentiana pedicellata, Gentiana bryoides, Podophyllum hexandrum, Ranunculus brotherusii*, etc.

The alpine zone above the altitude of 4000 m remains covered with snow for the major part of the year. The vegetation is very scarce and comprises of shrubby *Rhododendron* and herbaceous elements with spectacular, variously coloured attractive flowers *Aconitum ferox, Aconitum nagarum, Meconopsis napaulensis, Arenaria* spp., *Gentiana paralota, Gentiana sikkimensis, Primula scapigera, Primula* sp., *Polygonum vaccinifolium, Polygonum serrulatum*, *Rheum australe*, etc. are common in the alpine vegetation.

Secondary Forest: Various adverse factors, both biotic and abiotic, greatly influence the forests and modify the forest types occurring upto an altitude of 3000 m. Kaul & Haridasan identified 3 subtypes in this category as (a) Degraded forests, (b) Bamboo forests and (c) Grassland. These subtypes are widely distributed throughout the state and exhibits very low species diversity.

Aquatic vegetation: Some common hydrophytes growing in the marshes, roadside pools, nallas and paddy fields are *Alisma plantago, Eriocaulon puzulaefolium, Monocharia vaginalis, Polygonum alatum, Potamogeton nodosus, Sagittaria sagittifolia, Sanicula europea, Utricularia bifida, etc. Zeylanidium* the liverwort like plant of the family Podostemaceae grows underwater on the stones in the fast running streams at lower altitude. Besides, the water bodies are rich in algal flora.

Phytogeographical Affinities: Because of its distinctive flora, Arunachal Pradesh has been included in the Division Eastern India, province Mishmi and within the Eastern Himalaya it is recognised as a Province or Sub area or area. Assam (*Sensu lato*) has been included under the broader definition of Gangetic plain or as a part of Sub-Sub areas Assam along with north and northeast Burma or as a separate phyto-geographical area. Most of the northeastern mountainous states of India are included under the province Burma and its sub province northern Burma encompasses the area from the great land of Brahmaputra to the Chinese portion of Yunnan and continuous with the mountains of Nagaland, Mizoram, Manipur, etc. The vegetation of this region was recognized as similar to that of Eastern Himalaya only differing in the absence of an alpine flora. In a broader perspective, India is recognized within Indo-Chinese region of Indo-Malaysian sub kingdom of the Palaeo tropical kingdom. It can be surmised that the flora of this region is of much younger age - particularly the humid tropical forest ones are derived exclusively of Asiatic (Yunnan-Burma) tertiary flora. To look at this region as a biogeographical 'gateway' for Indo-Malayan elements to peninsular India or Western India or vice versa, a number of species namely *Aspidopterys indica*, *Elaeocarpus aristatus, Elaeocarpus rugosus, Schima wallichii, Turpinia pomifera*, etc. indeed show disjunct distribution. Orchidaceae which is represented by 545 species in the state, has only 10-15 common to the western Himalayas and 66 common with Burma and 30 common with Malaysia. Again out of 90 species of Rhododendron in the state, only 12 species are Himalayan and 7 species are of Indo-China. But for Rosaceae with 46 species about half of the species are distributed in the Himalayas as well as in Burma, Indo-China or Malaysia, Member of Malvaceae, Bombacaceae, Annonaceae, Polygalaceae etc. also indicate a close affinity to Burma and Malaysia. These exchanges probably occurred after closing of Tethys sea and formation of tertiary mountains. Arunachal Pradesh is in the Eastern Himalaya Province within eastern Asiatic region of Boreal sub-kingdom along with parts of eastern Nepal in the west upto Kali River valley, Darjeeling, Sikkim, Bhutan, parts of Assam Himalaya and southern parts of Tibet. Majority of the experts are of the opinion that the flora of Arunachal Pradesh shows great affinities with the flora of Indo-China, Indo-Malaysia apart from its rich endemism.

The Indo-Chinese elements e.g. *Betula alnoides, Callicarpa rubella, Cinnamomum obtusifolium, Dalbergia mimosoides, Litsea kingii, Lonicera adenophora, Magnolia campbellii, Meconopsis napaulensis, Millettia cinerea, Neillia rubiflora, Osmanthus suavis, Panax pseudoginseng, Potentilla griffithii, Rhododendron micromeres, R.*

neriiflorum. Rubus fragarioides, Shuteria hirsuta, Smilax ferox, Tetracentron sinense, etc. confirm a very close affinity of the flora of the state with this region.

The presence of species like *Ampelocissus barbata, Antidesma acuminatum, Brassaiopsis glomerulata, Carallia brachiata, Debregeasia longifolia, Dendrobium aggregatum, Engelhardtia spicata, Eria paniculata, Exbucklandia populnea, Hodgsonia macrocarpa, Lithocarpus elegans, Mangifera indica, Michelia champaca, Oroxylum indicum, Procris crenata, Talauma hodgsonii, Tetrameles nudiflora, Toona sureni, etc.*shows Indo-Malaysian affinity in Arunachal Pradesh

Arunachal Pradesh, accounts for 2.54 % of the total geographical areas of the country and is a custodian of more than 23.52% of the flowering plants of India. Inaccessibility and remoteness mark the area as one of the richest botanical treasure house of the country. 76.93% families of India are representing in Arunachal Pradesh. Chowdhary *et al* (1996) enumerates 4117 species of angiosperms belonging to 1295 genera and 192 families from the state as against about 17,500 species in 2984 genera and 247 families in India. Out of which 2986 species belonging to 970 genera and 165 families are of dicots and 1131 species under 325 genera belonging to 27 families are of monocots **Table 6.10**. The statistics suggest the proportion of dicot to monocot is 2.6: 1 whereas, genera to species are 1: 3.1. There are about 41 families that are monotypic. Among the dicots, the monotypic herbaceous families, Balsaminaceae, Begoniaceae are represented by 33 species of *Impatiens* and 19 species of *Begonia* respectively. While the monotypic families representing the tree species like Aceraceae and Symplocaceae are represented by 15 species of *Acer* and 13 species of *Symplocos* respectively. The monotypic families of the monocots are Dioscoreaceae and Smilacaceae. They are represented by 25 species of *Dioscorea* and 19 species of *Smilax* respectively.

The ferns and fern allies form a significant feature of the vegetation in the state. Out of about 1020 species of ferns occurring in India 452 spp. are recorded from Arunachal Pradesh and 51 pteridophytes have been reported to have medicinal properties **Annexure 6.1**. The diversity of ferns allies like *Selaginella* and *Lycopodium* are also best expressed in this region. There are 14 species of Lycopodium (*sensu* lato) in Arunachal against 3 species in western Himalaya. 89 taxa of liverworts belonging to orders Metzgeriales [07 species and one variety in a single genus and family], Porellales [75 species and one variety in 16 genera and 04 families] and Jungermanniales [05 species in 02 genera and as many families] that colonize the leaf surface of vascular plants are reported to occur in the Eastern Himalaya states (of Arunachal Pradesh, Sikkim and Darjeeling subdivision of West Bengal). Inventory of bryophytes of Arunachal Pradesh, Eastern Himalaya indicates presence of 197 species of which 139 are mosses (28 endemic species), 53 liverworts (8 endemic species) and 5 hornworts (1 endemic species). 2 species of liverworts are assessed as Endangered, 1 species vulnerable and 7 as rare species. The checklist of bryophytes (mosses, liverworts and hornworts), their endemism and threatened status is given in **Annexure 6.2**.

Table 6.10: Statistics of the flora in Arunachal Pradesh

Plant Groups	No. of families	No. of genera	No. of species
1. Angiosperms	192	1295	4117
Dicotyledons	165	970	2986
Monocotyledons	27	325	1131
2.Gymnosperms	8	18	29
3.Pteridophytes	43	133	452

The dominant families like Asteraceae, Cyperaceae, Ericaceae, Euphorbiaceae, Leguminosae, Orchidaceae, Poaceae, Rosaceae, Rubiaceae and Urticaceae are well represented and exhibit diversity and richness of the flora are given in table below in **Table 6.11**.

Table 6.11: Comparative account of ten dominant families of Angiosperms of Arunachal Pradesh, India

Sr. no.	Name of the family	Arunachal Pradesh Gen. Spp.	India Gen. Spp.	World Gen. Spp.
1	Orchidaceae	122 545	184 1229	735 2000
2	Leguminosae	67 196	191 1152	690 17600
3	Asteraceae	68 86	167 950	900 1300
4	Rubiaceae	52 159	115 659	500 6000
5	Ericaceae	9 58	15 199	50 1350
6	Poaceae	76 153	260 1200	620 10000
7	Urticaceae (including Moraceae)	25 129	25 114	45 550
8	Rosaceae	18 111	44 492	100 2000
9	Cyperaceae	22 96	38 545	90 4000
10	Euphorbiaceae	39 94	84 528	300 5000

A comparative account of dicot families of Arunachal Pradesh **Table 6.12** shows Leguminosae, Asteraceae, Rubiaceae, Rosaceae, Euphorbiaceae and Lamiaceae are included under ten dominant families.

Table 6.12: Dominant families of Dicots in Arunachal Pradesh

Sr. No.	Arunachal Pradesh	No. of species
1	Leguminosae	196
2	Asteraceae	186
3	Rubiaceae	159
4	Urticaceae (including Moraceae)	129
5	Ericaceae	158
6	Rosaceae	111
7	Euphorbiaceae	94
8	Acanthaceae	85
9	Lamiaceae	82
10	Lauraceae	61

Ten dominant families of Monocots of Arunachal Pradesh is given in **Table 6.13**.

Table 6.13: Dominant families of Monocots of Arunachal Pradesh

Sr.No.	Arunachal Pradesh	No.of Species
1	Orchidaceae	545
2	Poaceae	153
3	Cyperaceae	96
4	Liliaceae	64
5	Araceae	60
6	Zingiberaceae	55
7	Commelinaceae	44
8	Dioscoreaceae	25
9	Smilacaceae	25
10	Arecaceae	21

Orchidaceae is the most fascinating and highly evolved groups of plants with 1229 species belonging to 184 genera in India. 545 species belonging to 122 genera are reported from Arunachal Pradesh of which 20 species are endemic to the state.

However, in recent times, many more novelties are being described from the state by various botanists. Among all the described species of orchids from Arunachal Pradesh, 17 spp. are saprophytes, 138 spp. terrestrials and 383 spp. are epiphytes. *Bulbophyllum, Calanthe, Cymbidium, Dendrobium, Eria* are some of the dominant genera having maximum species diversity. *Paphiopedilum wardii*, once known from the higher ridges of Lohit Valley is feared lost from its natural habitat, whereas the status of 12 species are endangered, 16 species vulnerable, 31 species threatened and rests are common.

Apart from this, ten dominant genera of angiosperm e.g. *Agapetes, Bulbophyllum, Carex, Dendrobium, Impatiens, Eria, Ficus, Rhododendron, Rubus* and *Primula* with more than 25 species belonging to each genus exhibit overwhelming presence in the state (**Table 6.14)**.

Table 6.14: Comparative account of ten dominant genera of Arunachal Pradesh and India

Sr. No.	Genera in A.P.	No. of spp.	Genera in India	No. of spp
1.	*Rhododendron*	90	*Primula*	102
2.	*Bulbophyllum*	62	*Pedicularis*	100
3.	*Ficus*	51	*Bulbophyllum*	90
4.	*Dendrobium*	47	*Dendrobium*	90
5.	*Primula*	40	*Rhododendron*	90
6.	*Agapetes*	34	*Saxifraga*	80
7.	*Impatiens*	33	*Saussurea*	65
8.	*Carex*	31	*Gentiana*	54
9.	*Eria*	31	*Juncus*	44
10.	*Rubus*	29	*Coelogyne*	39

Comparative account of the genera depicts that *Pedicularis, Saxifraga, Saussurea, Gentiana, Juncus* and *Coelogyne* are replaced by *Ficus, Agapetes, Impatiens*, *Carex, Eria* and *Rubus* in Arunachal Pradesh. Orchidaceae alone is represented by two genera viz. *Bulbophyllum* and *Dendrobium* which are among the first five dominant genera in the both India and Arunachal Pradesh.

Rhododendron of Ericaceae with 90 species occurring in the state in contrast to 6 species in western Himalaya is considered as single largest genus of the flowering plants. Apart from the number, the genus also exhibits maximum diversity in the life form ranging from small herb to the tall trees. In the upper temperate ridges it often forms extensive liana that can be seen along Bumla, Zimithang, Ngula in Tawang district. Some of the common species are *Rhododendron arboreum, R. dalhousiae, R. griffithianum, R. hodgsonii, R. lindleyi, R. maddenii, R. nuttallii* etc. Some of the rare and endemic species of *Rhododendron* are *R. concinnoides, R. falconeri* ssp. *eximum, R. kendrickii, R. santapaui, R. subansiriense, R. talevalliensis, R. tawangensis*, etc.

The genus *Hedychium* of the family Zingiberaceae is another group of ornamental plants. There are about 40 species in India of which 35 species occur in eastern Himalaya alone. 21 species are reported from Arunachal Pradesh. Some common species of the genus are *Hedychium auranticum, H. coronarium, H. gracile, H. stenopetalum, H. thyrsiforme, H. wardii*, etc. whereas the rare and endemic ones are *Hedychium longipendunculatum, H.radiatum, H. raoa, H. robustum*.

Rhizomatous herbs like *Begonia* (19 spp.), *Arisaema* (16 spp.) and climbers like *Piper* (23 spp.) and *Dioscorea* (25 spp.) shows maximum diversity in the region.

Impatiens is one of the largest and much-diversified genera of the angiosperms in India with about 240 species, 33 species occur in Arunachal Pradesh.
A number of palms like *Caryota urens, Didymosperma nana, Livistona jenkinsiana, Phoenix rupicola, Pinanga gracilis, Wallichia densiflora, W. triandra; Zalacca secunda*, etc. grow profusely in this region.

Bamboos are also a dominant group of plants in the state. 23 genera and 120 species are so far known from India of which 17 genera and 89 species are represented in the Northeast India. 26 species belonging to 9 genera occur in Arunachal Pradesh such as *Bambusa* (4 spp.), *Chimonocalamus* (2 spp.), *Dendrocalamus* (6 spp.), *Dinochloa* (1 sp.), *Drepanostachyum* (1 sp.), *Gigantochola* (1 sp.), *Neomicrocalamus* (1 sp.), *Phyllostachys* (3 spp.), and *Schizostachyum* (7 spp.). A few important bamboo species are *Bambusa tulda*, *B.balcooa, Chimonobambusa callosa, Dendrocalamus hamiltonii*, *D. strictus*, *Phyllostachys assamica*, *Schizostachyum pallidum* etc. *Dendrocalamus sahnii* and *Schizostachyum arunachalensis* are rare and endemic to the state.

Primitive angiosperms

The state abounds in quite a large number of primitive flowering plants **Table 6.15** and many species belonging to families viz. Annonaceae, Piperaceae and Lauraceae do not occur in other parts of India except North Eastern region, Eastern Himalaya, Assam and Burma (Myanmar). This indicates that the flora of this region is primitive lending support to Takhtajan's view of 'cradle of flowering plants'.

Table 6.15: Primitive flowering plants reported in project area

Sr. No.	Name of species	Family	Localities
1	*Alnus nepalensis*	Betulaceae	Subansiri
2	*Altingia excelsa*	Hamamelidaceae	Subansiri
3	*Chloranthus brachystachi*	Chloranthaceae	Subansiri
4	*Exbucklandia populnea*	Hamamelidaceae	Subansiri
5	*Holboellia latifolia*	Lardizabalaceae	Subansiri
6	*Houttuynia cordata*	Piperaceae	Subansiri
7	*Illicium cambodianum*	Illiciaceae	Subansiri
8	*I. griffithii*	Illiciaceae	Subansiri
9	*I. simonsii*	Illiciaceae	Subansiri
10	*Magnolia gustavi*	Magnoliaceae	Subansiri.
11	*Magnolia hodgsonii*	Magnoliaceae	Subansiri
12	*Magnolia pealiana*	Magnoliaceae	Subansiri
13	*Magnolia pterocarpa*	Magnoliaceae	Subansiri
14	*Manglietia insignis*	Magnoliaceae	Subansiri.

Gymnosperms

The climate of Arunachal Pradesh is well suited for the growth, flowering and fruiting of Gymnosperms. The sub-tropical and temperate belts provide the most suitable habitat for their growth and abundance. Out of 48 species belonging to 12 genera and 8 families native in India, 24 species belonging to 12 genera in wild are found in Arunachal Pradesh. Apart from these 16 species like *Agathis robusta, Araucaria columnaris, Cryptomeria japonica, Taxodium distichum* and *Thuja orientalis* are also cultivated as ornamental plants. Thus, Arunachal Pradesh is well represented by at least 18 genera and 8 families **Table 6.16**. *Amentotaxus assamica* is an endemic species from Arunachal Pradesh.

Table 6.16: Gymnosperms recorded from Arunachal Pradesh

Sr. No.	Name of the species	Family
1.	*Abies delavayi*	Pinaceae
2.	*Abies densa*	Pinaceae
3.	*Abies spectabilis*	Pinaceae
4.	*Agathis robusta*	Araucariaceae
5.	*Amentotaxus assamica*	Taxaceae
6.	*Araucaria columnaris*	Araucariaceae
7.	*Cedrus deodara.*	Pinaceae
8.	*Cephalotaxus griffithii*	Cephalotaxaceae
9.	*Cryptomeria japonica*	Taxodiaceae
10.	*Cupressus corneyana*	Cupressaceae
11.	*Cupressus torulosa*	Cupressaceae
12.	*Gnetum montanum*	Gnetaceae
13.	*Gnetum gnemon*	Gnetaceae
14.	*Juniperus indica*	Cupressaceae
15.	*Juniperus recurva*	Cupressaceae
16.	*Larix griffithiana*	Pinaceae
17.	*Picea brachytyla*	Pinaceae
18.	*Picea spinulosa*	Pinaceae
19.	*Pinus armandi*	Pinaceae
20.	*Pinus bhutanica*	Pinaceae
21.	*Pinus merkusii*	Pinaceae
22.	*Pinus roxburghii*	Pinaceae
23.	*Pinus wallichiana*	Pinaceae
24.	*Pinus wallichiana* var. *parva*	Pinaceae
25.	*Podocarpus neriifolius*	Podocarpaceae
26.	*Taxodium distichum*	Taxodiaceae
27.	*Taxus wallichiana*	Taxaceae
28.	*Tsuga dumosa*	Pinaceae
29.	*Thuja orientalis*	Cupressaceae

Distribution of Gymnosperms exhibits certain zonation in the state. *Pinus roxburghii* and *P. wallichiana* are the chief elements of conifer in Kameng and Siang sector while *Pinus kesiya* is dominant in the Tirap and Lohit districts. *Pinus merkusii*, a Burmese pine occurs only in Kulung and Lati valley of Tirap district. Similarly, *Agathis robusta* is found in foothills of Changlang district. The solitary species representing the genera *Picea* and *Larix* are not distributed eastward of Tawang district. *Tsuga dumosa* is a temperate species distributed widely in the state. Similarly, both the species of *Gnetum* are abundant in the evergreen forests of the lower ridges.

From the comparative account of generic diversity in Arunachal Pradesh with that of India **Table 6.17**, it is observed that out of 7 species of *Pinus* reported from India 5 species and a variety are recorded from Arunachal Pradesh while *Amentotaxus, Cedrus, Larix, Taxus and Tsuga* are represented by their solitary species. Again, except *Juniperus* all the genera are better represented in Arunachal Pradesh.

Table 6.17: Gymnosperms of Arunachal Pradesh and India

Sr. No.	Genera	No. of spp in Arunachal Pradesh	No. of spp. in India (Singh *et al* 1997)	Percentage (%)
1.	Pinus	6	7	25.5
2.	*Abies*	3	4	75
3.	*Cupressus*	2	3	66.1
4.	*Gnetum*	2	5	20
5.	*Juniperus*	2	5	40
6.	*Picea*	2	3	66.1

Sr. No.	Genera	No. of spp in Arunachal Pradesh	No. of spp. in India (Singh *et al* 1997)	Percentage (%)
7.	*Larix*	1	1	100
8.	*Podocarpus*	1	2	50
9.	*Taxus*	1	1	100
10.	*Tsuga*	1	1	100
11.	*Cephalotaxus*	1	2	50
12.	*Cedrus*	1	1	100
13.	*Amentotaxus*	1	1	100

Endemism

The geographical position, physiography and geological history of Arunachal Pradesh has altogether contributed to high endemism in relatively younger mountain system The occurrence of endemics, which is determined by biogeography provinces, unique ecosystems, and topographical as well as climatologically interfaces, is suggestive of biogeography, center of speciation, extinction and adaptive evolution of the biota of a particular region. Out of *ca* 17,500 described species of flowering plants, over 5,000 species belonging to 140 genera and 47 families are endemic to India. It is estimated *ca 3,500* endemic species occur in Northeast India. 238 endemic taxa from Arunachal Pradesh have been listed as per State Biodiversity Strategy and Action Plan of Arunachal Pradesh. However, the Botanical Survey of India has listed 220 taxa of Endemic species from Arunachal Pradesh as given in **Annexure 6.3**.

As far as the richness and genetic diversity of the flora of Arunachal Pradesh is concerned, it may be mentioned that many taxa hitherto reported rare and endemic to Assam, Manipur, Meghalaya, Sikkim and Nagaland are also collected from the state and few of them are growing profusely. A few such species are *Acer sikkimensis, Acer thomsonii, Aeschynanthus superba, Angiopteris evecta, Angelica sikkimensis, Anisadenia pubescens, Begonia sikkimensis, Carlemania griffithii, Christensenia aesculifolia, Cyathea gigantea, Commelina sikkimensis, Gnetum ula, Glycosmis cymosa, Hoya polyneura, Hymenopogon assamicus, Impatiens khasiana, I. mannii, I. porrecta, I. gammiei, Iodes hookeriana, Jasminum adenophyllum, Litsea khasyana, Livistona jenkinsiana, Illicium simonsii, I. maniporensis, Magnolia pterocarpa, Pseudobrassaiopsis hispida, Pseudodissochaeta assamica, Pteracanthus nobilis, Oxyspora cernua, Rhododendron kendrickii, Rubus assamensis, Senecio linifolius, Syzygium assamicum, Tetrastigma obovatum, e*tc.

Threatened species

39 threatened plant species have been recorded in Arunachal Pradesh, as given in **Table 6.18**[21]. *Paphiopedilum wardii* Summerh has been assessed as a Plant which is Extinct and Possibly/ Presumed Extinct.

Table 6.18: Rare, Endangered and Threatened Taxa

Sr. No.	Species	Family	Threatened Status
1.	*Acer oblongum* var. *microcarpum*	Aceraceae	En
2.	*Arachnis clarkei*	Orchidaceae	I
3.	*Begonia aborensis*	Begoniaceae	R
4.	*Begonia burkillii*	Begoniaceae	R
5.	*Begonia scintillans*	Begoniaceae	I

[21] *http://www.bsienvis.nic.in/RET/Arunachal-Pradesh-index.htm*

Sr. No.	Species	Family	Threatened Status
6.	*Biermannia jainiana*	Orchidaceae	I
7.	*Boehmeria tirapensis*	Urticaceae	I
8.	*Bulleyia yunnanensis*	Orchidaceae	I
9.	*Calanthe alismaefolia*	Orchidaceae	I
10.	*Capparis pachyphylla*	Capparaceae	V
11.	*Chaerophyllum orientalis*	Apiaceae	I
12.	*Coptis teeta*	Ranunculaceae	En
13.	*Diplomeris pulchella*	Orchidaceae	V
14.	*Epipogium sessanum*	Orchidaceae	I
15.	*Galeola falconeri*	Orchidaceae	I
16.	*Gentiana crassuloides*	Gentianaceae	R
17.	*Hedychium longipedunculatum*	Zingiberaceae	I
18.	*Ilex venulosa*	Aquifoliaceae	I
19.	*Lagenandra undulata*	Araceae	I
20.	*Leptodermis scabrida*	Rubiaceae	I
21.	*Merriliopanax cordifolia*	Araliaceae	I
22.	*Paphiopedilum fairrieanum*	Orchidaceae	En
23.	*Pauia belladonna*	Solanaceae	R
24.	*Phanera khasiana*	Fabaceae	I
25.	*Phoenix rupicola*	Arecaceae	V
26.	*Pholidota wattii*	Orchidaceae	R
27.	*Phyllostachys assamica*	Poaceae	I
28.	*Psychotria aborensis*	Rubiaceae	En
29.	*Pueraria bella*	Fabaceae	R
30.	*Rhododendron concinnoides*	Ericaceae	En
31.	*Rhododendron dalhousiae*	Ericaceae	I
32.	*Rhododendron formosum*	Ericaceae	V
33.	*Rhododendron santapaui*	Ericaceae	En
34.	*Rhododendron subansiriense*	Ericaceae	En
35.	*Rhynochoglossum lazulinum*	Gesneriaceae	R
36.	*Saurauia griffithii*	Actinidiaceae	I
37.	*Semiarundinaria pantlingii*	Poaceae	R
38.	*Vanda coerulea*	Orchidaceae	R
39.	*Wallichia triandra*	Arecaceae	R

En = Endangered**, I =** Indeterminate**, R =** Rare**, V** = Vulnerable

Two threatened and Endemic taxa are recorded in wetlands of Arunachal Pradesh. *Aneilema glanduliferum* (family Commelinaceae is an Endangered species reported from Rini, North Bhalukpong, Kameng District while *Begonia burkillii* Dunn (family Begoniaceae) is a Rare species reported from Abor Hills. Both species are found outside the Subansiri Basin.

Biologically curious plants

The state harbours some curious plants, which have created interest on account of their special life support system and special morphological characters and thus add significantly to the floristic diversity. *Rhopalocnemis phalloides*, *Sapria himalayana* are abundantly occurring in Mehao wild life sanctuary, Namdapha NP and Kumon Bum area whereas *Balanophora dioica* shows its maximum population density towards Kumon Bum. *Monotropa uniflora* a nonchrophyllous showy plant grow on thick humus in the above areas. Certain plants like *Saussurea obvallata, Rheum nobile*, etc. have flowers, which act as warm houses as the flowers are enclosed by large, transparent, leafy bracts. The flowers open inside the bracts, where insects take shelter for warmth during winter and at the same time help in pollination.

i. Root parasite

i) *Sapria himalayana* (Rafflesiaceae) - Largest root parasite has attractive crimson flowers measuring *ca* 35 cm across.
ii) *Rhopalocnemis phalloides* (Balanophoraceae)
iii) *Balanophora dioica* (Balanophoraceae) - Associated with the roots of several tree species.
iv) *Boschniakia himalaica* (Orobanchaceae) - Root parasite on *Rhododendron* sp. in alpine area.
v) *Aeginetia indica* (Orobanchaceae) - Root parasite on grasses.
vi) *Orobanche* sp. (Orobanchaceae) – Root parasite particularly in vegetable crop field

ii. Saprophytic plants

i) *Epipogium roseum* (Orchidaceae)
ii) *Epipogium indicum* (Orchidaceae)
iii) *Epipogium sessanum* (Orchidaceae)
iv) *Galeola falconeri* (Orchidaceae) – one of the tallest orchids in India.
v) *Galeola nudifolia* (Orchidaceae)
vi) *Monotropa uniflora* (Monotropaceae)

iii. Insectivorous plants

i) *Drosera peltata* (Droseraceae)
ii) *Utricularia* spp. (Lentibulariaceae)
iii) *Utricularia bifida* (Lentibulariaceae)

6.7 Economically Important Plants

Wild Relatives of Cultivated Plants: The natural selection of crop plants from the wild species through mutation is a known fact. The Himalayan region alone harbours more than 270 such wild relative of crop plants and from the northeastern region 132 species has been reported. Arunachal Pradesh along with the northeastern region of the country has been referred as ‘Hindustan Centre of Origin of Cultivated plants’ and forms one of the major centres of origin of many of the crop plants. While living in wild these plants also develop resistance to diseases and pests, which causes heavy loss to the related cultivated crops. Thus these traits in wild relatives can be exploited in developing much improved, more resistant and high yielding varieties.

The region is very rich in *Musa* and *Citrus* germplasm. Many allied species of *Thea*, which are used as substitute for tea, also have been recorded from the state. Primitive rice cultivars were recorded in the localities ranging from 1800–2700 m in Arunachal Pradesh. The state has rich crop plant diversity particularly in the case of barley, maize, buckwheat, finger millet, foxtail millet, amaranth, French bean, soybean, cowpea, black gram, pea, scarlet, bean, pumpkin, cucumber, allium, ginger, tomato, Brassica, pome and stone fruits as given in **Table 6.19**.

Table 6.19: Wild relatives of cultivated plants

Category of plants	Name of the species
1. Cereals and millets	*Coix lacryma jobi*, *Coix gigantea* (Poaceae)
2. Legumes	*Atylosia barbata, Atylosia scarabaeoides, Vigna umbellata*(Fabaceae)
3. Fruits	*Abelmoschus manihot* (Malvaceae); *Artocarpus chama* (Urticaceae); *Citrus assamensis*, *C. aurantfolium*, *C. indica, C. jambiri,C. medica* (Rutaceae); *Mangifera*

Category of plants	Name of the species
	sylvetica (Anacardiaceae); *Ensete glaucum, Musa acuminata, M. balbisiana* , *M. glauca*, *M. nagensium, M. rosacea, M. velutina* (Musaceae);, *Myrica esculenta* (Myricaceae); *Prunus cerasoides*, *P. cornista*, *P. nepaulensis*, *Prunus persica, Pyrus domestica, Ribes gracile*, *Rubus ellipticus*, *R. lasiocarpus, R. lineatus*, *R. moluccans, Docynia indica, Duchesnea indica* (Rosaceae),etc.
4. Vegetables	*Alocasia macrorhiza*, *Amorphophallus bulbifer* (Araceae); *Cucumis hystrix, Momordica cochinchinensis*, *M. dioica*, *Trichosanthes cucumerina, T. dioica*, *T. dicaclosperma*, *T. truncata* (Cucurbitaceae); *Solanum indicum* (Solanaceae); *Dioscorea alata* (Dioscoreaceae);
5. Oil seeds	*Brassica trilocularis* (Brassicaceae)
6. Fibres	*Gossypium arboreum* (Malvaceae)
7. Spices and Condiments	*Allium tuberosum* (Iridaceae); *Amomum aromaticum*, *Amomum subulatum*, *Curcuma amada, Curcuma zedoaria* (Zingiberaceae); Piper *longum*, *Piper peepuloides* (Piperaceae).
8. Miscellaneous	*Camellia caudata* (Theaceae); *Miscanthus nepalensis*, *Saccharum longisetosum* (Poaceae), etc.

Timber Yielding Plants: The forests of Arunachal Pradesh are endowed with many valuable timber species. The economy of a major population depends primarily on timber. The timber of this state had great demand throughout the country. Indian Railways, Plywood factories, etc. exploited these plants heavily in the recent past apart from being used in making furnitures and other household articles. Bamboos and canes also play an important role in the economy of the people. Some of the important commercial timber species of Arunachal Pradesh are listed in **Table 6.20**.

Table 6.20: Important Timber yielding plants

Sr. No.	Name of the Species	Family	Local name
1.	*Actinodaphne obovata*	Lauraceae	Pajihuta
2.	*Albizia lucida*	Mimosaceae	Moz
3.	*Alstonia scholaris*	Apocynaceae	Satiana
4.	*Altingia excelsa*	Hamamalidaceae	Jutali
5.	*Anthocephalus chinensis*	Rubiaceae	Kadam
6.	*Artocarpus lakoocha*	Moraceae	Dewa chali
7.	*Bauhinia variegata*	Caesalpinaceae	Kanchon
8.	*Beilschmiedia pseudomicropora*	Lauraceae	Bonhingalo
9.	*Betula alnoides*	Betulaceae	Birch
10.	*Bischofia javanica*	Euphorbiaceae	Urium
11.	*Bombax ceiba*	Bombacaceae	Simul
12.	*Canarium strictum*	Burseraceae	Dhuna
13.	*Canarium bengalense*	Burseraceae	Dhuna
14.	*Castonopsis indica*	Fagaceae	Hingori
15.	*Chukrasia tabularis*	Meliaceae	Bogipoma
16.	*Cinnamomum glaucescens*	Lauraceae	Gonsoroi
17.	*Dipterocarpus retusus*	Dipterocarpaceae	Hollong
18.	*Duabanga grandiflora*	Sonneratiaceae	Khokan
19.	*Dysoxylum alliarium*	Meliaceae	Gondhaki-poma
20.	*Dysoxylum gobara*	Meliaceae	Lali
21.	*Garcinia cowa*	Clusiaceae	Tekra
22.	*Gmelina arborea*	Verbenaceae	Gomari
23.	*Gynocardia odorata*	Flacourtiaceae	Chalmugra
24.	*Juglans regia* var *kumonia*	Juglandaceae	Walnut
25.	*Kydia calycina*	Malvaceae	Pichola
26.	*Macaranga denticulata*	Euphorbiaceae	Morali
27.	*Magnolia hodgsonii*	Magnoliaceae	Boramthuri
28.	*Magnolia pterocarpa*	Magnoliaceae	Barampthuri-sopa
29.	*Mesua ferrea*	Clusiaceae	Nahar

Sr. No.	Name of the Species	Family	Local name
30.	*Michellia champaca*	Magnoliaceae	Champ
31.	*Michelia doltsopa*	Magnoliaceae	Sopa
32.	*Morus macroura*	Moraceae	Bola
33.	*Phoebe goalparensis*	Lauraceae	Bonsum
34.	*Phoebe paniculata*	Lauraceae	Mekahi
35.	*Picea spinulosa*	Pinaceae	Spruce
36.	*Pinus roxburghii*	Pinaceae	Chirpine
37.	*Pinus wallichiana*	Pinaceae	Blue pine
38.	*Quercus griffithii*	Fagaceae	Oak
39.	*Shorea assamica*	Dipterocarpaceae	Mekai
40.	*Sterculia hamiltonii*	Sterculiaceae	Pahari
41.	*Syzygium cumini*	Myrtaceae	Jamuk
42.	*Terminalia bellirica*	Combretaceae	Bohera
43.	*Terminalia chebula*	Combretaceae	Hilika
44.	*Terminalia myriocarpa*	Combretaceae	Hollock
45.	*Tetrameles nudiflora*	Datiscaceae	Bhelu
46.	*Toona ciliata*	Meliaceae	Poma
	Common bamboos		
47.	*Bambusa pallida*	Poaceae	Makal
48.	*Bambusa tulda*	Poaceae	Bijuli
49.	*Dendrocalamus hamiltonii*	Poaceae	Kakua
50.	*Dendrocalamus strictus*	Poaceae	Katabans
51.	*Melocanna baccifera*.	Poaceae	Muli
52.	*Schizostachyum polymorphum*	Poaceae	Bojal bans
	Common canes		
53.	*Calamus flagellum*	Arecaceae	Raidang bet
54.	*Calamus floribundus*	Arecaceae	Lejai bet
55.	*Calamus latifolius*	Arecaceae	Hauka bet
56.	*Calamus tenuis*	Arecaceae	Jati bet

A consolidated list of 768 economically important species along with their habit and occurrence in different forest types in Arunachal Pradesh is given in **Annexure 6.4**.

Medicinal Plants: Arunachal Pradesh can be termed as nature's repository of medicinal plants. The people of this remote state with their indigenous skill and close association with plants have accumulated an envious treasure of knowledge related to the utilization of plants surrounding their settlements. This traditional knowledge of medicinal plant is becoming a potential source for the Pharmaceutical Industries. Collection of the raw plant materials in bulk for these industries has posed a great threat to this wild wealth and large numbers of such species have already become rare and threatened. A sustainable utilization of this wealth is urgently required. Some of the commonly used medicinal plants are listed in **Table 6.21**.

Table 6.21: Medicinal plants of Arunachal Pradesh and their uses

Sr. No.	Name of the species	Family	Parts used	Treatment
1.	*Allium sativum*	Liliaceae	Tuber	Hypertension
2.	*Alpinia allughas*	Zingiberaceae	Tuber	Rheumatism & Lumbago
3.	*A. speciosa*	-do-	Rhizome	Gastric & Flatulence
4.	*Alstonia scholaris*	Apocynaceae	Latex	Ringworm, Eczema & Scabies
5.	*Amorphophallus campanulatus*	Araceae	Tuber	Piles
6.	*Anisomeles ovata*	Lamiaceae	Whole plant	Muscular pain
7.	*Aquilaria agallocha*	Thymeliaceae	Leaves	Fever
8.	*Argemone mexicana*	Papavaraceae	Leaves	Ringworm, Eczema

Sr. No.	Name of the species	Family	Parts used	Treatment
				& Scabies
9.	*Aristolochia saccata*	Aristolochiaceae	Tuber	Diarrhoea & Dysentery
10.	*A. tagala*	Aristolochiaceae	Tuber	Diarrhoea & Dysentery
11.	*Artemisia parviflora*	Asteraceae	Leaves & Stem	Mascular pain
12.	*A. nilagirica*	Asteraceae	Leaves	Cough & bronchial complaints
13.	*Cryptolepis elegans*	Asclepiadaceae	Young twig	Abortion
14.	*Calotropis procera*	Asclepiadaceae	Tender leaves	Cough & bronchial complaints
15.	*Coelogyne pectinata*	Orchidaceae	Pseudobulb	Cuts & wounds.
16.	*Crassocephalum crepidioides*	Asteraceae	Leaves	Cuts & wounds
17.	*Chloranthus officinalis*	Chloranthaceae	Roots	Cuts & wounds
18.	*Curcuma caesia*	Zingiberaceae	Rhizome	Diarrhoea & Dysentery
19.	*Cissampelos divaricatum*	Menispermaceae	Whole plant	Diarrhoea & Dysentery
20.	*C. pareira*	Menispermaceae	Whole plant	Snake bite
21.	*Carex polycephala*	Cyperaceae	Leaves	Fever
22.	*Croton oblongifolia*	Euphorbiaceae	Root bark Stem bark	Gastric & flatulence Gynecological disorder
23.	*Clerodendrum colebrookianum*	Verbenaceae	Tender leaves	Hypertension
24.	*Cyclosorus parasiticus*	Thelypteridaceae	Whole plant	Rheumatism & Lumbago
25.	*Callicarpa arborea*	Verbenaceae	Leaves	Rheumatism & Lumbago
26.	*Drymaria cordata*	Caryophyllaceae	Whole plant	Ringworm, eczema & scabies
27.	*Elatostemma rupestre*	Urticaceae	Leaves	Headache
28.	*Elsholtzia blanda*	Lamiaceae	Stem & leaves	Ringworm, eczema & scabies
29.	*Elsholtzia cariostachya* var. *pusila*	Lamiaceae	Stem & Leaves	Cough & bronchial complaint
30.	*Equisetum diffusum*	Equisetaceae	Whole plant	Fracture of bone
31.	*Eupatotium odoratum*	Asteraceae	Leaves	Cuts & wounds
32.	*Elaeocarpus sphaericus*	Elaeocarpaceae	Flower	Cardiac disorder
33.	*Ficus infectoria*	Moraceae	Leaves	Cuts & wounds
34.	*Garcinia acuminatus*	Clusiaceae	Fruit	Diarrhoea & Dysentery
35.	*G. cowa*	Clusiaceae	Fruit	Gastric & Flatulence
36.	*Gerbera diloselloides*	Asteraceae	Leaves	Rheumatism & Lumbago
37.	*Gnetum gnemon*	Gnetaceae	Leaves	Renovating
38.	*Gynura cusimbu*	Asteraceae	Leaves	Ringworm, Eczema & Scabies.
39.	*Houttuynia cordata*	Saururaceae	Rhizome	Cough & bronchial complaints
40.	*Luffa acutangula*	Cucurbitaceae	Seeds	Jaundice
41.	*Lantana camara*	Verbenaceae	Leaves	Ringworm, Eczema & Scabies
42.	*Molineria prainiana*	Hypoxidaceae	Leaves	Abortion
43.	*Mucuna pruriens*	Papilionaceae	Leaves	Eye disease
44.	*Musa velutina*	Musaceae	Pseudostem	Diarrhoea &

Sr. No.	Name of the species	Family	Parts used	Treatment
				Dysentery
45.	*Muchlenbackia platyclados*		Whole plants	Renovating
46.	*Myristica fragrans*	Myristicaceae	Seeds	Tuberculosis
47.	*Metathelypteris gracilescens*	Thelypteridaceae	Frond	Mascular pain
48.	*Ocimum sanctum*	Lamiaceae	Leaves	Gynecological disorder
49.	*Plantago major*	Plantaginaceae	Roots	Abortion, Diarrhoea & Dysentery
50.	*Polygonum flaccidum*	Polygonaceae	Leaves	Diarrhoea & Dysentery
51.	*Piper longum*	Piperaceae	Seeds	Tuberculosis
52.	*P. nigrum*	Piperaceae	Seeds	Fever
53.	*P. pedicellosum*	Piperaceae	Leaves	Fracture of bones
54.	*P. thomsonii*	Piperaceae	Root	Urinary disorder
55.	*Prunus communis*	Rosaceae	Root & bark	Fever
56.	*Plumbago zeylanica*	Plumbaginaceae	Leafy plants	Leprosy
57.	*Persicaria hydropiper*	Polygonaceae	Stem & leaves	Urinary disorder
58.	*Pothos scandens*	Araceae	Leaves	Small pox
59.	*P. cathcartii*	Araceae	Leaves	Fracture of bones
60.	*Rhus semialata*	Anacardiaceae	Seeds	Diarrhoea & Dysentery
61.	*Spilanthes acmella*	Asteraceae	Whole plants	Cuts & wounds
62.	*S. paniculata*	Asteraceae	Flowers	Pyorrhea & toothache
63.	*Stereospermum chelonoides*	Bignoniaceae	Leaves	Fever
64.	*Solanum spirale*	Solanaceae	Leaves	Rheumatism & lumbago
65.	*S. torvum*	Solanaceae	Fruits	Ringworm, Eczema & Scabies
66.	*Tacca integrifolia*	Taccaceae	Leaves	Diarrhoea & Dysentery
67.	*Toddalia asiatica*	Rutaceae	Roots	Diarrhoea & Dysentery
68.	*Thelypteris gracilescens*	Thelyoteridaceae	Fronds & rachis	Fracture of bones
69.	*Trema orientalis*	Ulmaceae	Bark	Nervous system
70.	*Villebrunea frutescens*	Urticaceae	Leaves	Ringworm, Eczema & Scabies
71.	*Webera corymbosa*	Rubiaceae	Leaves	Fracture of bones
72.	*Wedelia wallichi*	Asteraceae	Roots	Diarrhoea & Dysentery
73.	*Xanthium stramonium*	Asteraceae	Whole plants	Thyroid gland
74.	*Zanthoxylum armatum*	Rutaceae	Twig	Pyorrhea & Toothache
75.	*Zehneria umbellata*	Cucurbitaceae	Fresh roots	Jaundice

A consolidated list of 410 medicinal plants with their habit and occurrence in different forest types in Arunachal Pradesh is given in **Annexure 6.5**.

Wild Ornamental Plants: A large number of orchids *e.g.* species of *Calanthe, Coelogyne, Cymbidium, Dendrobium, Phaius, Phalaenopsis*, etc. species of *Rhododendron, Hedychium, Begonia, Impatiens* occurring in the state have great potential for horticultural exploitation. *Paphiopedilum fairieanum*, one of the rarest Lady's slipper orchids earlier thought to be a 'lost', has limited distribution in the West Kameng. Other elegant but rare, endangered species are *Cymbidium grandiflorum, C. longifolium, C. macrorhizon, C. mackinnoni, Dendrobium densiflorum* etc. *Rhododendrons* one of the most fascinating flowering plants is also horticulturally important and many species have been introduced in to cultivation.

List of wild ornamental plants is given in **Table 6.22**.

Table 6.22: List of wild ornamental plants

Sr. No.	Species	Family	Habit	Parts used
1.	*Aglaonema hookerianum*	Araceae	Herbs	Foliage
2.	*Alocasia fallax*	Araceae	,,	,,
3.	*Ariopsis peltata*	Araceae	,,	,,
4.	*Arisaema concinnum*	Araceae	,,	,,
5.	*Arisaema decipiens*	Araceae	,,	Foliage and spathes
6.	*Arisaema flavum*	Araceae	,,	,,
7.	*Arisaema jaquemontii*	Araceae	,,	,,
8.	*Arisaema nepanthoides*	Araceae	,,	,,
9.	*Arisaema speciosum*	Araceae	,,	,,
10.	*Arisaema wallii*	Araceae	,,	,,
11.	*Pothos scandens*	Araceae	Climber	Foliage
12.	*Rhaphidophora decursiva*	Araceae	,,	,,
13.	*Scindapsus officinalis*			,,
14.	*Paris polyphylla*	Liliaceae	Herbs	Foliage
15.	*Ophiopogon drucaenoides.*		,,	Whole Plant
16.	*Tacca integrifolia*	Taccaceae	,,	Foliar bracts
17.	*Stemona tuberosa*	Stemonaceae	Climber	Foliage and flowers
18.	*Asparagus racemosus*	Liliacease	,,	Whole plant
19.	*Arenga pinnata*	Arecaceae	Tree	,,
20.	*Calamus erectus*	Arecaceae	Shrubs	,,
21.	*Pinanga gracilis*	Arecaeae	,,	,,
22.	*Caryota urens*	Arecaceae	Trees	,,
23.	*Livistona jenkinsiana*	Arecaceae	,,	,,
24.	*Phoenix rupicola*	Arecaceae	,,	,,
25.	*Hypericum griffithii*	Hypericaceae	Shrubs	Flowers
26.	*Hypericum hookerianum*	Hypericaceae	,,	,,
27.	*Impatiens brachycentra*	Balsaminaceae	Herbs	,,
28.	*Impatiens acuminata*	Balsaminaceae	,,	,,
29.	*Impatiens bicornuta*	Balsaminaceae	,,	,,
30.	*Impatiens racemosa*	Balsaminaceae	,,	,,
31.	*Begonia nepalensis*	Begoniaceae	,,	Whole plant
32.	*Begonia palmata*	Begoniaceae	,,	,,
33.	*Begonia cathcartii*	Begoniaceae	,,	,,
34.	*Begonia griffithiana*	Begoniaceae	,,	,,
35.	*Begonia roxburghii*	Begoniaceae	,,	,,
36.	*Ixora acuminata* Roxb.	Rubiaceae	Shrubs	Flowers
37.	*Ixora cuneifolia*	Rubiaceae	,,	Flowers and foliage
38.	*Clerodendrum colebrookianum*	Verbenaceae	,,	,,
39.	*Osbeckia nutans*	Melastomataceae	,,	,,
40.	*Melastoma malabathricum*	Melastromaceae	,,	,,
41.	*Aster himalaicum*	Asteraceae	Herbs	,,
42.	*Aster sikkimensis*	Asteraceae	,,	,,

Sr. No.	Species	Family	Habit	Parts used
43.	*Senecio raphanifolius*	Asteraceae	,,	,,
44.	*Jasminum amplexicaule*	Oleaceae	Shrubs	,,
45.	*Clerodendron japonicum*.	Vebenaceae	,,	,,
46.	*Lobelia pyramidalis*	Lobeliaceae	,,	,,
47.	*Aristolochia tagala*	Aristolochiaceae	Climber	Flowers
48.	*Aristolochia saccata*	Aristrolociaceae	,,	,,
49.	*Thunbergia coccinea*	Acanthaceae	,,	,,
50.	*Thunbergia grandiflora*	Acanthaceae	,,	,,

6.8 Epiphytes

Epiphytes: The most common epiphytes found in the forest are *Loranthus ampullaceous, Ficus mysorensis*, *F. altissima, Ficus mysorensis, Ficus gibbosa, Ficus elastica, Ficus retusa,* etc. which cause damage to host tree. [22]

6.9 Floristic diversity in Subansiri Basin, Arunachal Pradesh

An inventory of flowering plants has been prepared based on secondary data and surveys in the Subansiri Basin and given in **Annexure 6.6**. A summary of the inventory at the family level is given in **Table 6.23** and no. of species recorded in Subansiri Basin is shown in **Figure 6.6**. It shows that there are one hundred and fourteen families (114) and one thousand three hundred and twenty three flowering plants (1323) which are reported to occur in Subansiri Basin, Arunachal Pradesh.

Table 6.23: Famlies and species recorded in Subansiri Basin, Arunachal Pradesh

Sr. No.	Family	No. of Species
1.	*Ranunculaceae*	24
2.	*Dilleniaceae*	2
3.	*Magnoliaceae*	16
4.	*Illiciaceae*	4
5.	*Schisandraceae*	4
6.	*Annonaceae*	9
7.	*Menispermaceae*	5
8.	*Berberidaceae*	3
9.	*Lardizabalaceae*	1
10.	*Fumariaceae*	61
11.	*Actinidiaceae*	18
12.	*Bombacaceae*	1
13.	*Sterculiaceae*	10
14.	*Elaeocarpaceae*	12
15.	*Linaceae*	2
16.	*Malpighiaceae*	5
17.	*Geraniaceae*	1
18.	*Balsaminaceae*	16
19.	*Oxalidaceae*	2
20.	*Rutaceae*	13
21.	*Simaroubaceae*	3
22.	*Burseraceae*	2
23.	*Meliaceae*	11
24.	*Olacaceae*	3
25.	*Icacinaceae*	1
26.	*Opiliaceae*	1

[22] *Arunchal Pradesh State Biodiversity Strategy and Action Plan, 2004.*

Sr. No.	Family	No. of Species
27.	*Cardiopteridaceae*	1
28.	*Aquifoliaceae*	5
29.	*Celastraceae*	10
30.	*Rhamnaceae*	5
31.	*Vitaceae*	13
32.	*Leeaceae*	5
33.	*Hippocastanaceae*	1
34.	*Sapindaceae*	5
35.	*Aceraceae*	4
36.	*Sabiaceae*	5
37.	*Anacardiaceae*	6
38.	*Connaraceae*	1
39.	*Fabaceae*	56
40.	*Caesalpiniaceae*	20
41.	*Mimosaceae*	13
42.	*Rosaceae*	46
43.	*Saxifragaceae*	5
44.	*Grossulariaceae*	1
45.	*Hydrangeaceae*	5
46.	*Hamamelidaceae*	3
47.	*Haloragidaceae*	1
48.	*Combretaceae*	6
49.	*Myrtaceae*	14
50.	*Lythraceae*	5
51.	*Onagraceae*	6
52.	*Passifloraceae*	3
53.	*Caricaceae*	1
54.	*Cucurbitaceae*	21
55.	*Begoniaceae*	4
56.	*Molluginaceae*	16
57.	*Caprifoliaceae*	8
58.	*Rubiaceae*	70
59.	*Valerianaceae*	1
60.	*Asteraceae*	53
61.	*Campanulaceae*	33
62.	*Primulaceae*	5
63.	*Myrsinaceae*	19
64.	*Ebenaceae*	1
65.	*Styracaceae*	4
66.	*Symlocaceae*	5
67.	*Oleaceae*	8
68.	*Apocynaceae*	2
69.	*Asclepiadaceae*	3
70.	*Buddlejaceae*	1
71.	*Gentianaceae*	2
72.	*Boraginaceae*	4
73.	*Convolvulaceae*	30
74.	*Gesneriaceae*	14
75.	*Bignoniaceae*	1
76.	*Pedaliaceae*	18
77.	*Verbenaceae*	14
78.	*Lamiaceae*	20
79.	*Plantaginaceae*	1
80.	*Nyctaginaceae*	1
81.	*Amaranthaceae*	11
82.	*Chenopodiaceae*	2

Sr. No.	Family	No. of Species
83.	*Polygonaceae*	21
84.	*Podostemaceae*	1
85.	*Piperaceae*	10
86.	*Saururaceae*	1
87.	*Chloranthaceae*	2
88.	*Lauraceae*	15
89.	*Thymelaeaceae*	2
90.	*Elaeagnaceae*	6
91.	*Santalaceae*	1
92.	*Balanophoraceae*	1
93.	*Euphorbiaceae*	20
94.	*Ulmaceae*	1
95.	*Cannabaceae*	10
96.	*Urticaceae*	20
97.	*Juglandaceae*	2
98.	*Betulaceae*	1
99.	*Fagaceae*	1
100.	*Salicaceae*	1
101.	*Orchidaceae*	232
102.	*Musaceae*	2
103.	*Taccaceae*	6
104.	*Agavaceae*	9
105.	*Smilacaceae*	2
106.	*Pontederiaceae*	1
107.	*Commelinaceae*	19
108.	*Juncaceae*	2
109.	*Araceae*	18
110.	*Lemnaceae*	2
111.	*Potamogetonaceae*	2
112.	*Eriocaulaceae*	3
113.	*Cyperaceae*	13
114.	*Poaceae*	48
		TOTAL SPECIES= 1323

In Subansiri Basin, Orchidaceae is the largest family having 232 species (among the top ten families), followed by Rubiaceae (70), Fumariaceae (61), Fabaceae (56), Asteraceae (53), Poaceae (48), Rosaceae (46), Campanulaceae (33), Convolvulaceae (30) and Ranunculaceae (24).

Salient features, climate, topography, forests type and vegetation found in and around 19 HEPs in Kurung Kumey, Lower Subansiri and Upper Subansiri districts are described below.

Kurung Kumey district: Seven Hydroelectric projects (HEPs) are proposed in Kurung Kumey District. The location of seven proposed HEPs, coordinates and altitude is given in **Table 6.24**.

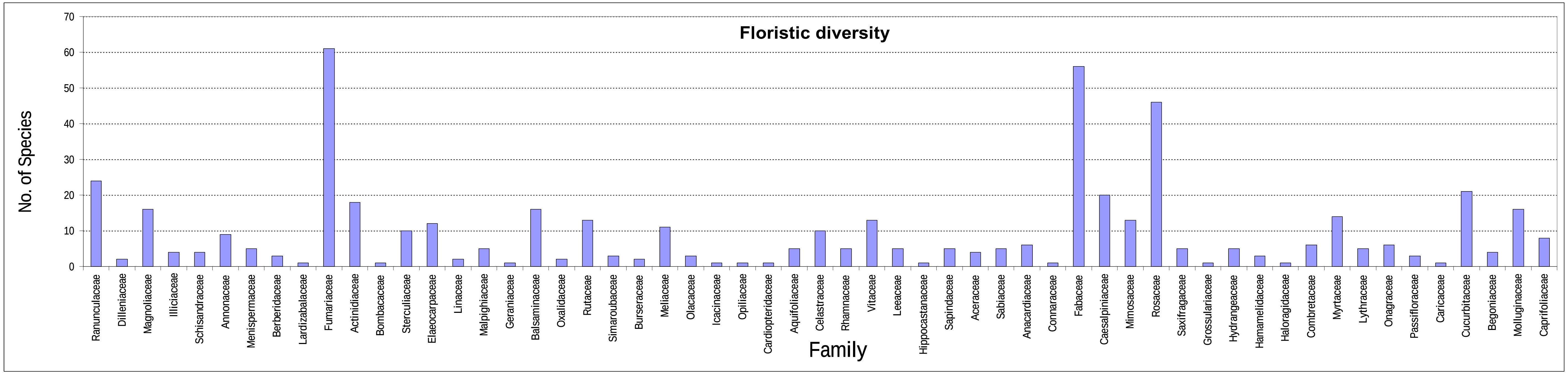
Table 6.24: Proposed HEPs, coordinates and altitude in Kurung Kumey District

Sr. No.	Name of the project	Latitude			Longitude			Altitude
		Deg.	Min	Sec	Deg.	Min	Sec	(in meters)
1.	Mili	27	58	0	93	3	0	1200
2.	Sape	27	57	0	93	5	0	1080
3.	Chomi	27	55	45.48	93	17	09.21	920
4.	Chela	27	53	45.05	93	22	47.63	960
5.	Nyepin	27	44	58.4	93	23	16.7	1020

Sr. No.	Name of the project	Latitude			Longitude			Altitude
		Deg.	Min	Sec	Deg.	Min	Sec	(in meters)
6.	Hiya	27	45	20.37	93	26	4.09	994
7.	Kurang Dam - I & II	27	35	0	93	55	0	640

The following sections describe salient features, climate, topography, forests type and vegetation found in and around the seven HEP locations as given in **Table 6.25**.

Description of Kurung Kumey District: Kurung Kumey district of Arunachal Pradesh is lying between 91º20' to 55º40' E longitude and 28º30' to 38º04' N latitudes with an area of 6340 sq.km. Layers of undulating mountains with inaccessible stiff hills makes the district one of the inaccessible regions. The district is bounded by Mc-Mohan line in the north, East Kameng District in the west, Upper Subansiri district on the east and Lower Subansiri district and Papum Pare district of the Arunachal Pradesh in the south. All the boundaries of the district are made up by high ridges of mountains and rivers, which run southward from the main Himalayan ranges. The Muphla and Jammung-la passing the Sarlee circle and Chimmungla, Bome la and Lutingla pass of Huri-Damin circle connect the district with China in the North-eastern side of the district in between 4800-5600m. The highest peak of the district is Tadikiri situated near Muphla pass with an altitude of about 6540m.



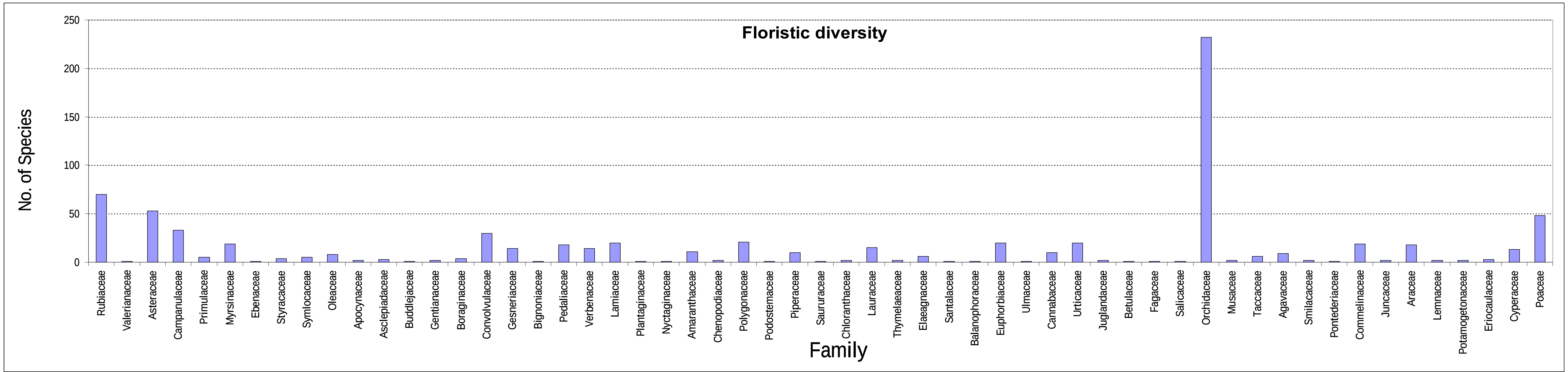


Figure 6.6: No. of species recorded in Subansiri Basin

The name of the district is derived from two rivers Kurung and Kumey; which are the main tributaries of river Subansiri, ultimately merging in the mighty Brahmaputra. As per the Indo-Tibetan Boundary Agreement, 1914 the district was part of “Northern Section” of the "North East Frontier Track". The entire area during British regime was regulated by an Inner Line. In 1919 this track was renamed as the "Subansiri Frontier Track" under Kimin Sub-Agency with headquarters at Lakhimpur-Kimin. After independence, it was renamed as the “Subansiri Frontier Division” under “North Eastern Frontier Agency” (NEFA) and it’s headquarters was transferred to Ziro-Yangtey (Lower Subansiri). After the reorganization of Arunachal Pradesh state in 1976, the region was under the jurisdiction of Lower Subansiri district with head quarters at Zero. The present Kurung Kumey district was bifurcated from Lower Subansiri district in the year 2001 with headquarters at Koloriang.

Administratively the district has been divided into 11 circles (Sub-divisions). The district is dominated by Nyishin tribe. They have a mother tongue Nyishi which they basically used. As per the Census 2011, the area of the district is 6040 sq.kms. The population of the district is 92,076 (with a growth rate of 116.56%) when compared to the population of 42,518 (Census 2001). As per Census 2011, sex ratio is 1032, average literacy rate is 48.75 and population density of 15 persons / Sq. km (as against the density of population 7 persons/Sq. km in 2001).

Climate: The climate varies sharply with changes in latitude. Three broad climatic zones are recognizable *viz.*, hot and humid subtropical area of foothills, cooler micro-thermal zone of the Lesser Himalayas, and alpine zone of the Greater Himalayas. Upper reaches adjoining Tibet (China) have perpetual snow. Rainfall, however the most prominent climatic factor and is fairly distributed throughout the months. The district received rainfall both from south-west monsoon and the northeast retreat monsoon. Pre-monsoon thunders are common in month of April. The summer monsoon or southwest monsoon sets in during month or June-July; Clouds brought during this period get intercepted by high ridges of the district, resulting in heavy precipitation throughout out the district. The monsoon which lasts till mid-October contributed almost 75% of the annual rainfall of the district. July-August is the typical monsoon months experiencing the heaviest downpour. The district is also influenced by the retreat monsoon in last quarter of the winter season. Annual rainfall is about 934.88 cm and relative humidity is high thorough out the year. Prolonged winter is observed in the high mountainous regions.

The northern region of the district, particularly Sarlee, Huri & Damin circles receive higher rainfall because of their geographical position. Amount of rainfall decreases towards the southern and south west part of the district. The Nyepin circle receives lesser rainfall. Temperature varies a great deal in the district. The average mean maximum and minimum temperature is 29.5 ^{0}C and 15.7^{0}C in subtropical humid regions and 19.4^{0}C and 1.4^{0}C in cold humid regions. Low temperature days are from December to February. Hot and warm months are June to July with maximum temperature around 30^{0}C. Foothills and plains experience higher temperatures. While in the interior parts of Northern part, the temperature goes below frizzing point. The great variation of the temperature is due to the variation of the altitude in the district. Generally November and April is the most pleasant months in the district, December and January are the coldest months.

Topography: The topography of the district Kurung Kumey is characterized by great variation in elevation. The range of elevation is enormous. By virtue of its location in the Lesser Himalayan Zone, the topography is out and out mountainous. To the North the district is highly rugged with deep valley and hill ranges running mainly east-west direction. A number of peaks built up of crystalline rocks accentuate the demarcation between China and Kurung Kumey.

Salient Features of the Flora of the Kurung Kumey Basin: Some of the interesting rare species, viz. *Crotolaria anagyroides* is a native of tropical America reported to be naturalized in Meghalaya and Mizoram is found in this region. Similarly, *Dalbergia thomsonii* and *Derris marginata* which were considered endemic to Khasia and Jaintia hill of Assam and Meghalaya have been reported for the first time from the district. *Shuteria involucrata* is another species which was collected from the district forms the basis of first report for Arunachal Pradesh.

It is also interesting to note that many spp. viz. *Begonia aborensis, Begonia silhetensis, Glochidion assamicus, Hodgsonia macrocarpa, Hoya parasitica, Illigera khasiana, Maesa nayarii, Modecca cardiophylla, Polygonatum opppositifolium, Pueraria bella, Raphiostema pulchella, Rubus birmanicus, Stauranthera grandiflora, Ventilago madaraspatana,* which are rare in their natural habitat are also encountered in this region.

During the recent floristic survey conducted in the Kurung Kumey District of Arunachal Pradesh, six interesting species were collected which were known only from the type locality. The present collection of these species from areas other than the type localities confirms that they may have a wider distribution in this region. Out of the six species, *Dalbergia thomsonii* Benth, *Larsenianthus assamensis* and *Plectocomia himalayana* are reported for the first time from the state while *Begonia silhetensis*, *Larsenianthus arunachalensis Tricarpelema glanduliferum* show extended distribution.[23]

Plant diversity in Kurung Kumey district and the proposed HEP locations: The district enjoys very ideal conditions for vegetation growth. High temperature, rainfall and humidity support very dense growth of plants, which is very diverse from southern parts (tropical) to northern parts (alpine). Distribution of forest types as well as species is quite interesting from south-east direction to north-west direction. Gigantic *Dipterocarpus* forms a very characteristic species of the evergreen forests of Chambang and Damin circle and gradually diminishes towards the western direction. Deep valleys in the Sangram and Koloriang circle support very good growth of *Terminalia* spp. The district Kurung Kumey, with diverse climatic conditions and complex topography, has different types of forest and vegetation. Certain parameters such as altitude, community structure, floral composition, habitat conditions, are to be taken into consideration while classifying vegetation types of the district. The major forest cover of the district is primary forest, though they are under severe anthropogenic pressure and fast eroding due to biotic as well as abiotic factors. The characteristic three-layer canopy of vegetation in tropical and subtropical belts is one of the most significant features of the vegetation of the district.

Primary Forest

Broadly, primary vegetation types in the Kurung Kumey can be categorised into

i. Tropical
ii. Sub-tropical
iii. Warm temperate (broad leaved)
iv. Cool temperate, (coniferous)
v. Sub-alpine and
vi. Alpine types.

Tropical Vegetation: The area come under this type can be characterized by heavy rainfall during monsoon and post monsoon period. The most dominant trees in this zone are *Dipeterocarpus retusus* (Hollung) and *Terminalia myriocarpa* (Holluck). The associated trees

[23] *Dash, S.S. & A.A. Mao (2011). Distribution of six little known plant species from Arunachal Pradesh, India. Journal of Threatened Taxa 3(9): 2095–2099..*

in the top canopy are *Aglaia chittagonga*, *Castanopsis indica, Cinnamomum bejolghota, Dysoxylum gobara,* many species of *Elaeocarpus, Magnolia hodgosonii, Quercus griffithii, etc.* The forest of this type of vegetation can be characterized by their close canopy, dense underground cover and luxuriant growth of the epiphytes. The middle canopy is formed by the medium sized trees viz. *Castanopsis lancifolia, Dysoxylum binectariferum, Elaeocarpus prunifolius, Ficus oligodon, Lithocarpus pachyphylla, Lithocarpus elegans,* etc.

Some of the large shrubs or small trees that are commonly found in the lower canopy are *Aralia foliosa, Baliospermum corymbiferum, Bauhinia purpurea, Boehmeria macrophylla, Boehmeria platyphylla, Clerodendrum colebrookianum, Clerodendrum serrulatum, Debregeasia longifolia, Dendrocnide sinuata, Goniothalamus sesquipedalis, Grewia disperma, Maesa ramentacea, Micromelum integerrimum,* many species of *Mussaenda, Oxyspora paniculata, Pseudodissochaeta assamica, Rhus griffithii, Sambucus hookeri, Saurauia napaulensis* and *Vernonia volkamerifolia,* etc.The important palms that are found within this forest are *Arenga obtusifolia, Licuala peltata, Pinanga gracilis, Wallichia densiflora, Pandanus furcatus* etc., while *Cyathea spinulosa* (tree ferns), species of wild banana, etc grow abundantly on moist hill slopes.

The climbers and lianas form a characteristic species composition in these forests. The commonly found climbers are *Acacia pennata, Bauhinia ornata* Kurz. var. *kerri, Beaumonita grandiflora, Hodgsonia macrocarpa* etc. Smaller lianas and less woody climbers are *Ampelocissus latifolia*, *Cayratia trifolia, Cayratia pedata, Cissus assamica Fissistigma bicolor, Natsiatum herpeticum, Parabaena segittata, Tetrastigma rumicisperum Tetrastigma serrulatum, Sabia lanceolata,* etc.

Subtropical Vegetation: The sub-tropical evergreen type of forest is found predominately throughout the district. This forest can be characterized by its evergreen and dense in nature. The forest has uniform species composition and no single species is found exclusively dominated. The trees occupied in the top storey are mixture of semi-evergreen and deciduous species with tall, luxuriant growth. The semi-evergreen species are more dominant than the deciduous elements.

The top storey in this forest mainly consist of *Acer oblongum, Actinodaphne obovata, Aphanamixis polystachya, Cinnamomum bejolghota, Cinnamomum paucifloum, Elaeocarpus aristatus, Elaeocarpus varunua, Engelhardtia spicata*, *Litsea monopetala, Macaranga denticulata, Phoebe attenuata, Terminalia bellirica, Trema orientalis etc.* The middle storey consists of *Osteodes paniculata, Desmos longiflorus, Exbucklandia populnea*, *Heteropanax fragrans*, *Saurauia armata, Saurauia punduana, Schima wallichii,* etc. The lower storey consist of *Capparis multiflora*, *Erythropalum scandens, Dendrocnide sinuata, Itea macrophylla*, *Millettia pachycarpa*, *Oreocnide integrifolia*, *Saurauia fasciculata, Schefflera wallichiana*.The common shrubs of this zone are *Abroma augusta, Clerodendrum serrulatum, Dichroa febrifuga, Diflugossa colorata*, *Embelia floribunda*, *Hydrangea heteromalla, Hydrangea anomala,Leea asiatica, Maesa indica*, *Maesa* spp., *Morinda angustifolia, Myrsine semiserrta, Mussaenda roxburghii, Melastoma malabathricum*, *Medinella himalayana, Musa velutina, Mussaenda macrophylla, Mussaenda incana, Myrioneuron nutans, Osbeckia stellata, Phlogacanthus curviflorus,Polyura geminata, Psychotria callocarpa, Sauropus trinervius, Styrax serrulatum,Vernonia volkameriaefolia,* etc.

The dominant canes and palms are *Calamus palustris, Calamus erectus, Calamus floribundus*, *Calamus flagellum, Areca triandra*, *Arenga obtusifolia, Pinanga gracilis, Caryota urens, Wallichia densiflora.* These forests are rich in epiphytic flora. Almost all the tree trunks and branches are heavily plastered with lichens, mosses, ferns and fern-allies, orchids and other angiosperms. The fern flora is more characteristic and takes dominance over others.

These plants belong to *Asplenium ensiforms, Drynaria propinqua, Lepisorus thunbergianum, Micorsorium sp.,* etc*.* The important epiphytic orchids that found in this type of forest are *Acrochaene punctate, Agrostophyllum callosum, Bulbophyllum cauliflorum, Bulbophyllum gymnopus, Coelogyne griffithii, Cymbidium elegans, Dendrobium chrysanthum, Dendrobium denudans, Dendrobium farmeri, Dendrobium sulcatum, Epigeneium amplum, Neogyna gardneriana, Pholidota imbricata, Pholidota undulata, Schoenorchis gemmata* etc.,

The unique saprophytic plants that found in this type of forest are *Balanophora dioica, Monotropasturm humile*, *Galeola falconeri,* and *Galeola lindleyana.* The ground flora or undergrowth are densely covered by herbaceous plants such as *Anaphalis adnata, Begonia hatacoa*, *Begonia tassaricarpa*, *Begonia sikkimensis, Crotalaria khasiana*, *Chirita oblongifolia*, *Desmodium laxiflorum, Gomphostemma lucidum*, *Lidernia anagallis Lysimachia japonica*, *Pilea bracteosa, Sonerilla maculata, Tovora virginiana*. The monocot plants found are *Alpinia nigra, Amischotolype mollissima, Commelina maculata, Costus speciosus, Disporum contoniense, Globba multiflora, Gonatanthus pumilus, Hedychium coccineum*, *Hedychium ellipticum*, *Murdannia nudiflora*, *Pollia subumbellata,* etc.

Broad leaved Temperate Vegetation: This is found in between 1800-2800 m around the upper slopes above the valley of Kurung and Kumey River. This type of forest is characterized by mostly Laurales, *Quercus Acer, Castanopsis, Magnolia*, and different species of *Rhododendron*, with low proportion of deciduous species. Ground flora is rich in herbaceous species; climbers and twinner are extremely rare. Trees such as the *Quercus lamellosa, Michelia doltsopa, Magnolia pterocarpa*, etc. constitutes the top canopy; while trees *Cinnanomum impressinervium*, *Lithocarpus elegans*, *Lithocarpus pachyphylla, Lindera latifolia*, *Litsea monopetala, Litsea cubeba*, are dominant in the second storey. The other main associated species that are found in these forests are *Acer hookeri, Acer oblongum, Alnus nepalensis, Exbucklandia populnea, Engelhardia spicata, Saurauia griffithii, Euonymus* spp., *Rhododendron* spp., *Symplocos racemosa*, etc. The lower storey is dominated by the shrubby vegetation which is quite dense and luxuriant. The main components comprise *Deutzia campacta, Illigera khasiana*, *Elaegnus umbellata, Berberis wallichiana, Caryopteris odorata, Ilex fragilis, Lyonia ovalifolia, Myrsine semiserrata, Rubus leneatea, Rubus* spp., etc. Ground flora consists of species of *Begonia, Drymaria, Fragaria, Polygonum, Elatostema, Aconogonon, Cardamine, Anaphalis, Cadonopsis*, *Ostodes, Pilea*, etc., Climbers are rare, but epiphytic species of *Agapetes, Vaccinium, Ficus, Coelogyne, Cymbidium* and various orchids are abundantly found.

Cool Temperate (Coniferous) Vegetation: The cool temperate forests of the district mainly occur in between 2800-3500 m. This type of forest is characterized by the mixed population of *Tsuga- Pinus- Taxus* series of conifers with *Rhododendron* species. This type of vegetation is typical in nature and not found in any other places in Arunachal Pradesh. The other type of mixed populations in the cool temperate zone comprises of *Tsuga-Abies-Rhododendron*, *Abies – Taxus*. Dominant temperate coniferous species *Tsuga dumosa, Abies densa* and *Taxus wallichiana* are found abundantly in this area. The underground vegetation which is found in this forest are species of *Oenanthe*, *Bistora, Polygonum, Aconogonon, Prunus, Rosa, Rubus* and *Spirea* etc. dominated by mixed coniferous species with Rhododendrons.

Subalpine and Alpine Vegetation: This type of vegetation is restricted in the zone ranges from 3500-5000 m. in the higher elevation beyond Sarlee. The lower altitudes of this zone support shrubby species of *Rhododendron, Euonymus, Salix, Vaccinium,* etc. while *Rhododendron anthopogon* and R. *pumilum* form dense tussocks near the sub-alpine mountain tops. Among the herbaceous flora, species of *Aconitum, Caltha, Cassiope, Pedicularis, Potentilla, Polygonatum, Primula, Rhodiola,* etc. are common in this zone.

Besides, the plants of great medicinal value, viz. *Aconitum ferox, Neopicrorhiza scruphulariiflora, Coptis teeta, Gentiana kurroo, Saussurea* etc. are common in higher hills.

Secondary Vegetation: Due to many biotic or abiotic activities, an extensive area of the primary vegetation has been much disturbed in the district. This has happened due to frequent landslides, incidence of developmental activities, and expansion of habitable areas. Direct interference of local people in the natural forests and their life style has majorly contributed to the change of the primary vegetation in the district. Most of these changes are rapid and irrevocable transformation of the forest lands to various landscapes.

Forest cover in the Project site: The proposed Hydroelectric projects (HEPs) in Kurung Kumey district falls under three rivers.

1. Milli and Sape over Kurung River
2. Chomi and Chella over Kumey River and
3. Nyapin and Hiya over Panyu River

The proposed HEPs are based on the two major river system in the district, that is of the River Kurung and Kumey. The entire district is drained by these two rivers, its numerous tributaries and innumerable sub-tributaries. Their usual flow is from the north-west to south-east.

Kumey: The River *Kumey* or *Kamla* forms an important part of the drainage system of the district. It emerges from the confluence of a number of small rivers cascading down from the north-western snowy heights of the district. It flows from the north-west to the south-east, intersecting north-eastern part of the district. Before meeting the Subansiri of which it is the principal feeder, it receives its main tributary the *Kurung* River. The *Kumey* is also fed by a number of other tributaries, the important being the *Selu* and *Hema* on the north bank, the *Pein* and *Persin* on the south bank. From the point of its confluence with the *Kurung*, the *Kumey* flows almost in a west-east course. The Kumey valley is a difficult terrain particularly beyond Huri. The river rumbles through steep cliffs and ravines of high mountains. The middle and the lower *Kumey* valleys are fairly populated, while the population in the upper reaches is very sparse.

Kurung*:* The *Kurung* (Khru) river takes rise from the high mountains in the north-west of the district, where its headwater is formed by a number of rivulets called the *Wabia*, *Vangee*, *Viang, Vari, Vaphi* and *Phurchi*. It meets its tributaries the *Pannyu* and the *Palin* before it joins the *Kumey* River near the village of Balu. The *Kurung* is a turbulent river and like the *Kumey* it too cuts through precipitous gorges. No baseline data on vegetation of the district is available except few (Dash 2010, 2012). Major portion of the area in the state is still covered with primary forests. Several forest types and subtypes with characteristic floristic composition occur in the studied area. The Recorded Forest Area in the district is 4736 sq km which is 75.55% of its geographic area. The vegetation of the proposed sites can be classified as below

The details of forest types in the basin is based upon data collected from different time, herbarium studies at ARUN and State Forest Research Institute, Itanagar. The major forest types encountered in the area have been described on the basis of the major forest types of India and compared with classification of Champion and Seth (1968). The findings are reinforced with the information collected from literature[24].

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[24] *Panigrahi & Nayak, 1961; Kaul and Haridasan,1987; Negi, 1989, 1996; Chowdhery, 1996; Muddgal & Hajra, 1999; Rao 2007;Mao, 2010; Dash 2011, 2012*

Milli and Sape Sub-Basin over Kurung River

Subtropical evergreen forest {East Himalayan sub-tropical wet hill forest (8b/C1)}: This type of forest is seen in between in the vicinity of Sarlee and on way from Sarlee to Parlo, Parlo to Milli and Milli to the dam site. The forest is characterized by the by the dominance of the Oaks and Laurales, *Quercus and Castanopsis*. Some of the temperate genera *Alnus, Prunus, Betula* and *Schima* are very characteristic of this type of forest and found throughout the range and show a downward extension towards the tropical forest, are often seen in this type of forest. Pines are not found in this region and the whole region may be classified as an excellent association of *Engelhardtia-Cantonopsis-Schima-Betula.* The top storey in this forest mainly consisting of *Actinodaphne obovata, Aphanamixis polystachya, Cinnamomum bejolghota, Elaeocarpus varunua, Engelhardtia spicata, Stereospermum chelonoides, Castanopsis purpurella,Castanopsis lanceifolia, Castonopsis indica, Lithocarpus elegans, Lithocarpus fenestrata, Lithocarpus pasania, Quercus griffithii, Quercus lamellosa* etc. The middle storey consist of *Acer oblongum, Litsea monopetala, Macaranga denticulata, Phoebe attenuata, Terminalia bellirica, Trema orientalis Exbucklandia populnea*, *Heteropanax fragrans*, *Saurauia armata, Schima wallichii,* etc. The lower storey consist of *Acer laevigatum, Acer pectinatum, Aralia montana, Brassaiopsis glomerulata, Brassaiopsis griffithii, Eurya acuminata, Eurya nitida, Fissistigma ployanthum, Gamblea ciliata, Magnolia pterocarpa, Michelia doltsopa, Schisandra neglecta,* etc*.* The common shrubs of this zone are *Abroma augusta, Clerodendrum serrulatum, Dichroa febrifuga, Diflugossa colorata*, *Embelia floribunda*, *Hydrangea heteromalla, Hydrangea anomala, Leea asiatica, Maesa indica*, *Maesa* spp*., Morinda angustifolia, Myrsine semiserrata, Mussaenda roxburghii, Melastoma malabathricum*, *Medinella himalayana, Musa velutina, Mussaenda macrophylla, Mussaenda incana, Myrioneuron nutans, Osbeckia stellata, Phlogacanthus curviflorus, Polyura geminata, Psychotria calliocarpa, Sauropus trinervius, Styrax serrulatum, Vernonia volkameriaefolia,* etc. In the range in between, *Engelhardtia* is more conspicuous than the other species in the same altitudinal distribution.

The ground flora or undergrowth are densely covered by herbaceous plants such as *Anaphalis adnata, Begonia hatacoa*, *Begonia tassaricarpa*, *Begonia sikkimensis, Crotalaria khasiana*, *Chirita oblongifolia*, *Codariocalyx motorius, Desmodium laxiflorum, Gomphostemma lucidum*, *Hydrocotyle himalaica, Lidernia anagallis Lindernia ciliata, Lysimachia japonica*, *Pilea bracteosa, Sonerilla maculata, Tovora virginiana*. The monocot plants found are *Alpinia nigra, Amischotolype mollissima, Colocasia fallax*, *Commelina maculata, Commelina sikkimensis*, *Costus speciosus, Disporum contoniense, Globba multiflora, Gonatanthus pumilus, Hedychium coccineum*, *Hedychium ellipticum*, *Murdania nudiflora*, *Phrynium pubinerve, Pollia subumbellata,* etc.

Sub-tropical semi-evergreen forest: {Subtropical wet hill forests (8b/C2): This type of semi evergreen forests is found along the Wabia River and vicinity of Milli village. Large trees, rarely exceeding 20m height, with smooth bole is the interesting characteristic of this forest. The second story of forest is hardly distinguishable and the amount of shrubby undergrowth varies considerable with the density of the upper canopy. There is heavy growth of epiphytic mosses, ferns on the tree trunks. The upper canopy consist of *Lithocarpus elegans, Lithocarpus fenestrata, Lithocarpus pachyphylla, Quercus lamellosa, Quercus semicarpifolia, Engelhardtia spicata, Litsea chartacea, Litsea cubeba, Litsea hookeri, Litsea salicifolia* var. *salicifolia, Persia minutiflora, Symplocos cochinchinensis subsp. cochinchinensis, Symplocos oxyphylla* etc. The middle storey is dominated by trees like *Gynocardia odorata, Meliosma simplicifolia, Turpinia nepalensis, Lagerstroemia parviflora, Quercus lamellosa, Croton chlorocalyx,* and various species of *Ficus* etc. *Ardisia virens, Coffea khasiana, Debregeasia longifolia, Maesa indica, Saurauia armata,* etc are few common shrubs. Among the climbers and lianas *Argyreia argentea, Dioscorea alata, Gauania tilaefolia, Mastersia assamica, Thunbergia coccinea, Thunbergia grandiflora, etc* are common. Epiphytic species of *Dendrobium, Pholidota, Eria, Hoya* and several species of ferns also occur in these forests. The forests of this region are abundant with many climbers. The important climbers are *Ampelocissus divaricata, Apios cornea, Argyreia argentea, Cayratia pedata, Cissampelos pereira, Cissampelopsis volubilis, Combretum wallichii var griffithii, Dalbergia thomsonii, Erycibe paniculata, Entada rheedei, Hedyotis scandens, Hoya globulosa*, *Mastersia assamica*, *Paederia scandens, Thunbergia grandiflora*, *Thunbergia coccinea, Pothos cathcartii, Raphidophora grandis, Raphidophora hookeri Schefflera venulosa*, *Tinospora cordifolia*, etc.

Terminalia forest {Eastern Hoolock forest (3C/E1:1S/2a, b)}: This type of forest is seen along the Kumey River along the downstream from the Parlo. An irregular patch of forest in which *Terminalia myriocarpa* and *Lagerstroemia speciosa* usually predominates, are more or less deciduous with a predominantly evergreen underwood. The main associated trees found in this forest are *Ailanathus grandis, Aphanamixis polystachya, Bischofia javanica, Bombax ceiba, Canarium strictum, Dillenia pentagyna, Dysoxylum benectariferum, Elaeocarpus rugosus, Ficus* spp*., Gmelina arborea, Sterculia villosa, Terminalia bellirica, etc,* whereas the next storey is represented by the species of *Calamus. Ficus, Meliosma, Murraya, Randia, Villebrunea, etc.* These species are associated with dense clumps of *Phragmites, Saccharum, Hedychium* spp. etc. The epiphytic flora is rather insignificant as compared to the other forest.

Temperate broad leaved forest {East Himalayan wet temperate forest (11b/C1)}: This type of vegetations is generally found in the areas of higher elevation beyond Milli. The main catchment areas of the proposed project fall under this type of forest. The area around Milli, Gane along the tract upto the Vadse and Muphla within the range of altitude 2250 – 3000 m exhibit this type of vegetation. The apparent lax storied nature with dominance of *Fagaceae* and members of *Ericaceae* particularly the species of *Rhododendron* is the characteristic feature of this type. These are mostly temperate rain forests having dominant species forming top canopy by tall trees like *Acer caesium, A. pectinatum, Betula alnoides, Exbucklandia populnea*, *Quercus lamellosa, Q. glauca*, *Castanopsis tribuloides*, *Magnolia campbelli, Populus ciliata, Rhododendron arboreum*, etc.The middle storey is dominated by small to medium sized trees and shrubby species. Common species met with are *Lyonia ovalifolia*, *Corylopsis himalayana, Myrsine semiserrata, Berberis wallichii, Debregeasia longifolia, Vaccinium sprengelii, Acer pectinatum, Pyruspolycarpa, Prunus cerasoides, Spiraea arcuata, Symplocos rasimosum* and species of *Rhododendron.*The ground flora mainly consists of herbaceous species like *Anemone elongata, Sedum multicaule, Drymaria villosa, Potentilla peduncularis, Potentilla polyphylla, Fragaria nubicola, Cardamine elegantula, Oenanthe javanica, Rorippa indica, Stellaria sikkimensis, S. vestita*, etc. Some epiphytic species like *Agapetes obovata, Rhododendron* spp., *Vaccinium nummularia*, *V. venosum* and few orchids are usually met with.

Temperate coniferous forest {East Himalayan mixed coniferous forest (12/C3a}: This type occurs between 3000 – 4200 m in the areas like higher slopes towards Muphla and Vadse. In the lower slopes of Vadse and above having temperate broad leaved forests vegetation, experiences heavy rainfall during winter months. Lower limits of such forests are dominated by mixed coniferous type including *Abies densa* and show succession of forests association like *Tsuga dumosa, Taxux wallichiana.* Sometimes broad leaved species of *Rhododendron, Photina, Betula, Ilex* etc. are also seen associated with those conifers. It forms the dominant component for most of this type of vegetation in association with shrubby and bushy species of *Rhododendron, Juniperus, Berberis, Salix, Cotoneaster, Lonicera*, etc. This altitude also favours growth of herbaceous species of *Anemone, Aconitum, Cassiope, Primula denticulata, Primula capitata, Potentilla, Pedicularis, Meconopsis, Fritillaria, Corydalis,* etc. and often *Betula alnoides* and *Juniperus wallichiana.* In association with trees like *Quercus spicata, Prunus nepalensis, Rhododendron falconeri, R.barbatum,* *Magnolia campbelli, Taxus wallichiana, Illicium griffithii, Symplocos racemosa* and bamboos like *Arundinaria racemosa*. Common shrubs in this type of vegetation are *Gaultheria fragrantissima* and *Skimmia arborescens,* grows on northern slopes at a higher elevation in association with trees like *Rhododendron falconeri, R. barbatum, R. hodgsonii, Lyonia ovalifolia*, etc.with sporadic patches of hill bamboos like *Arundinaria aristata*. A continuous bamboo brake of *Schizostachyum* sp. is found on the slopes from Vadse facing towards the east.

Temperate scrub forest {East Himalayan sub-alpine forest (14/C2)}: These forests occupy in between altitude 3500-4500 m and generally lack tree species. Subalpine forests are characterized by tree species like *Abies densa, Cupressus torulosa, Juniperus recurva* and *Rhododendron* spp. The common shrubs are *Berberis asiatica, Berberis wallichiana, Eurya cacuminata, Gaultheria fragrantissima*, and *Vaccinium venosum, etc.* Epiphytic orchids are represented by *Pleione hookeriana* and *Bulbophyllum* spp and among the terrestrial *Gymnodaenia orchidis*, *Herminium longilobatum, Spathoglottis irioides* etc. are commonly associated with other herbaceous plants namely *Aconitum ferox*, *Aconitum novoluridum*, *Primula* spp., *Gentiana pedicellata, Ranunculus brotherusii* etc.

This zone remains covered with snow for the major part of the year. The vegetation is very scarce and comprises of shrubby Rhododendrons and herbaceous elements with spectacular variously coloured flowers of *Aconitum ferox, Aconitum heterophyllum, Meconopsis napaulensis, Arenaria* spp, *Gentiana spp., Primula sikkimensis, Bistorta vaccinifolium, Rheum nobile, etc.* which are common here*.*

Rhododendron scrubs {Birch–Rhododendron scrub forest 15/C1): These meadows dominated by a mat of very dwarf *Rhododendron* species rarely exceeding 0.5 m. occur between 4000-4500 m. This represents typical alpine moorland type of vegetation consisting of dwarfed association of hardy cushion with thick perennial deep root-stocked herbaceous species like *Rheum, Arenaria*, *Saussurea, Saxifraga, Sedum, Festuca, Anaphalis, Rumex, Bistorta, Fagopyrum, Juncus*, *Aster, Anemone*, etc. mixed with stunted crawling bushes of *Rhododendron anthopogon, R. setosum, Sassurea gossypiphora. Arenaria festucoides, Leontopodium himalayana* along with *Meconopsis horridula,* etc*.,* which are common.

Alpine forest {alpine pastures (15/C3): Percentage of this type of vegetation is very low and highest northern hill slopes of the show this type of vegetation. These are open rocky areas. The woody vegetation is very restricted and trees are absent. These regions are more humid and characterized by gregarious patches of *Primula colderiana, Rheum nobile* and species of *Saxifraga, Artemisia, Leontopodium* and dwarf Rhododendrons*.* Towards higher elevation the landscape is relatively drier and stony deserts are seen with litter of scree and rock encrustation with lichen and deep rooted plants like *Sedum,* etc*.* growing amongst the rocks.

Chomi and Chella over Kumey River

Dipetocarpus forest {Assam valley tropical wet evergreen forests (Dipterocarpus 1B/C1)}: On the south bank of Kurung River on the down stream between 400-900 m. of the proposed site this type forests is seen. This type of forest is characterized by a uniform species composition with high diversity. The most dominated species is *Dipterocarpus retusus* with *Shorea assamica*. The trees occupied in the top storey are mixture of evergreen and deciduous species with tall, luxuriant growth. The evergreen species are more dominant than the semi-evergreen. The species composition of this type vegetation is quite unique. The top storey mainly consisting of *Ailanthus integrifolia*, *Altingia excelsa, Artocarpus heterophyllus, Bridelia retusa, Chukrasia tabularis*, *Cinnamomum bejolghota, Elaeocarpus floribundus, Macaranga denticulata, Phobe goalparensis, Terminalia chebula*, *Terminalia* *myriocarpa*, *Trema orientialis.* The proportions of the semi-evergreen species are more than the evergreen species. The middle storey consist of *Albizia procera, Baccaurea ramiflora, Castanopsis indica*,*Careya arborea, Crateva magna*, *Dellina indica, Desmos longiflorus, Dysoxylum benectariferum*, *Garuga pinnata*, *Goniothalamus sesquipedalis*, *Gynocardia odorata, Heterpanax fragrans, Knema linifolia*, *Lagerstroemia parviflora* , *Mesua ferrea,* while the lower storey consists of *Erythropalum scandens, Debregeasia longifolia,Dendrocnide sinuata, Itea macrophylla, Millettia pachycarpa, Oreocnide integrifolia*, *Saurauia armata,Saurauia fasciculata*, *Schefflera wallichiana, Trevesia palmate.* The undergrowth is dense and consists of evergreen species namely *Abroma augusta, Amischotolype mollissima, Baliospermum calycinum, Medinella himalayana, Musa sikkimensis, Mussaenda macrophylla, Mussaenda incana, Myrioneuron nutans, Osbeckia stellata, Phlogacanthus curviflorus,Polyura geminata, Psychotria calocarpa, Sauropus trinervius, Diflugossa colorata etc.*

The ground flora is dominated by herbaceous plants such as *Aeschynanthus acuminate*, *Begonia hatacoa, Begonia palmatum, Chirita oblongifolia, Chirita uriticaefolia, Cryptolepis buchnanii, Desmodium gyroides*, *Desmodium laxum, Gomphostemma lucidum, Hydorcotyle himalaica, Lidernia anagallis*, *Lindernia ciliate, Lysimachia japonica, Perperomia tetraphylla, Pilea bracteosa, Tovora virginiana, Torenia thouarsii,* etc.

Tropical evergreen forests (Upper Assam valley tropical evergreen Forests (1b/C2): This canopy of forest is confined to upper reaches of hill ranges beginning from Challo, Parlo and Chelli and extending upto Zemu and Wabia region area. Within this kind of forest, a few deciduous elements are also found. This forest has luxuriant growth of tropical flora under warm and humid conditions. The chief components of the forests are *Terminalia myriocarpa, T. catappa, Altingia excelsa, Magnolia hodgsonii, Elaeocarpus sikkimensis, E. aristatus, Castanopsis armata, C. indica, Chisocheton cumingianus, Combretum wallichii, Anogeissus acuminata, Artocarpus heterophyllous, Ficus cyrtophylla, F. hirta, Actinodaphne obvovata, Cinnamomum bejolghota, C. glanduliferum, C. tamala* etc. The next lower storey is composed of trees of 10-20 m height. The common species of this layer are *Ficus semicordata, Sapium eugeniifolium, Sterculia hamiltonii, Pterospermum acerifolium, Schefflera venulosa, Brassaiopsis hispida, Vernonia talaumifolia, Solanum erianthum, Saurauia armata, Baccaurea sapida, Bischofia javanica, Callicarpa arborea, Macaranga, peltata, M. denticulata, Mallotus philippensis, Ostodes paniculata, Erythrina stricta, Litsea cubeba, Persea odoratisssima, Phobe goalparnesis, P. lanceolata, Morus macroura, Wendlandia puberula, W. wallichii, W. tinctoria* etc. The trees of the lowest storey are 5-10 m high. Some of them are *Premna barbata, Saurauia panduana, S. roxburghii, Vernonia volkameriaefolia, Trevesia palmata, Styrax serrulatum, S. hookerii, S. polyspermum, Actephila excelsa, Miliusa globosa, Friesoldielsia fornicata, Pinanga gracilis, Oreocnide integrifolia, O. frutescens* etc.

The lowest storey is of small trees with small shrubs inbetween. This layer is generally merged with the small trees. The important components of this layer are *Abroma augusta, Pandanus odoratissimus, Embelia ribes, Maesa indica, Mussaenda roxburghii, Elatostema platyphyllum, Boehmaria macrophylla, Melastoma malabathricum, Polygonum chinense, Clerodendrum bracteatum, C. serratum, C. griffithianum, C. colebrookianum, Phlogacanthus tubiflorus, Casearia vereca, Difflugossa colorata, Eurya acuminata, E. japonica, E. nitida, Neyraudia arundincea, Cyperus terrestris, Phrynium pubinerve, Alpinia malaccensis* etc.

The ground flora is predominantly composed of dense herbaceous species namely *Hydrocotyle javanica, Centella asiatica, Lobelia montana, Ageratum conyzoides, Spilanthes paniculata, Osbeckia nutans, Osbeckia stellata, Urena lobata, Sida rhombifolia, Triumfetta pilosa, Vernonia scandens, Mazus pumilus, Lindernia antipoda, L. ciliata, L. crustacea, Bidens biternata, Polygonum pubescence, P. hydropiper, Chirata pumila, Elatostema* *sikkimensis, E. rupestre. Pilea insolens, P. smilacifolia, Impatiens laevigata, I. porrecta, I. drepanophora, Begonia annulata. B. griffithiana, B. barbata, B. palmata, Ophiorrhiza rugosa, O. mungos, O. repens, Globba multiflora, Drymaria diandra, Achyropermum densiflorum, Mosla dianthera, Anisomeles indica, Calamintha gracilis, Eupatorium odoratum, Carex cruciata* etc.

The epiphytic flora is also considerably rich particularly in the occurrence of orchids. Amongst the most common orchids growing in the region are *Dendrobium nobile, D. hookerianum, Cymbidium aloifolium, Rhynchostylis retusa, Bulbophyllum odoratissimum, Vanda stangeana, Luisia zeylanica, Eria pannea.* Amongst the other epiphytes, mention may be made of *Aeschynanthes gracilis, A. acuminatus, Lysionotus serratus* etc.

Bamboo brakes {Cane brakes (1B/C3/E1)}: This type of forest is seen along the river and characterized by thick patches of bamboo forest mixed with tall trees. This type of forest is seen in the northern and eastern slopes around the village Zema and steep uncultivable slopes and rocky riverside. Climbers are more common in these forests. The main species composition of this forest is mixed type comprising *Ailanthus grandis, Echinocarpus, Michelia doltsopa, Quercus lamellosa, Tetrameles nudiflora, Dysoxylum hamiltonii, Altingia excels*a in the upper canopy; *Aphanamixis polystachya, Beilschmiedia, Gynocardia odorata, Sapium baccatum* in the middle canopy. The main species of bamboo that are encountered in this forest are *Dendrocalamus hamiltonii, Melocanna bambusoides, Bambusa balcooa, Bambusa pallida, Bambusa tulda, Schizostachyum polymorpha,* etc. The main climbers of this zone are *Entada phaseoloides, Acacia pinnata, Combretum flagracarpum, Mucuna nigricans, Vitis* spp, *Leea* spp., *Ampellocissus divaricata, Argyreia argentea, Cayratia pedata, Caesalpinia bonduc, Cissampelos pareira, Cissampelopsis volubilis, Dalbergia thomsonii, Erycibe paniculata, Hedyotis scandens, Hoya globulosa*, etc. Gregarious patches of *Calamus* spp. and sometimes the creeping bamboo *Neohouzeaua dullooa*; a few palms such as *Licuala* and *Zalacca* are also found in this type of forest. The dominant canes and palms are *Calamus palustris, C. tenuis, C. erectus, C. floribundus, C. flagellum, Areca triandra, Livistona jenkinsiana, Pinanga gracilis, Caryota urens, Wallichia densiflora, etc.*

Tropical semi evergreen forests {Assam valley semi evergreen forest (2B/C1)}: This type of forest is seen around the dam site and towards the village Zema. Almost all the entire area is dominated by this type of forest. The main characteristic of this forest is that trees occupied in the top storey are mixture of evergreen and deciduous species with tall, luxuriant growth. The evergreen species are dominant than the semi-evergreen. The top storey mainly consists of *Ailanthus integrifolia, Altingia excelsa, Aphanamixis polystachya, Artocarpus heterophyllus, Bridelia retusa, Cinnamomum bejolghota, Elaeocarpus floribundus, etc. Macaranga denticulata, Phoebe goalparensis, Terminalia bellirica, Terminalia chebula*, *Terminalia myriocarpa*, *Trema orientialis.* The proportions of the semi-evergreen species are more than the evergreen species. The middle storey consists of *Baccaurea ramiflora, Castanopsis indica*, *Careya arborea, Crateva magna, Dillenia indica, Desmos longiflorus, Dysoxylum benectariferum*, *Garuga pinnata*, *Goniothalamus sesquipedalis*, *Gynocardia odorata, Heteropanax fragrans, Knema linifolia*, *Lagerstroemia parviflora, Mesua ferrea,* while the lower storey consist of *Erythropalum scandens, Debregeasia longifolia, Dendrocnide sinuata, Itea macrophylla, Millettia pachycarpa, Oreocnide integrifolia*, *Saurauia armata, Saurauia fasciculata*, *Schefflera wallichiana, Trevesia palmata*. The undergrowth is dense and consist of evergreen species namey *Abroma augusta, Amischotolype mollissima, Baliospermum calycinum, Begonia hatacoa, Chirita uriticaefolia, Chloranthus elatior, Chasalia curviflora* etc. The most dominant shrubby species that are encountered in this region are *Medinella himalayana, Musa sikkimensis, Mussaenda macrophylla, Mussaenda incana, Myrioneuron nutans, Osbeckia stellata, Phlogacanthus curviflorus, Polyura geminata, Psychotria calocarpa, Sauropus trinervius, Diflugossa colorata, Typha angustifolia, etc.*

Moist deciduous forests {East Himalayan Moist mixed deciduous forests (3C/C3b)}: This type of forest includes the deciduous forests which occupy well drained soils on the terraces. The species composition is of mixed type. The ground vegetation in this type of forests is abundant and shrubby undergrowth is without grass. The main tree species found are *Careya arborea, Sterculia villosa, Bombax malabarica, Schima wallichii, Dillenia pentaphylla*, *Dysoxylum benctaricum* etc.

Terminalia forest {Eastern Hoolock forest (3C/E1:1S/2a,b)}: This type of forest is seen along the Kumey River along the downstream from the Parlo to Huri. The main associated trees encountered in this forest are *Ailanathus grandis, Bischofia javanica, Dillenia pentagyna, Dysoxylum binectariferum, Elaeocarpus rugosus, Ficus sps., Sterculia villosa, Terminalia bellerica etc,* whereas the next storey is represented by the species of *Calamus, Ficus, Meliosma, Murraya, Randia, Villebrunea, etc.* These species are associated with dense clumps of *Phragmites, Saccharum, Hedychium* spp. etc. The epiphytic flora is rather insignificant as compared to the other forest.

Temperate broad leaved forest {East Himalayan wet temperate forest (11b/C1)}: These types of vegetation are generally found in the areas of higher elevation beyond Zema. The main catchments area of the proposed project fall under this type of forest. The forest composition is similar to the forests composition of the Milli-Sape.

Temperate coniferous forest {East Himalayan mixed coniferous forest (12/C3a}: This type occurs between 3000 – 4200 m in the areas like higher slopes towards Zema and Lutinla.

Temperate scrub forest {East Himalayan sub-alpine forest (14/C2)}: These forests occupy in between altitude, 3500-4500 m and generally lack tree species.

Rhododendron scrubs {Birch –Rhododendron scrub forest 15/C1): The meadows are dominated by a mat of very dwarf *Rhododendron* species, rarely exceeding 0.5 m. and occur between 4000-4500 m.

Alpine forest {alpine pastures (15/C3): Percentage of this type of vegetation is very low and highest northern hill slopes of the show this type of vegetation. These are found in open rocky areas. The woody vegetation is very restricted and trees are absent.

Nyepin and Hiya over Payam River

Subtropical Evergreen forest {East Himalayan subtropical wet Hill forests (8b/C1)}: These forests are charecterized by the high and more dense trees species. The species composition of the primary vegetation is sub-tropical semi-evergreen mixed with moist deciduous elements. The forest is more or less having uniform species composition. The trees of the top storey are mixture of semi-evergreen and deciduous species with tall, luxuriant growth. The semi-evergreen species are more dominant than the deciduous elements. The vegetation along the Panyu River from Zero point to Hiya, attains a height of 50 m in top canopy, while the middle canopy is with medium sized trees of evergreen in nature. A shrubby undergrowth is found and grass is almost absent. The top canopy is dominated by a *Castanopsis-Schima-Engelhardtia* association, while the middle canopy is *Phoebe-Terminalia- Talauma*. The top canopy is dominated by *Actinodaphne obovata, Cinnamomum bejolghota, Castonopsis tribuloides, C. indica, Cinnamomum impressinervium, Elaeocarpus aristatus, Elaeocarpus lanceifolius, Engelhardtia spicata, Litsea monopetala, Macaranga denticulata, Phoebe attenuata, Schima wallichii, Terminalia crenulata, Trema orientalis,* while the middle canopy is dominated by *Archidendron monadelphum, Desmos longiflorus, Celastrus monospermus, Exbucklandia populnea,* *Glochidion assamicum, Glochidion hirsutum, Heteropanax fragrans, Ostodes paniculata, Lithocarpus spicata, Quercus fenestrata, Q. serrata, Phoebe attenuata*, *P. lanceolata*, *Saurauia punduana, Saurauia macrotricha, Schima wallichii,* species from *Brassaiopsis Macropanax, Cinnamomum, Litsea, Machilus, Syzygium* etc. The lower storey consist of *Capparis multiflora, Erythropalum scandens*, *Itea macrophylla, Millettia pachycarpa, Oreocnide frutescens*, *Oreocnide integrifolia*, *Saurauia armata, Saurauia fasciculata*, *Schefflera wallichiana, Trevesia palmata* and comparatively smaller species such as *Symplocus, Crataeva, Emblica, Psychotria, and Flacourtia* etc. The common shrubs of this zone are *Abroma augusta, Dicroa febrifuga*, *Strobilathus hamiltoniana*, *Embelia floribunda*, *Embelia ribes*, *Hydrangea anomala, Hydrangea heteromalla, Leea asiatica*, *Maesa* spp., *Morinda angustifolia, Mussaenda macrophylla*, *Mussaenda incana*, *Melastoma malabathricum*, *Musa velutina, Myrioneuron nutans, Osbeckia nepalensis*, *Osbeckia stellata, Pavetta indica*, *Phlogacanthus curviflorus, Polyura geminata, Psychotria calocarpa, Styrax serrulatum,* etc.

The forests of this region are abundant with many climbers. The important climbers are *Apios cornea, Ampelocissus divaricata, Aspidopterys glabriuscula, Argyreia argentea, Cissampelos Pereira, Combretum wallichii* var *flagocarpum, Crawfurdia speciosa, Dioscorea deltoidea, Dioscorea pentaphylla, Erycibe paniculata, Illigera khasiana, Mastersia assamica, Mikania micrantha, Paederia scandens, Rhaphidophora hookeri, Rhaphidophora glauca, Stephania glandulifera, Schefflera venulosa, Thunbergia grandiflora, Tinospora sinensis etc.*

The ground flora is dominated by herbaceous plants such as *Alpinia malaccensis, Alpinia nigra, Antenoron filiforme, Arundina graminifolia, Begonia griffithiana, Blumea densiflora, Boehmeria clidemioides, Capillipedium assimile, Carlemenia griffithii, Chirita oblongifolia, Colocasia affinis, Costus speciosus, Crassocephalum crepidioides, Deeringia amaranthoides, Desmodium caudatum, Desmodium podocarpum, Digitaria ciliaris, Globba multiflora, Gonatanthus pumilus, Hedychium stenopetalum, Ichnanthus pallens, Impatiens latiflora, Persicaria chinesis, Persicaria microcephala, Phrynium pubinerve, Pilea bracteosa, Pilea racemosa, Piper rhytidocarpum, Pouzolzia bennettiana, Scrophularia elatior, Smithia ciliata, Spilanthus paniculata, Triumfetta rhomboidea, Urena lobata, Vernonia cinerea, etc.*

Secondary Forest: The forest along the roadsides in between zero point to Hiya and Hiya to Nyapin is adversely affected due to various biotic and abiotic factors such as jhum cultivation, land slides and fires etc. The primary forest is destroyed completed and developed into secondary forests. The secondary forests of this region can be classified in to two categories (i) Degraded forests and (ii) Bamboo forests.

Degraded Forest: As compared to the original primary forest, these degraded forests have very low species diversity and are generally dominated by weedy shrubs and inferior quality of trees. Of the common trees the species of *Bauhinia variegata, Callicarpa arborea, Glochidion lanceolarium, Careya arborea, Mallotus, Lagerstroemia parviflora, Dillenia pentagyna, Miliusa velutina* are more prominent, whereas *Capparis, Clerodendrum, Croton, Eurya, Randia, Rubus, Viburnum* species are common shrubs associated with weeds like *Ageratum, Eupatorium, Mikania,* etc

In these forests, upper canopy, which exhibit only single strata are clearly perceptible in first look. The upper canopy of this type of forest comprise only one or two species of *Abroma augusta, Callicarpa arborea, Aralia armata, Grewia acuminata, Osbeckia nutans, Pseudodissochaeta assamica, Saurauia armata, Saurauia fasciculata, Saurauia macrotricha* etc. The other tree species which are found in the degraded secondary forest are *Albizia chinensis*, *Allophylus triphyllus*, *Aralia foliosa, Boehmeria penduliflora*, *Calicarpa rubella*, *Callicarpa macrophylla*, *Castanopsis indica, Cinnanomum pauciflorum, Cinnamomum* *impressinervius*; *Debregeasia longifolia, Dendrocnide sinuata, Ehretia acuminata, Ficus fistulata, Ficus subincisa, Glochidion hirsutum, Itea macrophylla, Lithocarpus elegans, Macaranga denticulata, Macaranga peltata, Meliosma simpicifolia, Micromelum integerrimum, Poikilospermum suaveolens, Saurauia fasciculata, Saurauia macrotricha, Schefflera venulosa* etc. The shrubs which are commonly found in the secondary forests were *Ardisia thyrsiflora, Artemisia nilagirica, Buddleja asiatica, Chloranthus elatior, Claoxylon khasianum, Girardinia diversifolia, Hedyotis scandens, Maesa indica Melastoma malabathricum, Mussaenda macrophylla, Oxyspora paniculata*, *Pavetta indica, Rubus ellipticus and Saurauia griffithii etc.* The herbaceous species form the first succession stage and among the pioneers are *Achyranthes aspera, Ageratum conyzoides, Antenoron filiforme, Arundinella bengalensis, Capillipedium assimile, Boehmeria clidemioides, Colocasia affinis, Commelina diffusa, Commelina maculata, Crassocephalum crepidioides, Cyperus iria, Desmodium gyroides, Desmodium laxiflorum, Elatostema rupestra, Eragrostis unioloides, Galinsoga parviflora, Gonatanthus pumilus, Gynura bicolor, Isachne globosa, Lindernia crustacea, Oplismenus composites, Persicaria hydropiper, Persicaria microcephala, Pilea bracteosa, Piper pedicellatum, Pogonantherum crinitum, Saccharum arundinaceum, Sida rhombifolia, Sonchus wightianus, Spermococe hispida, Spilanthus paniculata, Torenia asiatica, Triumfetta rhomboidea, Urena lobata, Vernonia cinerea, Youngia japonica,* etc.

Bamboo Forest: This type of secondary forest mostly occurs in the areas which were abandoned after "Jhum" cultivation. The main bamboo species found in this region are *Arundinaria racemosa Bambusa balcooa, B. nutans, B. pallida, B. tulda, Dendrocalamus strictus, D. hamiltonii, Bambusa khasiana, Bambusa vulgaris, Cephalostachyum latifolium, Chimonobambusa callosa, Dendrocalamus hamiltonii, D. giganteus, D. hookeri, Phyllostachys assamica, Schizostachyum arunachalensis, Schizostachyum fuchsianum, Schizostachyum polymorphum,* etc.

Kurang (I and II) HEP over Kurung River

The predominant vegetation generally met within this area is sub-tropical broadleaved forests, which is basically of evergreen type. The important tree species found in the area are *Terminalia myriocarpa (*Hollock), *Attingia excelsa (*Jutuli*), Michelia champaca (*Champa*), Duabanga grandiflora (*Khokan), *Amoora wallichi (*Amari*), Alianthus grandis (*Borpat*), Cederella toona, Cinnamomum tamala, Mangifera sylvatica, Vitis latifolia, Gnetum scandens, Derris secunda, etc.* Along the river banks and the riverine plains, the dominant species found are *Artocarpus chama, Bombax ceiba, Canarium strictum, Albizzia* sp., *Castanopsis* sp, etc. The epiphytic flora of this forest is mainly comprise a number of orchid species of *Bulbophyllum, Coelogyne, Dendrobium, Octochilus, Ritaia* and fern species of *Asplenium, Drymaria, Lepisorus and Pyrrosia,* etc.

Tropical semi-evergreen type of vegetation occurs along the foothills and river banks. The top canopy in this type generally consists of deciduous trees whereas the lower storeys are dominated by evergreen species and thick undergrowth of shrubs, climbers and lianas. The climax vegetation is disturbed in many places due to jhum cultivation and these areas are replaced by the secondary formation of various species of bamboo and *Musa* etc.

Lower Subansiri district

Lower Subansiri district is one of the districts of the Northeastern state of Arunachal Pradesh. Ziro is the headquarter of the district. The Lower Subansiri District ranks eight in population size and third in area among all the sixteen districts of Arunachal Pradesh. To the north of the Lower Subansiri district lays the Upper Subansiri district. To the south of the Lower Subansiri district lays Papum Pare district and Assam. To the east of the district lies west Siang and Upper Subansiri district and on the west lies East Kameng. The name Lower Subansiri district comes from the Subansiri River, a tributary of the Brahmaputra River, flowing through Raga circle of the district. The district was a part of the Lakhimpur district of Assam till 1914. By the Government of India Notification of 1914, the area covered by the district became a part of the Lakhimpur Frontier Tract of the Northeast Frontier Tract. In 1919 the tract was named as the Balipara Frontier Tract. In 1946 the district was carved out of the Balipara Frontier Tract as Subansiri area. In 1965 it was renamed as Subansiri district. In 1980 Subansiri district was divided into Upper Subansiri district and Lower Subansiri district. Papum Pare district was formed by the division of the Lower Subansiri district.

Climate: Winter lasts in the district from December to February. Winter months are accompanied by mist and fog. Monsoon starts from June and lasts till October. During monsoon the area is heavily clouded. July and August are the warmer months. Annual rainfall in the south is higher than in the north of the district. The average annual rainfall of Ziro was 934.88 cm during 2000. Humidity is high throughout the year. In the low high belt area of the district the climate condition is moderate.

Demography: According to 2011 India Census, Lower Subansiri district has a population of 83,030 as against 55, 726 in 2011. The sex ratio is 984. The average literacy rate is 74.35%. Indigenous and traditional customs are followed by the people of the district. The three main tribe of the district are Apatani, Nyishi, and Hill Miri Tribe

Topography: The topography of the area is mostly mountainous terrain. A greater part of the district falls within the higher mountain zone consisting of peaks and valleys. River Kamala which originates from China is one of the important rivers of the district.

Four Hydroelectric projects (HEPs) are proposed in Lower Subansiri District. The location of four proposed HEP's, coordinates and altitude is given in **Table 6.25**.

Table 6.25: Proposed HEP locations, coordinates and altitude in Lower Subansiri District

Sr. No.	Name of the project	Latitude			Longitude			Altitude (in meters)
		Deg.	Min	Sec	Deg.	Min	Sec	
1.	Tamen/Pararam	27	45	0	93	0	0	320
2.	Tago – I	27	28	0	93	48	0	480
3.	Subansiri Lower	27	33	15	94	15	30	112
4.	Subansiri Middle (Kamala HEP)	27	46	18	93	59	19	320

Lower Subansiri HEP (under Construction)

The vegetation of the submergence area is mostly semi-evergreen interspersed with deciduous components. Some areas near Damporijo had riverine vegetation. Except for the areas under riverine vegetation, most of the areas have secondary vegetation. Bamboos were also observed in few areas. The forests were mainly 'Open forests' having 10-40% forest *cover.* List of plant species with their family and local names found at the project affected area of Lower Subansiri Project is given in **Annexure 6.7**.

Three threatened plant species *viz. Heritiera acuminata* (a tree species), *Bambusa mastersii* (a bamboo species) and *Cyathea spinulosa* (a fern species) were found in the submergence area/construction site of the dam. One species of endangered plant, i.e. *Heritiera acuminata* and two rare species, i.e. *Bambusa mastersii* and *Cyathea spinulosa* have been reported in the project area. These species are observed in the nearby forests also, and only a very small proportion of the total forest area in the region is being acquired, hence, no major impacts are anticipated during the construction phase of Lower Subansiri project. It may be noted that these species are not listed in Red Data Book of Indian Plants (Vol 1-3.), BSI. However, these species are listed in EIA/EMP report of Lower Subansiri Project and Preservation plans and project cost was also suggested in the EIA/EMP report. [25]

NHPC has carried out Biodiversity study in the submergence area of Lower Subansiri HEP-Floral aspects to document and inventorise plants and microorganisms diversity from 13 areas in the submergence areas covering three seasons of the year. The objectives of the study were: isolation and identification of micro-organism including symbiotic ones, documentation of micro-faunal communities, to establish relationships amongst these species and recommendations and conservation strategies. Vegetation of the site is mostly tropical evergreen type but sub tropical deciduous and degraded forests were also found. About 417 species were recorded during one year study. 250 species belonged to dicots, 97 to monocots and 70 pteridophytes. Dominant species of different sites including orchids in the submergence area have been documented. Seasonal variation and phenological data of plants in the submergence area have also been recorded, Herbaceous plants were observed as having maximum seasonal variation. The study documented 69 Angiosperm families comprising 228 species and 18 Pteridophytic families comprising 37 species in the 13 study sites in the submergence area of Lower Subansiri Hydro Power Project as given in **Annexure 6.8**.

NHPC has also carried out Identification of Orchids in the submergence area of Subansiri Lower H.E. Project through State Forest Research Institute, Itanagar. The same was submitted to MoEF, Govt. of India in Dec'2009. The survey was carried out in the submergence area and orchid samples were collected. 8 areas were surveyed namely Dam site and nearby areas, confluence of Gayu nallah-Subansiri, Sipu Nallah-Subansiri River confluence, Sinkro Subansiri River confluence near Siberite village, Kamla River- Subansiri River confluence, Subansiri River near Mugli village and Near Dumporijo-Panimuri Village. Orchids in the submergence areas have been identified and frequency of their distribution recorded. Ecological habitats in the submergence area are Open sandy river banks, Moss covered hill slopes, Dry or moist shady forest floors and moss covered large and small areas. 82 species of Orchids belonging to 34 genera has been recorded. Out of 82 species, 74 species of 27 genera are ephiphytes, 7 species of 6 genera are autotrophic terrestrials and 1 species of 1 genus is saprophyte. *Bulbophyllum* is represented by 14 species followed by *Dendrobium* with 11 species and *Eria* with 8 species. List of 82 Orchid species identified from submergence area, frequency of their distribution in submergence area, status as per BSI/IUCN, and the location of their rehabilitation sites (Orchidaria at Tipi and Gerukamukh) for *ex situ* conservation[26] is given in **Annexure 6.9**.

As per IUCN, 9 plant species were categorised as rare, threatened, endangered, and critically rare. 41 economically important plants are recorded. Microbial diversity has also been documented. List of Rare, Endangered and Threatened Plant Species collected from different sites in the submergence areas of Lower Subansiri Hydro Power Project [27] is given in **Table 6.26**.

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[25] *Environment Impact Assessment and Environment Management Plan for Subansiri Lower Project, Arunachal Pradesh and Assam (2000 MW), NHPC/WAPCOS,Gurgaon*

[26] *Survey and Identification of Orchids upto species level in submergence areas of Subansiri Lower Hydroelectric Project and rehabilitation of Rare and Endangered Orchid species in Orchidaria of State Forest Research Institute and NHPC, Gerukamukh, 2009.*

[27] *Department of Botany, Gauhati University: Final report on Biodiversity study in the submergence area of Subansiri Lower HE Project-Floral Aspects. (Study done during January 2006-December 2007)*

Table 6.26: Rare, Endangered and Threatened Plant species collected from different sites in the submergence areas of Lower Subansiri Hydro Power Project

S. No.	Name of Plant Species	Status
1	*Anoectochilus sikkimensis*	R & E
2	*Aquilaria malaccensis*	CR
3	*Begonia aborensis**	T
4	*Begonia scintillans***	R
5	*Begonia tessaricarpa*** *	R
6	*Livistona jenkinsiana**** *	E
7	*Pholidota wattii******	R
8	*Tacca integrifolia*	R & E
9	*Vanda coerulea*******	R & T

R- Rare, E- Endangered, CR- Critically Rare, T- Threatened

An account of threatened species reported from submergence areas of Lower Subansiri HEP covering their distribution, altitude and conservation status is given below [28] [29] :

* ➔ *Begonia aborensis* is an Endemic species reported from Abor hills (Lohit and Dibang Valley district), Changlang, Dibang Valley, Lohit, Siang, Subansiri 400-1200 metres in more illuminated clearings. It grows on old overgrown clearings and extending just to the plains above Rotung at an altitude of 300 metres between Kebang and Dihong, The species is assessed as Rare.

** ➔ *Begonia scintillans* is an Endemic species reported from Abor Hills (Lohit and Dibang Valley district), Dibang Valley, Siang, Tirap at an altitude of 500-2000 m in Arunachal Pradesh. It is recorded from the mountain of Bapus, both on the south face and towards Wotung, between 1200-2000 m alititudes. The species has not been collected since 1912, although its distributional localities have been botanised. Cause of its rarity is not known and is assessed as Indeteminate.

*** ➔ *Begonia tessaricarpa* is apparently rare and not collected since 1862 in Assam (no specific location) and is Endemic. The area of its reported occurrence is not well botanised and is likely that some population may still be surviving. The species is assessed as Indeterminate. This species has been collected from Upper Subansiri District and Changlang District (Namdapha National Park), Arunachal Pradesh as well. It shows that this species is still surviving in a few pockets of Arunachal Pradesh. It is found growing in damp, rocky crevices in association with *Selaginella, Funaria, Polytrichum, Impatiens, Alocasia,* etc. It is in danger of extinction in the near future because of destruction of the habitat due to various biotic and abiotic factors.

**** ➔ *Livistona jenkinsiana* is an Endemic species to North East India and is also assessed as Endangered due to extensive deforestation and degradation. In Arunachal Pradesh, it is reported in moist forests upto 1000 metres from mountain valleys of Lohit and Tirap Districts. This palm is among the commonly met with palms in the forests of Arunachal Pradesh. However, the species has been assessed as Endangered.

***** ➔ *Pholidota watti* is an Endemic species to North-Eastern India. It is reported from Subansiri between 500-100 metres on moss covered trees associated with *Pholidota imbricata* in Arunachal Pradesh and North Cachar Hills, Assam. *Pholidota watti* is also assessed as a Rare species.

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[28] Botanical Survey of India, 1987-1990: Red Data Book of Indian Plants, Editors: M P Nayar and A R K Sastry, Volume 1-3.
[29] Botanical Survey of India: Materials for the Flora of Arunachal Pradesh, Edited by P K Hajra, D M Verma and G S Giri, Vol 1-3, 1996-2009.

****** ➔ *Vanda coerulea* is reported from Tirap between 1200-1500 metres on tree trunks in sub tropical evergreen forests of Arunachal Pradesh. It is also reported from Assam, Manipur, Meghalaya (Khasia Hills) and Nagaland in North East India in mixed pine forests on hills between 1300-2000 metres usually on *Quercus* spp. It is assessed as a Rare species.

Family Ericaceae is represented by 13 genera and c. 200 species in India and nine genera and 130 species in Arunachal Pradesh (Chowdhery et al. 2008[30]). 25 taxa belonging to Ericaceae Talley Valley Wildlife Sanctuary has been reported[31]. Most of the taxa of Ericaceae were found to occur between Pange (1800m) and Lebbya-Penggo Pass (2732m) under this wildlife sanctuary. The checklist of Taxa is given in **Annexure 6.10**.

Upper Subansiri District

The Upper Subansiri district derives its name from the Subansiri River which meanders through the entire length of the district. For a long period it was a part of then Subansiri district with headquarters at Ziro. The district was further bifurcated into two districts: Upper Subansiri and Lower Subansiri. Daporijo is the headquarters of Upper Subansiri district. Upper Subansiri district is a mountainous tract in Arunachal Pradesh which covers approximately between 7032 sq. km. of area, at latitude between 27.45"N and 28.13"N and longitude 93.13"E and 94.36"E. It is bounded Tibet in the north, West Siang in the east, West Siang and Lower Subansiri district in the south and Lower Subansiri district in the west. The MacMohan line border is China at north.

Climate: Temperature of the district headquarters varies from 10.50C in December to 35.80C in August. The rainfall varies from 1500mm to 2000mm. The district can be divided three broad zones.

I. The sub-tropical humid low altitude zone of Daporijo, Dumporijo and Baririjo.
II. Humid altitude zone of Puchigeko, Giba, Taliha and Siyum circle.
III. The high altitude zone of Nacho, Limeking and Taksing circle.

Demography: According to 2011 India Census, Upper Subansiri district has a population of 83, 448 (as against 55, 346 in 2001), the growth rate being 50.78% .The sex ratio is 998. The average literacy rate is 63.80 %. The population density is 12 persons per sq.km.

Eight Hydroelectric projects (HEPs) are proposed in Upper Subansiri District. The location of eight proposed HEPs, coordinates and altitude is given in **Table 6.27**.

Table 6.27: Proposed HEP locations, coordinates and altitude in Upper Subansiri district

Sr. No.	Name of the project	Latitude			Longitude			Altitude
		Deg.	Min	Sec	Deg.	Min	Sec	(in meters)
1	Oju -I	28	25	34	93	21	34	---
2	Oju -II	28	23	18	93	26	5	---
3	Niare	28	21	42	93	30	17	---
4	Naba	28	22	25	93	34	12	---
5	Subansiri Upper	27	50	46	94	16	48	---
6	Nalo	28	24	26.68	93	49	53.71	630

30 Chowdhery, H.J., G.S. Giri, G.D. Pal, A. Pramanik & S.K. Das (2008). Ericaceae, pp. 57–99. In: Giri, G.S., A. Pramanik & H.J. Chowdhery (eds.). Materials for the Flora of Arunachal Pradesh 2 (Asteraceae: Ceratophyllaceae). Botanical Survey of India, Kolkata.

31 Subhasis Panda & M. Sanjappa: Checklist of Ericaceae of Talle Wildlife Sanctuary in Lower Subansiri District of Arunachal Pradesh, India, Journal of Threatened Taxa | www.threatenedtaxa.org | January 2012 | 4(1): 2322–2327

Sr. No.	Name of the project	Latitude			Longitude			Altitude
		Deg.	Min	Sec	Deg.	Min	Sec	(in meters)
7	Dengser	29	0	51.54	93	55	0	560
8	Tammu	27	58	0	94	25	0	200

The area covering the four proposed projects from Naba to Oju I (namely Naba, Niare, Oju II and Oju I) possess a difficult terrain with rugged hills, dense forest-cover, intersected by a number of hilly streams and with a gradual altitudinal variation. The vast catchment area of the proposed projects possess mainly subtropical forest with patches of lower temperate forest towards the area in Oju 1 project site with comparatively higher altitude position. But the area of actual of submergence covers mostly sub tropical forests with a considerable diverse composition. Forest types under Daporijo Forest Division (within which these projects are located) and flora of the project area is described below:

Forest Type

The forest under Daporijo Forest Division is located in a zone of high rainfall, short dry season and relatively high average humidity. They are evergreen in nature and comprise large number of tree species, occurring in varying proportions at different locations. The main of these forests is the heterogeneous mixture of species, a clear description of which is difficult. Structurally these forests cannot be clearly differentiated into distinct storeys. However, at place especially in hills two storeys can be identified depending upon species composition. In general, the top storey is rather open composed of mixture of evergreen, semi-evergreen and deciduous species. Pure patches of bamboos are very common and are scattered all over the area.

As per Champion and Seth's revised classification of forest types of India, the forests under this division can be group into following forest types. [32]

1. 2B/C1 (b): Eastern Sub-Montane Semi-Evergreen Forests.
2. 2B/C1/1S1: Sub-Himalayan High Alluvial Semi-Evergreen Forests.
3. 2B/2S1: Secondary Moist Bamboo Brakes.
4. 13/C6: Eastern Himalayan Dry Temperate Coniferous Forests (at higher altitudes near Taksing)

General Description of Forest Types

Eastern Sub-Montane Semi-Evergreen Forests - 2B/C1 (b)

This type of forests is generally found in the Sub- Himalayan Tract and lower slopes of the hills in various reserve Forests of the division. Makrisal *(Schima wallichii),* Hinguri *(Castanopsis indica),* and Hollock *(Terminalia myriocarpa)* are dominant in this type of forest. The floristic composition in given below:-

Top Storey: Makrisal (*Schima wallichii*), Hollock *(Terminalia myriocarpa),* Hinguri *(Castanopsis indica)*, Jetuli (*Altingia excelsa),* Dhuna *(Canarium resiniferum),* Poma *(Toona ciliata* syn. *Cedrela toona),* Sopa (*Magnolia spp*), Hatipoila (*Pterospermum acerifolium*), Borpat (*Ailanthus grandis*), Siris (*Albizia procera*), etc
Middle Storey: Banderdima (*Dysoxylum procerum*), Jamun (*Syzygium cumini*), Pichda (*Kydia calycina*), Selleng (*Sapium baccatum*), Paroli (*Pterospermum chelonoides*), Gahori sopa (*Flaceocarpus aristatus*).

[32] Champion H.G. & S.K. Seth (1968). A Revised Survey of the Forest Types of India. The Manager of Publications. Government of India, New Delhi, 404pp.

Lower Storey: Baramthuri (*Talauma hodgsonii*), Poreng (*Olea dioica*), Morhal (*Vatica laceaefroia*), Tejpat (*Cinnamomum tamala*), Thekera (*Garcinia species*), Morolia (*Mallotus tetracoccus= M. albus*), etc.
Ground Flora: Kaupat (*Phrynium imbricatum*), Ban posala (*Saraufa punduana*), Kolgoch (*Musa species*), Tora tenga (*Citrus* sp.), Bogitora (*Alpinia malaccensis*), Bihlougoni (*Pteris quadriaurita*), Bhat (*Clerodendrum viscosum = C. infortunatum*) etc.
Bamboo: Kako bans (*Dendrocalamus hamiltonii*) and Bijuli bans (*Bambusa pallida*).
Cane: Lejai bet (*Calamus floribundus*), Jati bet (*Calamus tenuis*).
Palm: Toko Palm (*Livistona jenkinsiana*).
Climber: Kuchai (*Acacia pinnata*), Panilata (*Vitis planicaulis*), Ghila lata (*Bauhinia vahlii*), Gowalia lata (*Vitis latifolia*), Dhekia lata (*Dioscorea indica*) etc.

Sub-Himalayan light alluvial semi-evergreen forests 2B/C1/1S1

This type of forest is found in the zone of Higher Himalayas in the division. Under this type of forests, evergreen species are dominant though deciduous species also present in significant proportion and the forest is mixture of evergreen and deciduous species with abundantly shrubby under growth. Hollock (*Terminalia myriocarpa)* and Jetuli (*Altingia excelsa*) are common/dominant species in this type of forest. The floristic composition is given below:-

Top Storey: Hollock (*Terminalia myriocarpa*), Jetuli (*Altingia excelsa*), Bonsum (*Phoebe goalparensis)*, Sopa (*Magnolia* sp.*)*, Hingori (*Castanopsis indica*), Dhuna (*Canarium strictum = C. resiniferum*), Poma (*Toona ciliata* syn *Cedrela toona*), Mekahi (*Phoebe cooperiana*), Amari (*Amoora wallichii*), Bohera (*Terminalia bellirica*), Khokam (*Duabanga grandiflora*).
Middle Storey: Jamun (*Syzygium cumini*), Nahar (*Mesua ferrea*), Banderdima (*Dysoxylum procerum*), Sam (*Artocarpus chaplasa*), Pichola (*Kydia glabrescens*), Moj (*Albizia lucida*), Sia Nahar (*Kayea assamica*), Selleng (*Apium baccatum*) etc.
Lower Storey: Bual (*Ethretia acuminata*), Boromthuri (*Talauma hodgsonii),* Gahori Sopa (*Magnolia griffithii*), Bonam (*Mangifera sylvatica*), Surat (*Laportea crenulata*) etc.
Ground Flora: Hati bhekuri (*Solanum subtruncatum*), Banposala (*Sarauria punduana),* Kaupat (*Phrynium imbricatum*), Tora (*Alpinia allughas*), Bhat (*Clerodendrum viscosum*), Kolgoch (*Musa species*), Bogitora (*Alpinia malaccensis*).
Bamboo: Kako bans (*Dendrocalamus hamiltonii*) and Bojal bans (*Pseudostachyum poly-morphum*).
Cane: Lejai bet (*Calamus floribundus*), Raidang bet (*Calanis flagellum*)
Palm: Toko Palm (*Livistona jenkinsiana*), Jeng (*Calamus erectus*).
Climber: Ghila lata (*Entada scandens*), Pani lata (*Vitis planicaulis*), Kuchai (*Acacia pinnata*), Gowalia lata (*Vitis latifolia*), Dimorulata (*Ficus scandens*), Mermeri lata (*Gnetum scandens*) etc.

Secondary Moist Bamboo Brakes 2B/2S1

Secondary Moist Bamboo Brakes occur in scattered patches throughout all tropical Semi-Evergreen forest in the carious Reserve Forest of the Division. When bamboo brakes have overhead trees, they form thinner clump. Where bamboo patches are pure, the clumps are thick and there is no possibility of regeneration of any other tree species in these bamboo patches. At places, shrubby and grassy under growth is found. The bamboo species found in the forest are given below:

Ako bans- *Dendrocalamus hamiltonii*
Ijuli bans- *Bambusa pallida*
Bojal bans- *Pseudostachyum poly-morphum*
Bambusa tulda

Chimonobambusa callosa
Cephalostachyum capitatum
Dendrocalamus giganteus
Neohouzeauahelferi

Eastern Himalayan Dry Temperate Coniferous Forest 13/C6

This forest type is characterized by the predominance of conifers, the principal species being Blue Pine (*Pinus wallichiana*). The pure crop of tall and elegant blue pine in various stages of growth is more or less open in nature, which has undergrowth of broad leaved associates along with grasses typical of conifer forest. The top middle storey are composed of only blue pine, whereas, the lower storey and ground vegetation are typical coniferous associates. The floristic composition is given below:-
Top Storey: Blue pine *(Pinus wallichiana)*
Middle Storey: Blue pine *(Pinus wallichiana)*
Lower Storey: Oak, Rhododendrons
Ground Cover: Jetelu Poka *(Rubus ellipticus),* Berbery *(Berberis asiatica), Imperata cylindrica* etc.
This forest type is found on the northern boundary of the division near Taksing where there is enough snow falls during the winter season.

Orchids

Valuable orchids are found in the Reserve Forest of the division which need preservation as well as protection of avoid extinction of these species within a short span of time. Some of the endangered orchids e.g. *Coelogyne barbata, Galeola falconeri, Paphiopedilum fairrieanum* etc. are also found in the forests of the area.

Some of the important species are *Acampe papillosa, Acanthephippium sylhetense, Beirmannia bimaculata, Bulbophyllum capillipes, Calanthe clavata, Ceratostylis teres, Cleisocentron recemferum, Dendrobium acinaciforme, Eria acervata, Geodorum purpureum, Liparis duthiei, Malaxis latifolia, Oberonia maxima, Papilionanthe teres, Vanda coerulescens, etc.*

Vegetation and floristic components as observed in the proposed projects are as follows.

Oju I HEP
In this project area, towards the upper basin of the river, the upper mountain slopes above the valley exhibit lower temperate vegetation type. The top storey comprises of tall tree species of *Quercus lamellosa, Acer hookeri, Acer oblonga, Betula alnoides, Magnolia campbellii, Populus ciliata,* etc. The middle storey is dominated by *Lyonia ovalifolia, Corylopsis himalayana, Myrsine semiserrata, Berberis wallichii, Caryopteris odorata, Vaccinium sprengelii,* etc. The ground flora mainly consist of herbaceous species belonging to genus *Begonia, Corydalis, Sedum, Drymaria,Polygonum, Potentilla, Fragaria, Pilea,* etc. Climbers and twiners like *Clematis sp*. and *Holboellia latifolia* are occasionally seen in such forests.

Oju II HEP
The subtropical forest type of this area is rich in floristic diversity and dominated by a number of evergreen tree species. Top storey comprises of species of tall trees like *Alnus nepalensis, Dichroa febrifuga, Engelhardtia spicata, Magnolia pterocarpa, Prunus nepalensis, Ulmus lancifolium etc.* Middle storey comprises of' species like *Capparis multiflora, Lepisanthes senegalensis* with *Oxyspora* sp*. Symplocos* sp. *Ardisia* sp*. Luculia* sp. The common climbers met with in the area are *Holboellia latifolia, Tinospora sinensis,*

etc. The ground flora comprises of' bushy shrubs and herbs like *Rosa indica, Tephrosia candida, Viburnum foetidum. Begonia* sp*. Impatiens* spp*. Oxalis* sp. *Campanula* sp., etc.

Niare HEP
The dense forest cover of the area is of sub-tropical type dominated by tall evergreen trees. Top storey comprises of the species like *Actinodaphne obovata, Beilschmiedia roxburghiana, Bythneria grandiflora, Callicarpa arborea, Sterculia hamiltonii.* Middle storey comprises of species like *Lepisanthes senegalensis, Hydrangea sp., Turpinia sp.*, in association with *Artimisia indica*, *Berberis wallichiana*, *Camellia caudata*, *Cassia mimosoides, Drymaria diandra*, etc. The common climbers met with in the area are *Clematis acuminata, Naravelia* sp., *Jasminum* sp*.,* with stragglers like *Actinidia callosa, Argyreia wallichii, Clerodendrum sp*., etc. The ground flora comprises of the bushy shrubs and herbs like *Sophora acuminata, Tephrosia candida, Vernonia seligna.*

Naba HEP
The predominant vegetation is sub-tropical type and is basically dense and evergreen in nature. Top storey comprises of the species of tall trees like *Acer oblongum, Kydia calycina, Castanopsis indica, Saurauia punduana, Schima wallichii.* Middle storey comprises of species like *Capparis multiflora, Photinia integrifolia* in association with species like *Eurya acuminata, Myrsine semiserrata, Camellia caudata*, etc. The common climbers met within the area are *Clematis acuminata*, *Holboellia latifolia, Tinospora sinensis*, etc. The ground flora comprises of the bushy shrubs and herbs like *Cassia mimosoides, Dianella ensifolia, Drymaria diandra, Plectranthus griffithii, Rosa indica, Solanum erianthum,* etc.

Nalo HEP
The forest are composed of a large number of evergreen as well as deciduous species like Hollock *(Terminalia myriocarpa),* Jetuli *(Altingia excelsa),* Amari *(Amoora wallichii),* Tita Sopa *(Mechelia champaca),* Gonsoroi *(Cinnamomum cecieodaphanie),* Makrisal *(Schima wallichii),* Bogipoma *(Chukrasia tabularis),* Khokam *(Duabanga grandiflora),* Hillika *(Terminalia chebula),* Dhuna *(Canarium resiniferum),* Bahera *(Terminalia bellerica),* Borpat *(Ailanthus grandis),* Simul *(Bombax ceiba),* Nahar *(Mesua ferrea),* Urium *(Bischofia javanica),* Moj *(Albizia lucida),* Udal *(Sterculia villosa),* Siris *(Albizia procera),* Sam *(Artocarpus chaplasha),* etc. in the Semi-Evergreen forest. The proportions of evergreen species are more than that of the deciduous species mainly due to favourable climatic conditions in the area. The middle storey in these forests is mainly composed of evergreen species like Nahar *(Mesua ferrea),* Hinguri *(Castanopsis indica),* Urium *(Bischofia javanica),* Selleng *(Sapium baccatum),* etc. with a little mixture of deciduous species like Paroli *(Stereospermum chelonoides),* Pichola *(Kydia calycina)* etc.

Dengser HEP
The predominant vegetation is sub-tropical type and is basically dense and evergreen in nature. The floristic components observed in the area dominated by tall trees like *Oblongum, Actinodaphne obovata, Alnus nepalnensis, Beilschemiedia roxburghiana, Bytineria grandiflora, Callicarpa arborea, Castanopsis indica, Dichroa febrifuga, Kydia calycina, magnolia pterocarpa, Sauraria punduana, Schima wallichii, Sterculia hamiltonii*, etc. The next storey is composed of small trees like *Lepisanthes senegalensis, Capparis muliflora, Photinia integrifolia.* etc. Third storey is comprised of small trees and shrubs like *Eurya acuminata, Myrsina semiserrata, Camellia candata,* etc. Common climbers generally occurring in the area are *Clematis acuminata, Holboelia latifolia, Tinospora sinensis,* etc.

The ground flora formed by the dense growth of shrubs and herbs is represented by *Cassia mimosoides, Drymaria diandra, Mahonia acanthifolia, Plectranthus griffithii, Solanum erianthum, Sophora acuminata, Tephrosia candida, Vernonia saligna, Viburnum foetidum, Begonia picta, Oxalis corniculata, O. corymbosa, Impatiens* spp*. Lobelia* spp., etc. These forests shows good diversity of epiphytic flora including a variety of ferns and a number of Orchid species of *Cymbidium*, *Bulbophyllum*, *Dendrobium*, *Oberonia* etc.

Upper Subansiri HEP

Following forest types and sub types comprises the project area:

Tropical Semievergreen Forests (Sub Group 2B 'Northern Tropical Semievergreen Forests)

This type of forests occurs along foot hills and river banks of the project area. Upper storey of these forests consists of deciduous and evergreen trees. Depending on its species contents these forest further divided into following subtypes:

Low Hills and Plains Semi evergreen Forests (2B/C1a)

These forests are seen in the heavy rainfall tract of Lesser Himalayan region where the soil is usually light and alluvial. Such types of forest occur near downstream of dam site area between Daporijo and Menga village. In such forest the upper storey is dominated by tall trees like *Terminalia myriocarpa*, *Ailanthus integrifolia*, *Castanopsis indica*, *Michelia* sp., *Phoebe* sp., *Pterospermum acerifolium*, *Altingia excelsa*, *Bombax ceiba* and *Syzygium cumini,* etc. Middle storey is represented by trees like *Albizia* sp. Understory is represented by bambooes, canes, *Musa* sp, along many shrubs and climbers. Shrubs in these forests are represented by *Boehmeria macrophylla*, *Calamus* sp., *Oxyspora paniculata*, *Solanum* sp. etc. Among the climbers and lianas *Disocorea alata* and *Tinospora cordifolia* are very common. Some of the common epiphytic ferns, the species of *Asplenium, Colysis*, and *Nephrolepis* etc. are also accounted. The forest floor which are disturbed at many places create gaps and covered with herbs and grasses like *Ageratum conyzoides*, *Bidens bipinnata*, *Commelina benghalensis*, *Kyllingia* sp., *Oxalis corniculata,* etc.

2B/C1b Eastern Sub Montane Semi Evergreen Forests

This type of forest is associated with a heavy rainfall of even upto 5,000mm and well drained slopes with a predominating evergreen species in the top canopy. These types of forests generally found in the sub - Himalayan tract and lower catchment of the study area covered various reserve forests. Such forests have a mixture of the wet evergreen trees and moist deciduous trees. The forest is dense and is filled with a large variety of trees of both types. Top canopy of this type of forests comprises with *Schima wallichii*, *Terminalia myriocarpa*, *Castanopsis indica*, *Altingia excelsa*, *Canarium resiniferum*, *Alianthus grandis* and *Albizia* sp. Middle canopy of these type forests bears *Kydia calycina*, *Dysoxylum procerum*, *Sapium baccatum* and *Flaceocarpus aristatus*. *Talauma hodgsonii*, *Olea dioca* and *Mallotus* sp. present dominantly in the lower storey. Ground flora of this type of forest comprises with *Musa* sp., *Saraufa punduana* and *Alpinia molluccensis*. Kako Bans (*Dendrocalamus hamiltoni*) and Bijuli Bans (*Bambusa pallida*) are the dominant Bamboo species along cane species like *Calamus floribundus* and *Calamus tenuis*. The popular house plant Toko Palm (*Livistona jenkinsiana*) is also associated with these types of forests. Besides above species a variety of climbers also encounter in which *Acacia pinnata*, *Vitis panicularis*, *Vitis latifolia* and *Dioscorea indica* are very common. A luxuriant growth of ferns has also seen on the forest floor.

Sub Himalayan High alluvial Semi Evergreen Forests (2B/C1/1S1)

This type of forests encountered at middle catchment of proposed hydro-electric project. Evergreen species are dominant in these types of forests though deciduous species are also present in a good proportion. Middle storey of these forests is rather prominent with abundantly shrubby under growth. The top canopy of these forests dominated with *Terminalia myriocarpa*, *Altingia excelsa*, *Phoebe goalparensis*, *Magnolia* sp., *Castonopsis indica*, *Canarium strictum*, *Terminalia bellirica* and *Duabanga grandiflora*. *Musa* sp., *Syzygium cumini*, *Dysoxylum procerum* and *Albizia* sp. dominated in the middle storey whereas lower storey of these forests accounted with *Ehretia acuminata*, *Talauma hodgsonii*, *Magnolia grifithii* and *Mangifera sylvatica.* Forest floor is well covered with *Spilanthes paniculata*, *Solanum* sp., *Saurauia punduana*, *Alpinia allughas*, and *Musa* sp. Kako Bans (*Dendrocalamus hamiltoni*) is the major bamboo species whereas Lejai bet (*Calamus floribundus*), Raidang bet (*Calamus flagellum*) and Jeng (*Calamus erectus*) dominated among canes. Tako palm (*Livistonia jenkinsiana*) present in good account all around the forest area. Climber of Ghilla lata (*Entada scandens*), Pani lata (*Vitis latifolia*), Dimrulta (*Ficus scandens*) are frequently found.

Eastern Himalayan Dry Temperate Coniferous Forests

These types of forests are found in the upper catchment of study area and are characterized by the predominance of conifer species. This type of forest area could not be sampled due to tough topographic and harsh climatic conditions. The forests comprise with principal species Blue pine (*Pinus wallichiana*). The pure crop of tall and elegant blue pine in various stages of growth is more or less open in nature, which has undergrowth of broadleaved associates along with grasses typical of conifer forest. Both the top canopies (Top and middle) of the forest dominated with Blue pine (*Pinus wallichiana*) whereas the lower storey and ground vegetation composed with typical coniferous associates. This type of forest found near Taksing area where there is enough snowfall during winters.

Secondary Forests

Primary forests are the subject of some adverse biotic and abiotic factors in the study area in which shifting cultivation or '*jhum*' cultivation, development activities and urbanization, landslides, fires, etc., are common. These activities forced the forest area into lesser valuable secondary forests.

Shifting (*jhum*) cultivation is very popular all over north-eastern India and it is also being practiced along the slopes in the valleys of the study area. It is an agricultural system in which plots of land are cultivated temporarily, and then abandoned. This system often involves clearing of a piece of land followed by several years of wood harvesting or farming, until the soil loses fertility. Once the land becomes inadequate for crop production, it is left to be reclaimed by natural vegetation, or sometimes converted to a different long-term cyclical farming practice. The ecological consequences are often deleterious, but can be partially mitigated if new forests are not invaded. Of these cultivators, very few use a practice of slash and burn as one element of their farming cycle. Most of them employ land clearing without any burning, and some cultivators are purely migratory and do not use any cyclical method on a given plot. Sometimes no slashing at all is needed where re-growth is purely of grasses, an outcome not uncommon when soils are near exhaustion and need to lie fallow. The land considered fallow due to steepness of the slope or porosity of the soil is now put to use because of population pressure. It is responsible for reduction in the area of the rain forests and is causing immense damage to the forests. These areas are generally covered with bamboos, canes, grasses and different species of climbers and epiphytes. The composition of the crop in such areas primarily depends on the condition of the soil and its drainage.

The secondary forests divided into the following types.

Moist Bamboo brakes (2B/2S1) and Musa Forest

Secondary moist bamboo brakes are present all over the study area but predominant around the lower catchment including all project zones i.e. submergence and other area of the project. It mostly present throughout all the Tropical semi-evergreen forests in the various reserve forests of the study area. It is commonly seen that wherever the tree density is good, thinner clump of bamboo are seen but in most of the cases bamboo brakes are found in scattered form with thicker clump having the potential to check the regeneration of co-species. Shrubby and grassy vegetation is associated with these bamboo brakes. Most dominant bamboo species found in the forests are *Dendrocalamus hamiltoni*, *Bambusa pallida* and *Bambusa tulda*. Most of the *Musa* species encountered in these forests are *Musa acuminata, M. balbisiana and M. rosacea*. These patches associated with moist evergreen forests strengthened exclusive ground floral growth.

Degraded Forests

A scattered series of this type of forest patches present in the vicinity of inhabited areas. As compared to the original primary forest these degraded ones have very low species diversity and generally dominated by shrubs and small trees. *Bauhinia, Bombax ceiba, Cedrela toona* species are more prominent where as *Clerodendrum, Randia, Opuntia, Solanum* species are common shrubs along weed species like *Ageratum* and *Euphorbia* species.

Grasslands

Abandoned *jhum* land, occasional fire areas, overgrazed land and sun facing hill top are the chief constituents of grassland in the study area. The clear felled forest patches in the study area are the subject of early phase of secondary succession where ferns, herbs, lianas and very few young seedlings (pioneer species) are seen rapidly colonizing. This early stage of succession may influence the later stages of vegetation development, which in their turn determine the character of the secondary forest and the recovery of the original biodiversity. Common grass species found in these grasslands are *Cynodon dactylon, Erianthus* sp*., Saccharum* sp*., Thysanolaena maxima, Chrysopogon aciculatus*, *Imperata* sp. etc.

6.10 Community Structure

Primary Floristic Study

Objectives

The primary floristic study has been carried out as per the ToR covering following objectives:

- To make an inventory/checklist of plants including Angiosperms, Gymnosperms, Pteridophytes, Bryophytes, Lichens and Macro Fungi found in the study area.
- Frequency, Abundance and density of each species of Tree, Shrub and Herb at representative sampling sites.
- Determination of Importance Value Index (IVI) and Shannon Wiener Diversity Index of trees, shrubs and herbs in the study area.

Methodology

Sampling Sites

Plant sampling was carried out in three seasons in 35 locations covering 10 HEPs. The sampling locations and their coordinates are given in **Table 6.28**.

Table 6.28: Plant sampling locations in Subansiri Basin

Sr. no.	Sampling Site	Degree	Min	Sec	Lat	Degree	Min	Sec	Long
1.	Tago-S1	27	27	25.25	27.4570	93	48	4.31	93.8012
2.	Tago-S2	27	27	26.74	27.4574	93	48	19.44	93.8054
3.	Tago-S3	27	28	8.88	27.4691	93	48	26.46	93.8074
4.	Tago-S4	27	27	54.91	27.4653	93	49	7.66	93.8188
5.	Nyepin-S1	27	44	27.93	27.7411	93	22	53.7	93.3816
6.	Nyepin -S2	27	43	57.5	27.7326	93	22	34.42	93.3762
7.	Nyepin S3	27	45	21.18	27.7559	93	23	0.07	93.3834
8.	Nyepin -S4	27	44	50.79	27.7474	93	22	55.31	93.3820
9.	Hiya-S1	27	45	57.05	27.7658	93	27	53.78	93.4649
10.	Hiya-S2	27	45	46.61	27.7629	93	27	15.18	93.4542
11.	Hiya-S3	27	45	19.51	27.7554	93	26	51.69	93.4477
12.	Dengser-S1	28	23	47.73	28.3966	93	52	43.16	93.8787
13.	Dengser-S2	28	24	51.09	28.4142	93	50	34.92	93.8430
14.	Dengser-S3	28	22	3.92	28.3678	93	51	33.48	93.8593
15.	Subansiri U-S1	28	4	7.02	28.0686	94	10	58.96	94.1830
16.	Subansiri U-S2	28	7	0.66	28.1169	94	8	39.37	94.1443
17.	Subansiri U-S3	28	7	40.95	28.1280	94	8	52.12	94.1478
18.	Subansiri U-S4	28	8	14.62	28.1374	94	8	56.43	94.1490
19.	Subansiri L-S1	27	32	54.83	27.5486	94	15	37.51	94.2604
20.	Subansiri L-S2	27	32	41.3	27.5448	94	15	17.3	94.2548
21.	Subansiri L-S3	27	33	33.26	27.5592	94	15	7.55	94.2521
22.	Subansiri L-S4	27	33	58.67	27.5663	94	14	7.72	94.2355
23.	Nalo-S1	28	24	34.26	28.4095	93	48	27.18	93.8076
24.	Nalo-S2	28	24	56.8	28.4158	93	47	49.9	93.7972
25.	Nalo-S3	28	24	24.11	28.4067	93	48	41.89	93.8116
26.	Naba-S1	28	22	37.31	28.3770	93	38	37.88	93.6439
27.	Naba-S2	28	22	34.17	28.3762	93	38	2.8	93.6341
28.	Naba-S3	28	23	3.12	28.3842	93	39	9.85	93.6527
29.	Niare-S1	28	21	32.51	28.3590	93	31	6.93	93.5186
30.	Niare-S2	28	21	45.91	28.3628	93	30	32.28	93.5090
31.	Niare-S3	28	21	16.94	28.3547	93	31	39.89	93.5277
32.	Middle Subansiri-S1	27	46	39	27.7775	93	58	54.97	93.9819
33.	Middle Subansiri-S2	27	46	43.19	27.7787	93	58	53.88	93.9816
34.	Middle Subansiri-S3	27	46	29.31	27.7748	93	58	53.88	93.9816
35.	Middle Subansiri-S4	27	46	19.65	27.7721	93	59	3.84	93.9844

To understand the community composition and structure of vegetation of the study area, stratified random sampling method was used. The size and number of quadrats needed were determined using the species-area curve method (Mishra, 1968). The sampling was conducted by randomly placing quadrats of 10 x 10 m^2 for trees, 5 x 5 m^2 for shrubs and 1 x 1 m^2 for herbs. Quadrats used for shrubs and herbs were nested within the quadrats laid for trees. All the quadrats were spatially distributed so as to minimize the autocorrelation among the vegetation. The data on vegetation were analyzed for density, frequency and abundance as per Curtis & McIntosh (1950). The Importance Value Index (IVI) for trees was determined as the sum of relative density, relative frequency and relative dominance (Curtis, 1959). Tree individuals with > 31.5 cm CBH (circumference at breast height i.e., 1.37 m from the ground) were individually measured for CBH. Data were collected for all the three seasons except tree and shrub species.

For the calculation of dominance, the basal area was determined by using following formula (Mishra, 1968).

Basal area (BA) = $(CBH)^2 / 4\pi$

The index of diversity was computed by using Shannon Wiener Diversity Index (Shannon Wiener, 1963) as: $H = - \Sigma (ni/n) \times \ln (ni/n)$ Where, ni is number of individual of i species and n is total number of individuals of all the species.

The Evenness Index (E) is calculated by using Shannon's Evenness formula (Magurran, 2004).

Evenness Index (E) = $H / \ln (S)$

Where, H is Shannon Wiener Diversity index; S is number of species.

Margalef Species Richness (SR) = $S-1/\ln(N)$ Where, S is total number of species and N is total number of individuals

SITE 1: TAGO

The studied area of Pyne River catchment is situated on Lumshi Mountain where a luxuriant vegetation growth was recorded especially along left bank of the River. In left bank, upper stretch of the valley was dominated with tall trees of temperate broadleaved forest whereas the lower stretch of this bank was full of secondary forests; moist bamboo breaks and bamboo-Musa associations. In right bank, mid elevations of catchment was full of temperate conifer (*Pinus sp*) forests. Some agriculture practices have also been recorded in low areas of valley on both banks of river.

Sampling Locations

Floristic sampling has been carried out at following sampling locations:

Site Code	Site Description
S1	Left Bank of Pyne River near proposed Dam Site
S2	Left Bank of Pyne River upstream, submergence area
S3	Right Bank of Pyne River 1 km upstream of Dam site
S4	Right Bank of Pyne River 2 km upstream of Dam site

Taxonomic diversity

In present primary study, a total of 74 angiosperms, 3 pteridophytes, 2 fungi, 1 gymnosperm and 1bryophyte have been recorded. **(Figure 6.7)**

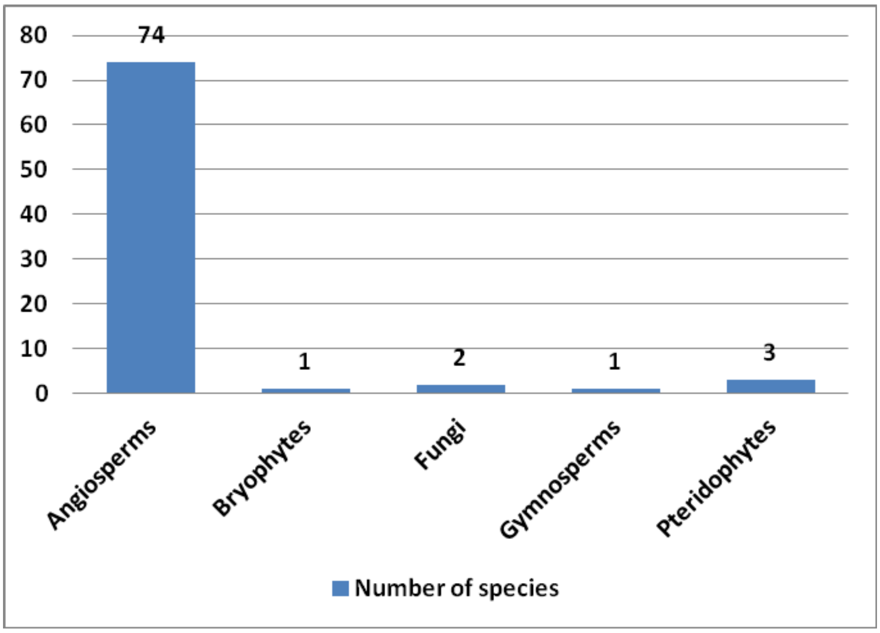


Figure 6.7: Number of species recorded under different taxonomic groups

Plant Species and Families

Higher plants in the study area included a total of 14 tree species belong to 12 families, 26 shrub species belong to 16 families and 37 herb species belong to 18 families have been recorded from all the studies. (Figure 6.9) Bignoniaceae and Lythraceae in tree, Arecaceae and Asteraceae in shrub and Asteraceae and Araceae in herb were recorded as dominant families. **(Fig 6.8)**

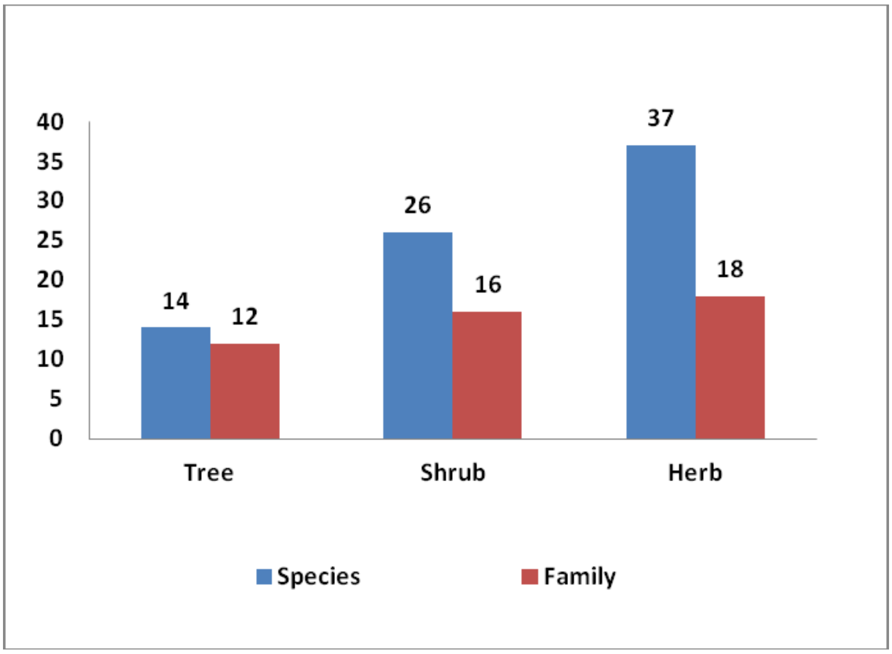
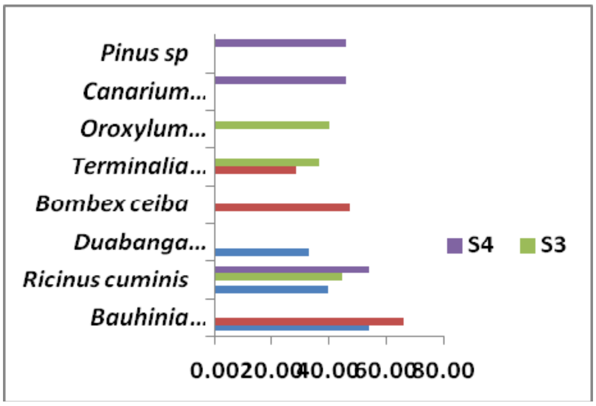


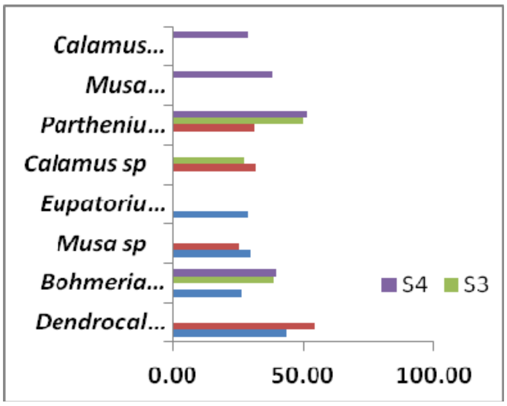
Figure 6.8: Number of Species and Families recorded

Importance Value Index (IVI)

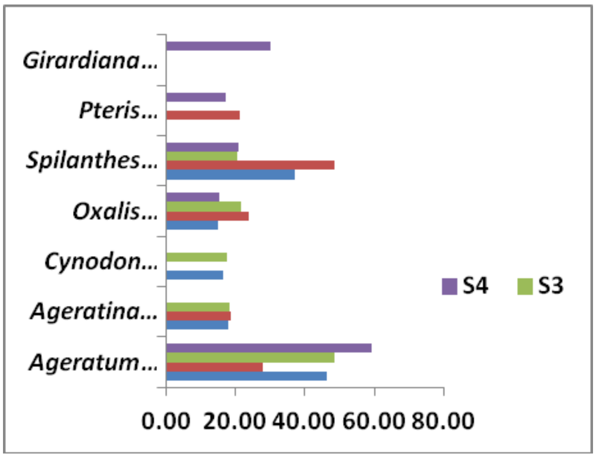
As per the Importance Value Index (IVI), *Bauhinia purpurea, Ricinus cuminis, Duabanga grandiflora, Bombax ceiba, Terminalia myriocarpa, Oroxylum indicum, Canarium strictum* and *Pinus sp* were recorded the dominant tree species having high IVI values. Among shrub species, *Dendrocalamus sp, Bohmeria macrophylla, Musa sp, Eupatorium sp, Calamus sp,* *Parthenium sp, Musa acuminata, and Calamus latifolius* were recorded as dominant species whereas *Ageratum conyzoides, Ageratina adenophora, Cynodon dactylon, Oxalis corniculata, Spilanthes paniculata, Pteris quadriaurita* and *Girardiana diversifolia* were found dominant among herb species. **(Fig 6.9)**



Tree



Shrub



Herb

Figure 6.9: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

Maximum tree density (600 plants/ha) was recorded in S4 (2 km upstream of Dam site) while shrubs and herbs density was highest near to proposed dam site (S1 site) which were as 5500 plants/ha for shrubs and 166500 plants/ha for herbs. As far as the Shannon Diversity Index (H') is concerned, maximum diversity values for herb (3.04), shrub (2.53) and tree (2.33) were recorded at right bank of Pyne River (1km upstream of Dam site). Evenness (E) was recorded highest at dam site in case of tree (0.98) and shrub (0.96) species whereas it was found highest (0.93) at site4 for herb species. Highest species richness values were recorded as 3.68 (S3), 3.37 (S4) and 4.82 (S1) for tree, shrub and herb species respectively. **(Table 6.29)**

Table 6.29: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3	S4
Density (plants/ha)	475	575	550	600
Diversity (H')	2.26	2.30	2.33	2.07
Evenness (E)	0.98	0.96	0.91	0.90
Species Richness (SR)	3.06	3.19	3.68	2.65
Shrub				

Tree	S1	S2	S3	S4
Density (plants/ha)	5500	4850	3750	3550
Diversity (H')	2.47	2.32	2.53	2.49
Evenness (E)	0.96	0.93	0.91	0.88
Species Richness (SR)	2.55	2.40	3.20	3.37
Herb				
Density (plants/ha)	166500	137500	119000	104000
Diversity (H')	3.00	3.00	3.04	2.94
Evenness (E)	0.89	0.91	0.92	0.93
Species Richness (SR)	4.82	4.63	4.75	4.31

Detailed phytosociological characters of floral species given in **Annexure 6.11**:

SITE 2: NYEPIN

A pristine forest patches have been recorded in the right bank of the river predominated with multi storied forest vegetation at upper elevations and Musa forests at lower areas of valley. Some agricultural practices have seen in the left bank of the forest whereas most of the area of right bank was found to be inaccessible. Density of bamboo was found scanty in this area as compared to the other areas of State.

Sampling Locations

Floristic sampling has been carried out at following sampling locations:

Site Code	Site Description
S1	Left Bank Upstream near Dam site
S2	Left Bank 1 km Downstream of Dam site
S3	Right Bank 1km Upstream of Dam Site
S4	Right Bank Upstream, Influenced Zone

Taxonomic diversity

Under present survey, a total of 69 angiosperms, 4 pteridophytes, and 1 bryophyte have been recorded. **(Figure 6.10)**

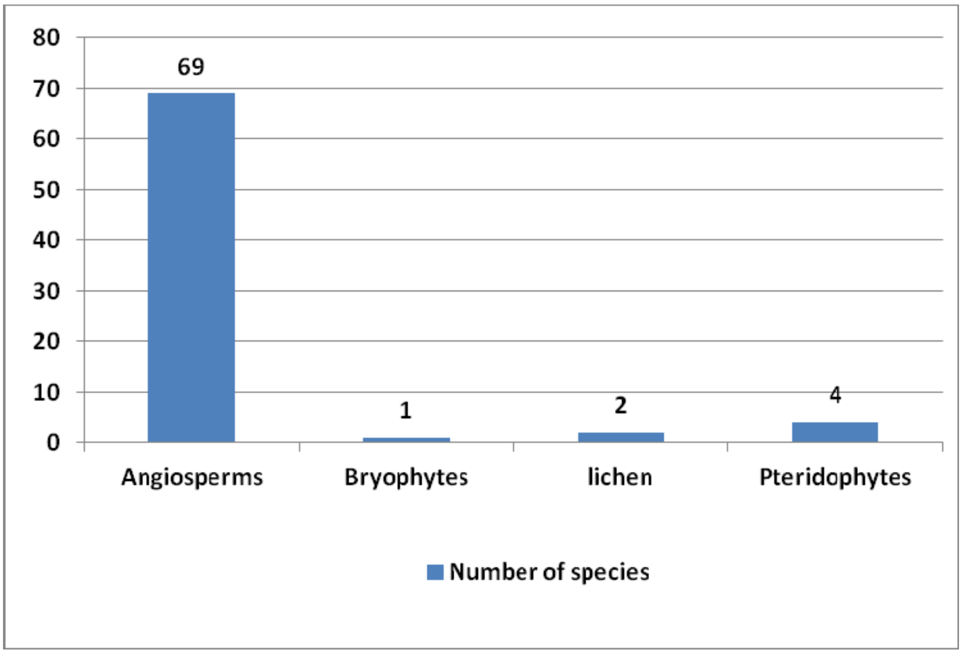


Figure 6.10: Number of species recorded under different taxonomic groups

Plant Species and Families

Among higher plants, a total of 15 trees, 24 shrubs and 34 herbs species has been recorded in this site which belong to 10, 16 and 18 families of tree, shrub and herb respectively. Asteraceae was found the dominant family having 5 species in case of herb whereas Mimosaceae and Rosaceae were dominating with 3 species each in case of tree and shrub respectively. **(Fig 6.11)**

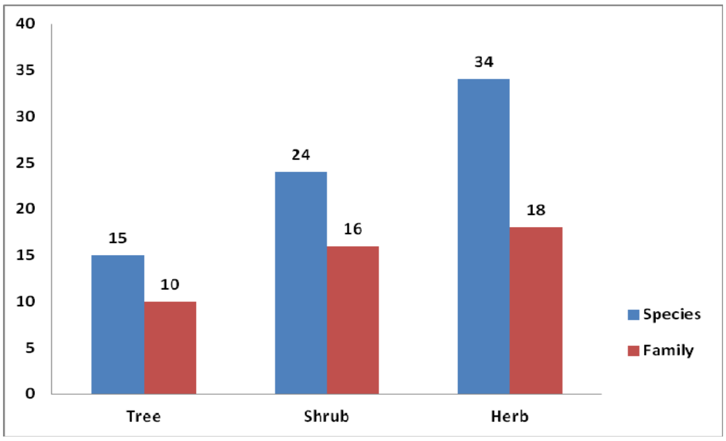
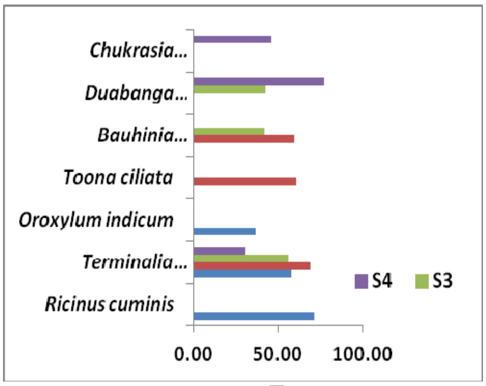


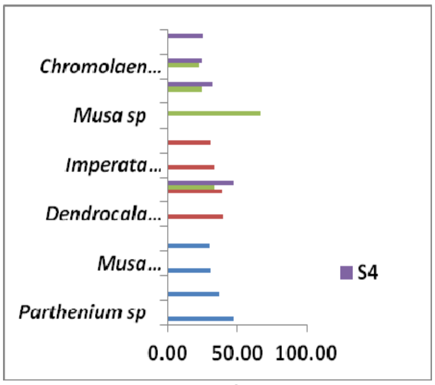
Figure 6.11: Number of Species and Families recorded

Importance Value Index (IVI)

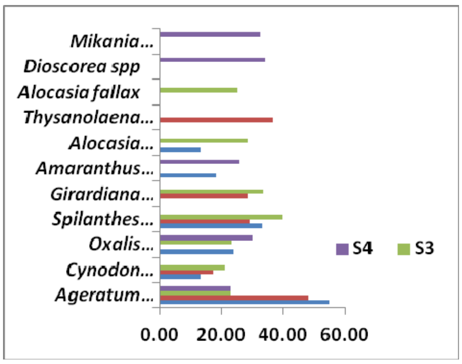
Among tree species, *Terminalia myriocarpa*, *Bauhinia purpurea*, *Duabanga grandiflora*, and *Toona ciliata* were recorded dominant tree species having highest values of IVI. *Livistona jenkinsiana, Debregiasia longifolia, Chromolaena odorata, Parthenium sp,* and *Bohmeria macrophylla* were recorded dominant in shrub vegetation while *Ageratum conyzoides*, *Cynodon dactylon*, *Spilanthes paniculata*, *Oxalis corniculata*, and *Girardiana diversifolia* were the leading species in herb flora. **(Fig 6.12)**



Tree



Shrub



Herb

Figure 6.12: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

Tree density was recorded highest (525 trees/ha) at S3 (Right Bank 1km Upstream of Dam Site), shrub density was found maximum (2950 plants/ha) at site 2 (Left Bank 1 km Downstream of Dam site) while herb density was recorded maximum (145000) near to proposed dam site (S1 site). Highest values of Shannon Diversity Index (H') for tree (2.24), shrub (2.68) and herb (2.98) was recorded at those sites where the maximum density values occurred. Evenness (E) was recorded highest at the Right Bank Upstream (Influenced Zone) for tree (0.98), shrub (0.98) and herb (0.93) whereas species richness was found highest at Site2, Site3 and Site1 for tree, shrub and herb respectively. **(Table 6.30)**

Table 6.30: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3	S4
Density (plants/ha)	450	275	525	500
Diversity (H')	2.11	2.21	2.24	2.04
Evenness (E)	0.96	0.96	0.97	0.98
Species Richness (SR)	2.59	3.32	2.96	2.34
Shrub				
Density (plants/ha)	2750	2950	2900	2600
Diversity (H')	2.58	2.68	2.62	2.59
Evenness (E)	0.95	0.97	0.97	0.98
Species Richness (SR)	3.22	3.24	3.45	3.29
Herb				
Density (plants/ha)	145000	96000	93500	88000
Diversity (H')	2.98	2.82	2.70	2.80
Evenness (E)	0.88	0.90	0.92	0.93
Species Richness (SR)	4.59	4.18	3.44	3.67

Detail phytosociological characters of floral species given in **Annexure 6.11**.

SITE 3: HIYA

Lower stretch of right bank of the river was dominated with *Musa* forest whereas the upper elevation of the valley was dominated with tall trees and multistory vegetation was occurred in the forests. Most of the habitations were found in the left bank of the river and therefore the sign of anthropogenic pressure is very common at this bank. Lower areas of valley experiencing sub-tropical semi-evergreen forest whereas temperate broadleaved forest was seen at the higher elevations of the area.

Sampling locations

Present primary sampling has been carried out at following sampling locations.

Site Code	Site Description
S1	Left Bank Upstream near Dam site
S2	Left Bank 1 km Upstream of Dam site
S3	Left Bank 4km Upstream of Dam Site

Taxonomic Diversity

In the primary vegetation survey, a total of 67 Angiosperms, 4 Pteridophytes, 1 Lichen and 1 bryophyte species were recorded. **(Fig 6.13)**

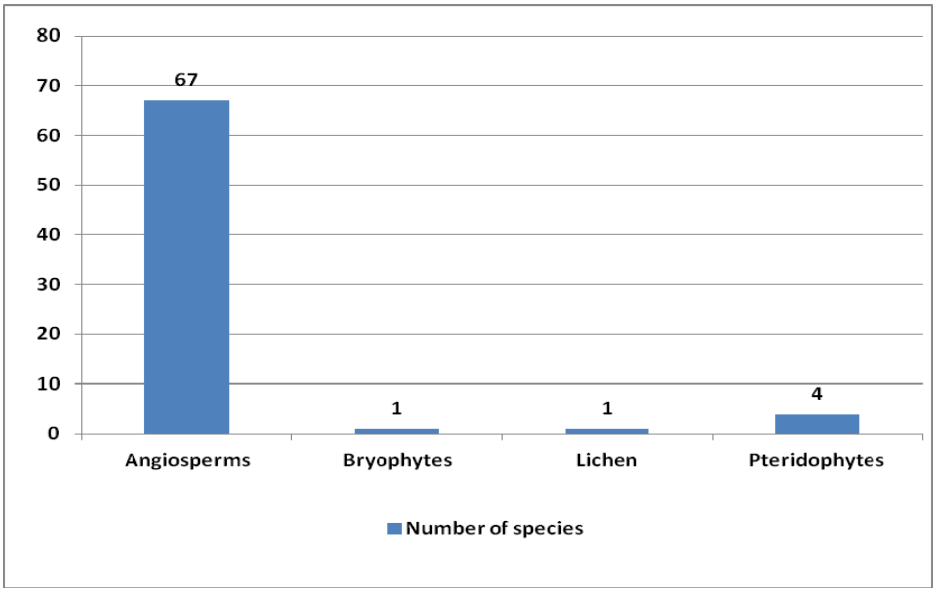


Figure 6.13: Number of species recorded under different taxonomic groups

Plant Species and Families

Higher plants recorded in the study area were also classified into tree, shrub and herb and a total of 13 trees, 19 shrubs and 39 herbs species were recorded from all the sampling sites. Asteraceae (7 species), Bignoniaceae (2 species) and Poaceae (3 species) were found the dominant families in herb, tree and shrub respectively. **(Fig 6.14)**

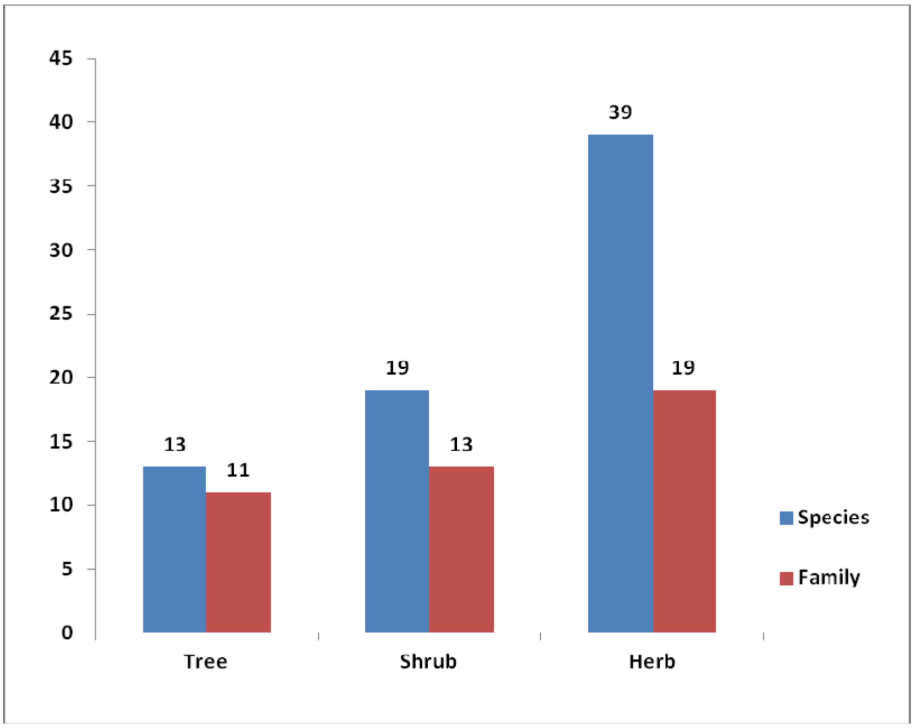
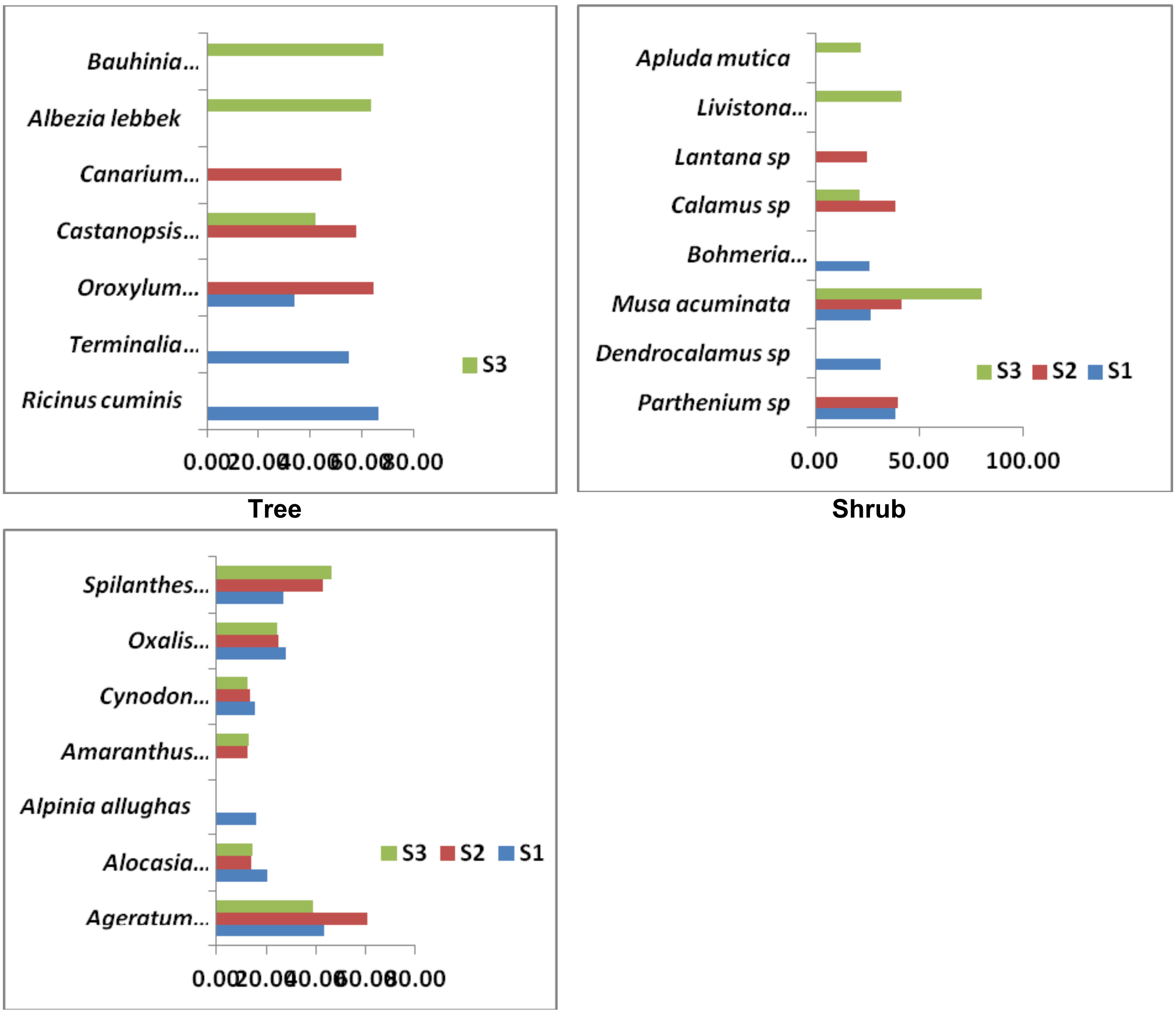


Figure 6.14: Number of Species and Families recorded

Importance Value Index (IVI)

Castanopsis indica, *Oroxylum indicum, Ricinus cuminis*, *Bauhinia purpurea*, and *Albizia lebbeck* species showed the dominance among tree flora whereas species like *Musa acuminata, Calamus* sp., *Parthenium* sp., *Livistona jenkinsiana* and *Lantana* sp., were found dominant in shrub layer. The herb layer was constituted with the domination of *Ageratum* *conyzoides*, *Alocasia fornicata*, *Cynodon dactylon*, *Oxalis corniculata*, and *Spilanthes paniculata*. **(Fig 6.15)**



Tree

Shrub

Herb

Figure 6.15: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

Under present study, tree density was recorded highest (550 trees/ha) at S1 and S3 (near Dam Site & 4km Upstream of Dam Site), shrub density (3850 plants/ha) and herb density (177500 plants/ha) was also recorded highest near dam site. As far as the Shannon diversity index is concerned, it's values were recorded highest near to dam site at the left bank of river for tree (2.11), shrub (2.58) and herb (3.04). Evenness (E) for tree species was highest (0.97) at S2 while in case of shrub and herb it was found highest in S1. Tree (2.59) and shrub (3.25) species richness was highest near to dam site whereas the species richness in herb flora was recorded highest (4.94) at S3 (Left Bank 4km Upstream of Dam Site; Influenced Zone). **(Table 6.31)**

Table 6.31: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3
Density (plants/ha)	550	400	550
Diversity (H')	2.11	1.89	1.99

Tree	S1	S2	S3
Evenness (E)	0.96	0.97	0.90
Species Richness (SR)	2.59	2.89	2.59
Shrub			
Density (plants/ha)	3850	3700	2950
Diversity (H')	2.58	2.36	2.46
Evenness (E)	0.95	0.87	0.93
Species Richness (SR)	3.22	3.25	3.19
Herb			
Density (plants/ha)	177500	166000	176500
Diversity (H')	3.04	2.89	3.01
Evenness (E)	0.91	0.88	0.88
Species Richness (SR)	4.60	4.48	4.94

Detail phytosociological characters of floral species given in **Annexure 6.11.**

SITE 4: DENGSER

The vegetation of the proposed project area is dominated by broad-leaved trees that form a dense upper canopy (layer of foliage) and contain a diverse array of vegetation. A clear delineation has seen in the lower and upper stretches of this forest community. Lower stretch (near to dam site)- forest community was comprised with mature tree individuals in top canopy with some young tree individuals in lower canopy. The upper stretches of this study site was comprised with a thick vegetative growth of Bamboo and Musa species. Ground cover was moist-shady which supports the growth of Pteridophytes.

Sampling locations

The present study was carried out in the following sampling sites.

Site Code	Site Description
S1	Left Bank near Dam
S2	Left Bank Upstream of Dam site
S3	Right Bank Upstream of Dam Site

Taxonomic diversity

In primary study, a total of 57 Angiosperms, 5 Pteridophytes, 1 Lichen and 1 Fungi species has been recorded. **(Fig 6.16)**

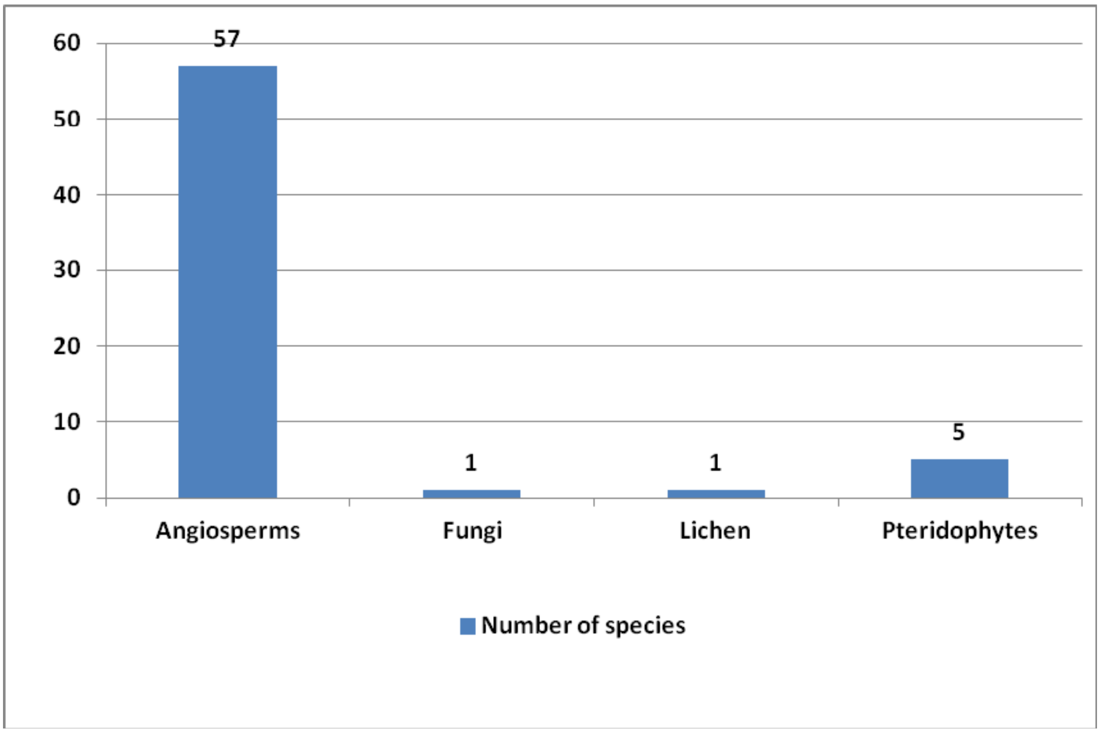


Figure 6.16: Number of species recorded under different taxonomic groups

Plant Species and Families

In present primary survey, a total of 13 tree species belong to 12 families, 16 shrub species belong to 12 families and 33 herb species belong to 18 families has been recorded. Fabaceae was the leading family in tree flora whereas Arecaceae and Poaceae were the dominant families in shrub. Highest numbers of herb species were recorded for Araceae and Asteraceae family. **(Fig 6.17)**

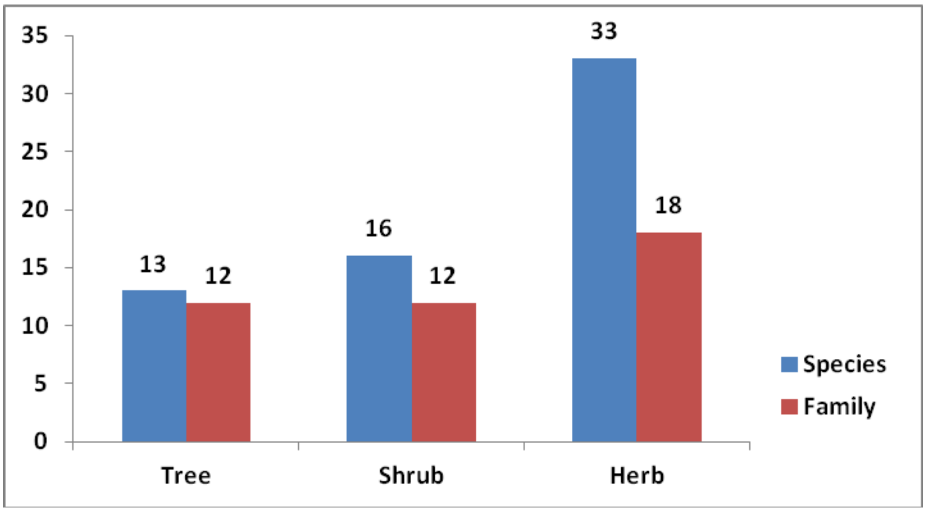
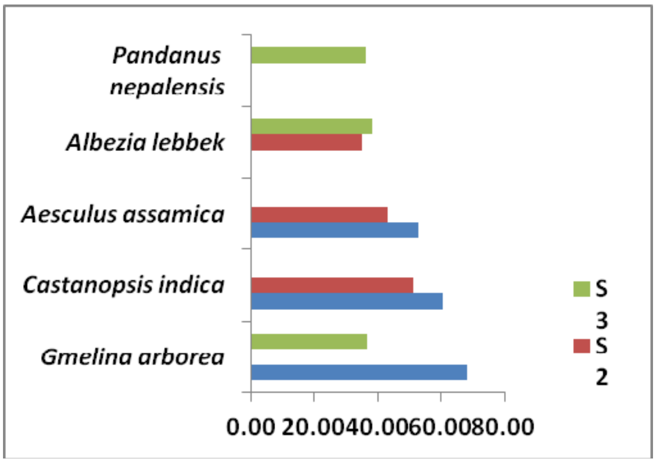


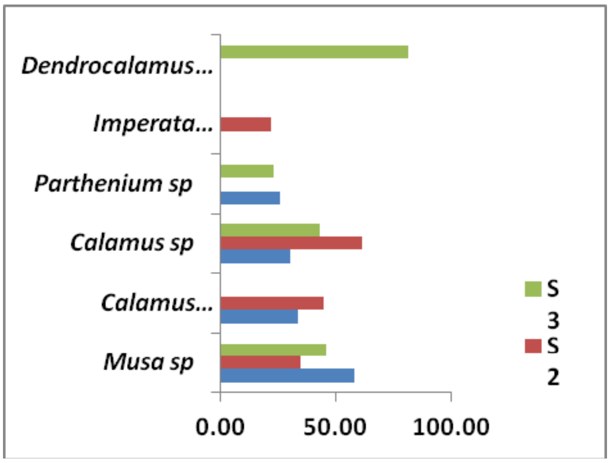
Figure 6.17: Number of Species and Families recorded

Importance Value Index (IVI)

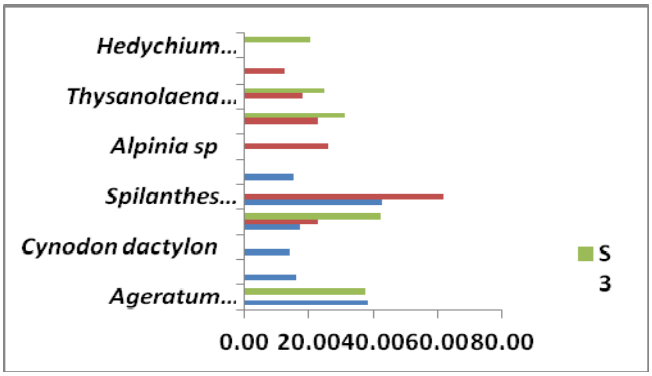
Tree canopy was found dominated with *Gmelina arborea*, *Castanopsis indica*, *Aesculus assamica*, and *Albizia lebbeck* whereas species like *Musa sp, Calamus* sp, *Parthenium* sp, *Calamus floribundus* and *Dendrocalamus* sp. were found dominant in shrub layer. The herb layer was constituted with the domination of *Ageratum conyzoides*, *Thysanolaena maxima*, *Ageratina adenophora*, *Oxalis corniculata*, and *Spilanthes paniculata*. **(Fig 6.18)**



Tree



Shrub



Herb

Figure 6.18: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

Density of tree species was recorded between 425 trees/ha to 475 trees/ha and it was recorded highest (475 trees/ha) at S2 site (Upstream of Dam Site & left bank), shrub density (3600 plants/ha) was highest at the influenced area while the herb density (129000 plants/ha) was recorded highest near dam site (S1). Shannon diversity index was found highest (2.23) at Upstream of Dam Site & left bank for tree species whereas it was maximum near to dam site for herb (3.03) and shrub (2.41) flora. Similar trend was recorded for Evenness (E) index and species richness. **(Table 6.32)**

Table 6.32: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3
Density (plants/ha)	425	475	425
Diversity (H')	2.04	2.23	2.18
Evenness (E)	0.93	0.97	0.99
Species Richness (SR)	2.82	3.06	2.82
Shrub			
Density (plants/ha)	3400	3100	3600
Diversity (H')	2.41	2.40	2.13
Evenness (E)	0.94	0.91	0.86
Species Richness (SR)	2.84	3.15	2.57

Tree	S1	S2	S3
Herb			
Density (plants/ha)	129000	114000	66500
Diversity (H')	3.05	2.85	2.75
Evenness (E)	0.94	0.88	0.92
Species Richness (SR)	4.50	4.42	3.89

Detail phytosociological characters of floral species given in **Annexure 6.11.**

SITE 5: MIDDLE SUBANSIRI (KAMALA HEP)

Left bank of the river was found to be degraded and the lower stretch was predominated with shrubs whereas good vegetation cover recorded in the right bank of the river. Lower areas of valley were dominated with mixed deciduous forest along with bamboo breaks. Signs of anthropogenic activities in and around of the study site was very common. Left bank of the river is sun-facing, steep and dry therefore it bears scant vegetation cover especially towards upper reaches.

Sampling locations

Under present study, vegetation sampling has been carried out in following sites.

Site Code	Site Description
S1	Left Bank near Tamen Bridge & Upstream
S2	Left Bank Upstream of Dam site
S3	Right Bank Upstream of Dam Site
S4	Right Bank near Dam site

Taxonomic Diversity

61 Angiosperms, 1 Fungi, 1 Bryophyte, 1 Pteridophyte species were recorded during primary survey in the present project area. **(Figure 6.19).**

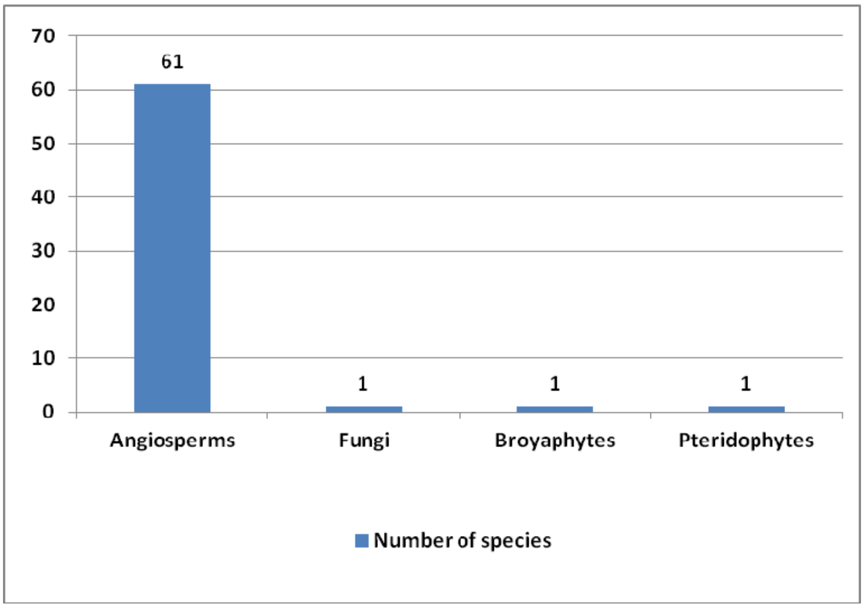


Figure 6.19: Number of species recorded under different taxonomic groups

Plant Species and Families

A total of 13 trees, 19 shrubs and 30 herbs species were recorded during primary sampling carried out at four sites of proposed HEP area. Tree flora was distributed into the 11 families whereas shrub flora was represented by 14 families and herb species were distributed in 17 families. Asteraceae, Euphorbiaceae and Arecaceae were the dominant families in herb, tree and shrub flora respectively. **(Figure 6.20).**

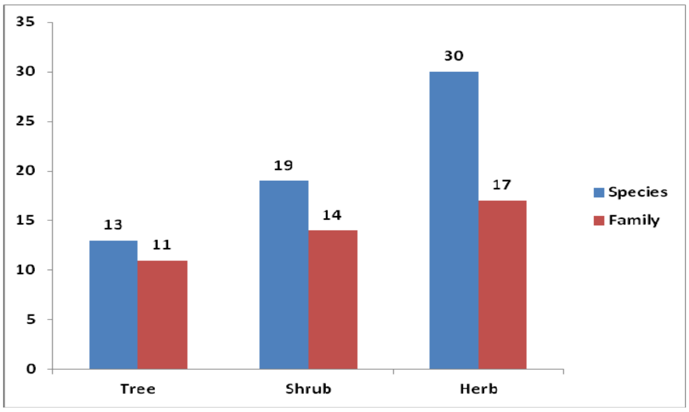
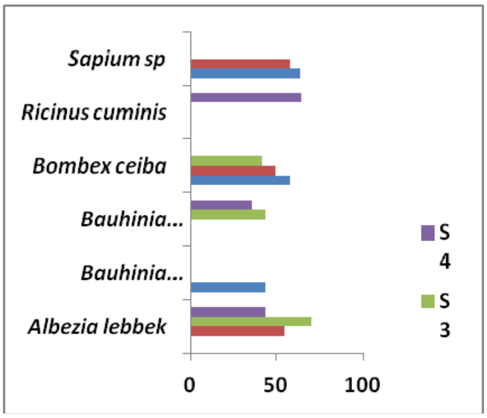


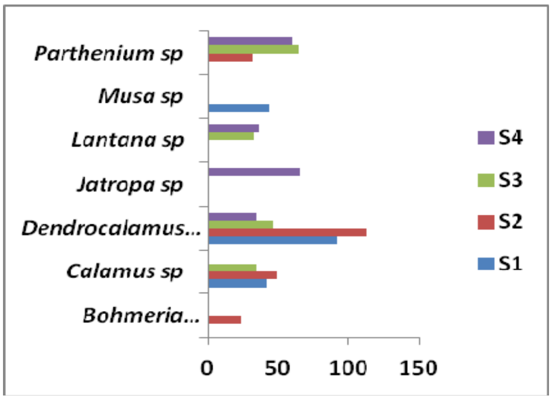
Figure 6.20: Number of Species and Families recorded

Importance Value Index (IVI)

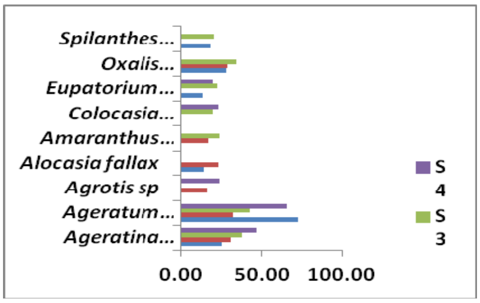
On the basis of IVI, dominate tree species recorded from the study area were *Albizia lebbeck*, *Bauhinia purpurea, Bombax ceiba*, *Sapium* sp, and *Ricinus cuminis*. Shrub flora was found dominated with *Dendrocalamus* sp, *Parthenium* sp., *Calamus* sp. and *Lantana* sp whereas in the herb species *Ageratina adenophora*, *Ageratum conyzoides*, *Oxalis corniculata*, *Spilanthes paniculata*, and *Alocasia fallax* has been recorded dominant species. **(Figure 6.21).**



Tree



Shrub



Herb

Figure 6.21: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

Tree Density values varies from 200 plants/ha to 450 plants/ha and was recorded highest at site 2 (Left Bank Upstream of Dam site). Density of shrubs was also recorded highest (5250 plants/ha) at site 2 whereas maximum herb density was recorded (119000 plants/ha) at site 1 (Left Bank near Tamen Bridge & Upstream). Shannon diversity (2.04), species richness (3.19) and Evenness (0.98) for tree species were found highest in S4 (Right Bank river near dam site). Shannon diversity and evenness for shrub and herb species were recorded highest in S1 (left bank near Tamen Bridge). Species richness for shrub and herb was found highest Right Bank Upstream of Dam Site and Left Bank near Tamen Bridge & Upstream respectively. **(Table 6.33)**

Table 6.33: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3	S4
Density (plants/ha)	375	450	200	225
Diversity (H')	1.97	1.99	1.91	2.04
Evenness (E)	0.95	0.95	0.98	0.98
Species Richness (SR)	2.58	2.42	2.89	3.19
Shrub				
Density (plants/ha)	4100	5250	2850	2750
Diversity (H')	2.14	1.99	2.05	1.94
Evenness (E)	0.86	0.78	0.78	0.84
Species Richness (SR)	2.50	2.58	3.22	2.25
Herb				
Density (plants/ha)	119000	93500	49500	52500
Diversity (H')	2.87	2.84	2.66	2.49
Evenness (E)	0.90	0.93	0.90	0.88
Species Richness (SR)	4.20	3.82	3.92	3.44

Detail phytosociological characters of floral species given in **Annexure 6.11.**

SITE 6: UPPER SUBANSIRI

The forest of this site mainly differentiated with three distinct storeys viz. upper, middle and lower. Upper story of the vegetation dominated with tall trees. The right bank of the dam site is steep and rocky which make scant vegetation coverage in the lower stretch but there is good vegetation cover present on upper stretch. Left bank of the dam site is experiencing a luxuriant growth of pteridophytes. Jhoom fellows and bamboo breaks were also very common on the left bank of river near dam site along with few orange orchards.

Sampling locations

Present vegetation survey has been carried out at following sites.

Site Code	Site Description
S1	Left Bank downstream near Sippi Village
S2	Right Bank near Dam site
S3	Right Bank Upstream near Marah Village
S4	Right Bank near Naccho Village

Taxonomic Diversity

107 plants species has been recorded in the primary survey and among these species 102 were Angiosperms, 1 Bryophyte, 3 Pteridophytes and 1 Lichen. **(Fig 6.22)**

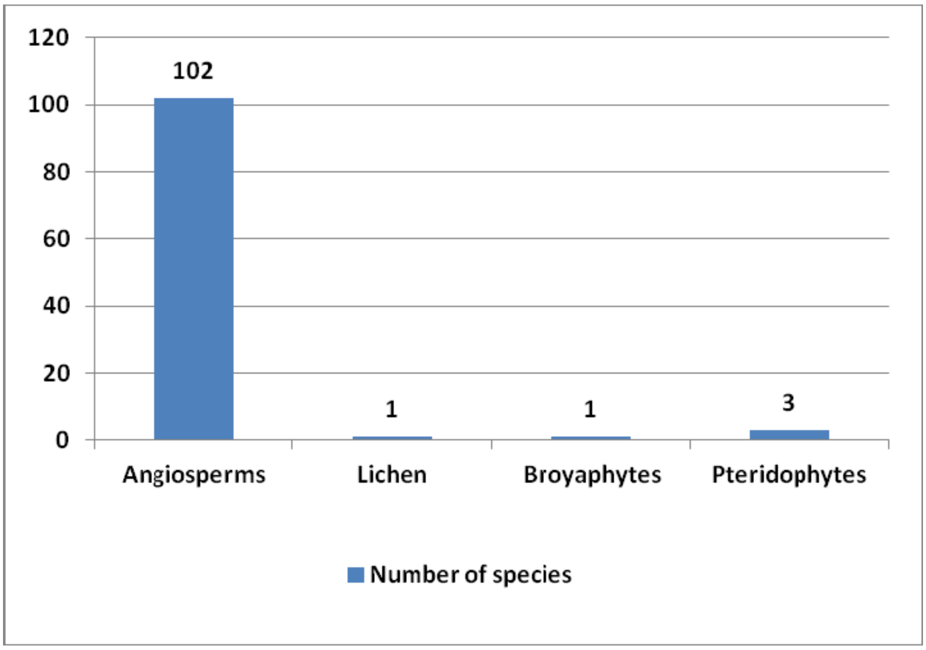


Figure 6.22: Number of species recorded under different taxonomic groups

Plant Species and Families

Higher plants in the study area include 33 trees, 35 shrubs and 37 herbs species. These plant species belong to 21, 17 and 25 families of tree, shrub and herb respectively. Fagaceae in tree flora, Arecaceae in shrub flora and Asteraceae in herb flora were found the dominant families. **(Fig 6.23)**

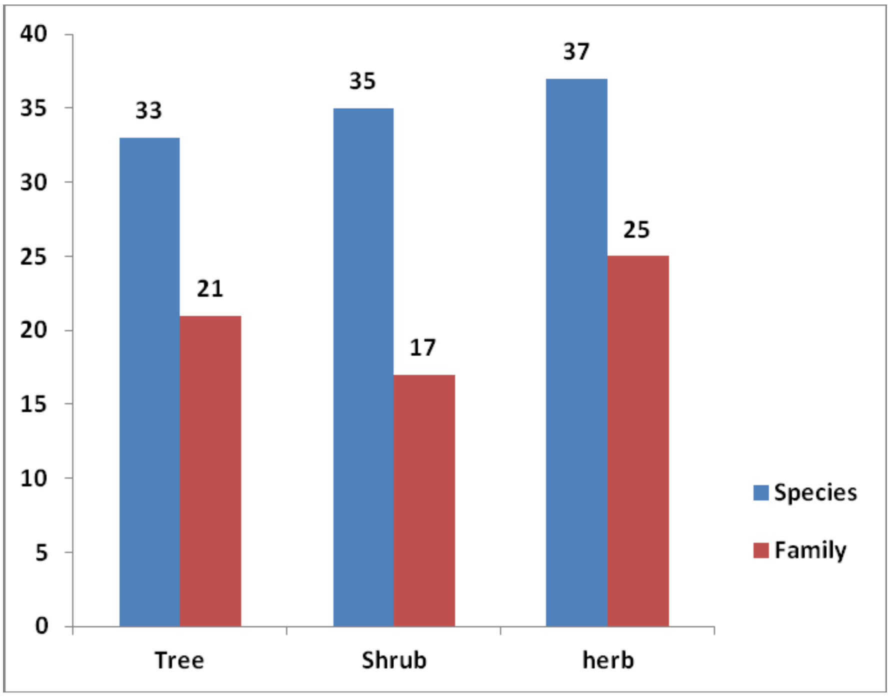


Figure 6.23: Number of Species and Families recorded

Importance Value Index (IVI)

Maximum IVI values in tree species were recorded for *Terminalia myriocarpa*, *Ficus semicordata*, *Kydia calycina*, and *Duabanga grandiflora*. Shrub flora was found dominated with *Musa acuminata*, *Dendrocalamus hamiltonii*, *Bambusa pallida* and *Musa balbisiana* while the dominant herb species were recorded as *Adiantum caudatum*, *Ageratum conyzoides*, *Alpinia malaccensis*, *Spilanthes paniculata* and *Girardiana diversifolia.* **(Fig 6.24)**

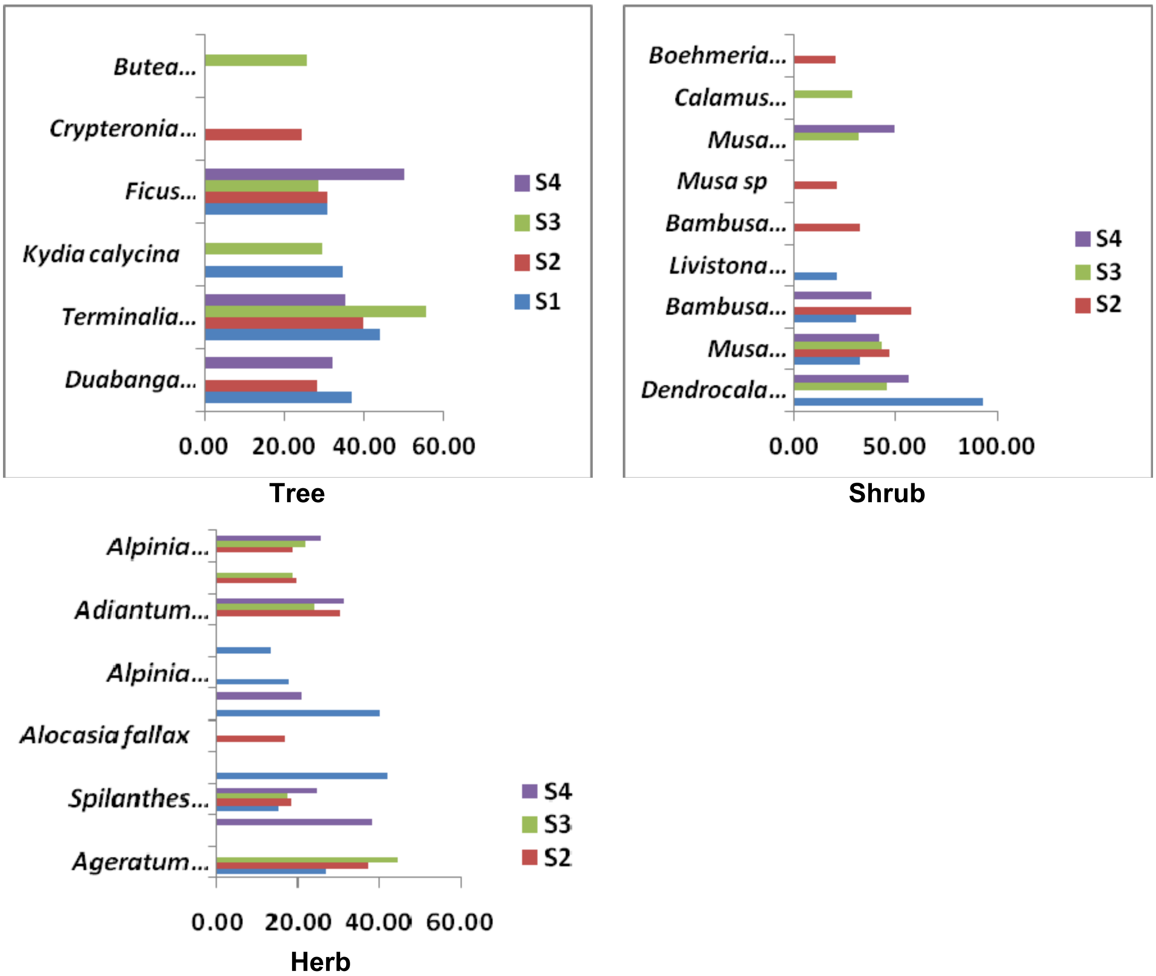


Figure 6.24: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

In present survey, tree density value was recorded highest (650 plants/ha) at site2 (Right Bank near Dam site). Density of shrub (9150 plants/ha) and herb (110500 plants/ha) was highest at site 1. Shannon diversity was recorded more or less similar in all sampling sites for tree species and it was recorded highest (2.65) in S2. Shrub diversity was found highest (2.72) at the Right Bank Upstream near Marah Village whereas the herb diversity was highest (3.15) at Site 2. Species richness for tree species were found highest (4.27) at S4 (Right Bank river near Nachoo village) while the Evenness for tree species was found highest (0.98) at S1 and S2. Shrub species richness was recorded highest (3.96) at both S3 and S4 and herb species richness has been found highest (5.02) near Sippi village. **(Table 1.6)**

Table 6.34: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3	S4
Density (plants/ha)	475	650	500	525
Diversity (H')	2.58	2.65	2.62	2.56
Evenness (E)	0.98	0.98	0.97	0.97
Species Richness (SR)	4.42	4.30	4.67	4.27
Shrub				
Density (plants/ha)	9150	6500	6050	6050
Diversity (H')	2.43	2.59	2.72	2.46
Evenness (E)	0.88	0.93	0.91	0.82
Species Richness (SR)	2.88	3.08	3.96	3.96
Herb				
Density (plants/ha)	110500	79500	83000	76000
Diversity (H')	3.08	3.15	2.99	2.93
Evenness (E)	0.92	0.97	0.95	0.96
Species Richness (SR)	5.02	4.90	4.30	3.98

Detail phytosociological characters of floral species given in **Annexure 6.11.**

SITE 7: LOWER SUBANSIRI

Submergence zone of the river experienced a steeper rocky topographic feature where some individuals of grasses were recorded. Upper stretches of the catchment area in both banks of river were associated with tropical evergreen forest where the forest can be easily classified into distinct. The vegetation community located in the catchment zone of the Lower Subansiri seems very short term interaction between environmental and anthropogenic factors. Presence of grasses along with pteridophytes at middle and lower stretches were very common. Selective harvesting of floral species for daily uses especially bamboo and canes near to habitations is very common which led to a gradual invasion of less important pioneer species in forest areas.

Sampling locations

Sampling has been carried out at following sampling points.

Site Code	Site Description
S1	Left bank near Dam Site
S2	Right bank down stream
S3	Right Bank upstream 1 km from Dam site
S4	Right Bank upstream 3 km from Dam site

Taxonomic Diversity

In present floral survey only two taxonomic groups of plant species has been recorded. Among 65 plant species which has been recorded during the survey, 62 belong to Angiosperm and 3 belong to Pteridophytes. **(Fig 6.25)**

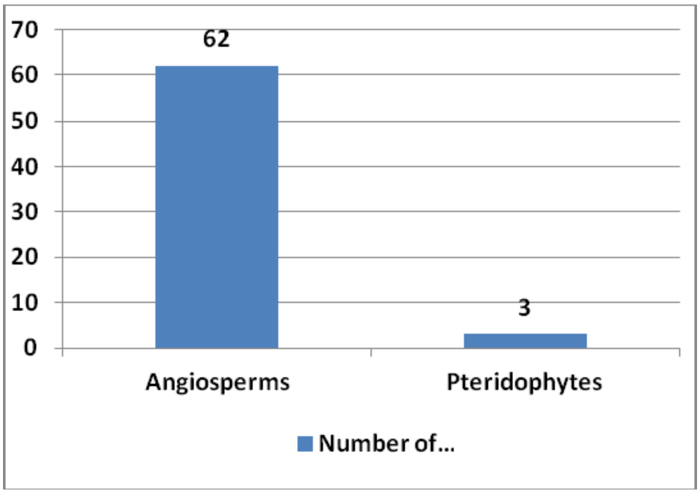


Figure 6.25: Number of species recorded under different taxonomic groups

Plant Species and Families

Higher plants recorded from the study area have also been classified into trees, shrubs and herbs and a total of 15 trees, 18 shrubs and 32 herbs have been recorded. Mimosaceae in tree, Arecaceae and Asteraceae in shrub and Asteraceae and Pteridaceae in herbs were the dominant families. 10 families in tree, 12 families in shrub and 18 families in herb have been recorded. **(Fig 6.26)**

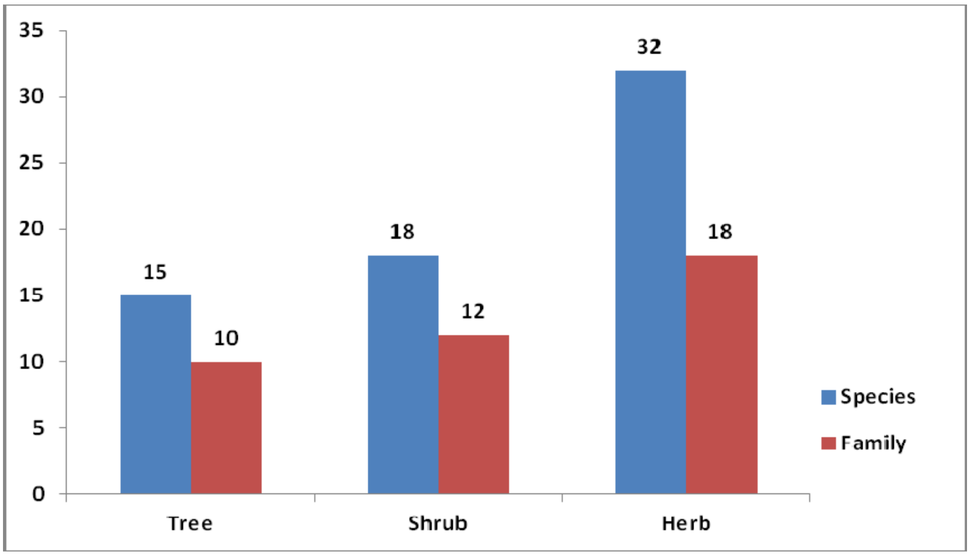
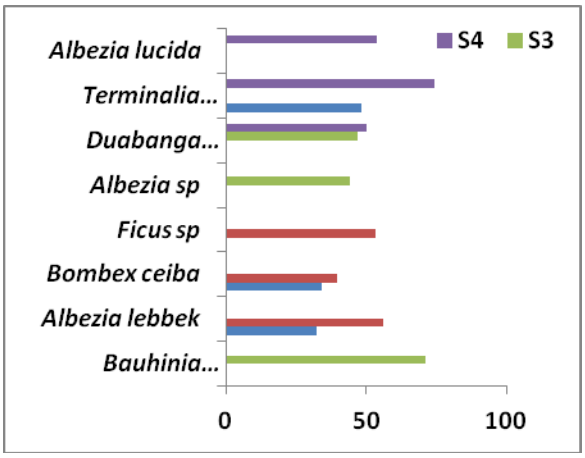


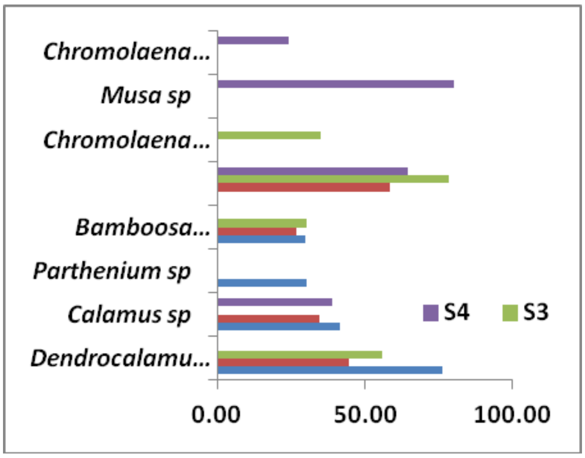
Figure 6.26: Number of Species and Families recorded

Importance Value Index (IVI)

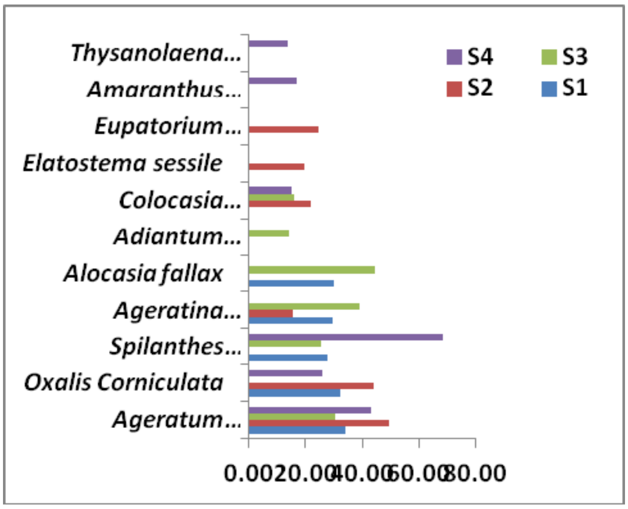
Albizia lebbeck, *Bombax ceiba*, *Duabanga grandiflora*, *Terminalia myriocarpa*, *Bauhinia purpurea,* and *Ficus* sp. were the dominant flora in tree layer. Dominant shrub flora was recorded as *Dendrocalamus* sp., *Calamus* sp., *Bambusa pallida*, *Calamus flagellum*, *Musa sp*, and *Parthenium* sp whereas *Ageratum conyzoides, Ageratina adenophora*, *Colocasia esculenta*, *Spilanthes paniculata* and *Oxalis corniculata* species were found dominant within herb. **(Fig 6.27)**



Tree



Shrub



Herb

Figure 6.27: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

As far as the tree density (575 plants/ha), diversity (2.26), evenness (0.98) and species richness (2.87) were concerned, these values were recorded highest at the left bank of the river near dam site. Highest shrub density (5950 plants/ha), diversity (2.47), evenness (0.91), and species richness (2.93) values were found highest at the right bank the river-downstream. Herb density (92500 plants/ha), diversity (2.92), evenness (0.95) and species richness (4.15) were recorded highest in the influenced zone of the dam. **(Table 6.35)**

Table 6.35: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3	S4
Density (plants/ha)	575	425	350	325
Diversity (H')	2.26	2.04	2.01	1.93
Evenness (E)	0.98	0.98	0.97	0.93
Species Richness (SR)	2.87	2.47	2.65	2.73
Shrub				
Density (plants/ha)	5350	5950	5250	4250
Diversity (H')	2.33	2.47	2.26	2.21
Evenness (E)	0.91	0.91	0.86	0.89
Species Richness (SR)	2.57	2.93	2.79	2.48
Herb				

Tree	S1	S2	S3	S4
Density (plants/ha)	80500	74500	78500	92500
Diversity (H')	2.84	2.79	2.92	2.73
Evenness (E)	0.93	0.93	0.95	0.90
Species Richness (SR)	3.94	3.80	4.15	3.83

Detailed phytosociological characters of vegetation given in **Annexure 6.11.**

SITE 8: NALO

Sampling locations

Sampling has been carried out at following sampling points.

Site Code	Site Description
S1	Downstream of damsite
S2	Dam site
S3	Upstream of damsite

Taxonomic Diversity

During primary study, 65 angiospermic species has been recorded along 1 species of Pteridophyte (*Adiantum caudatum*) **(Fig 6.28).**

Species and Families

Under higher plants, a total of 11 trees (10 families), 15 shrubs (10 families) and 40 herbs (22 families) species have been recorded. Fabaceae in tree, Arecaceae in shrub and Asteraceae and Araceae in herbs were found the dominant families. **(Figure 6.29)**

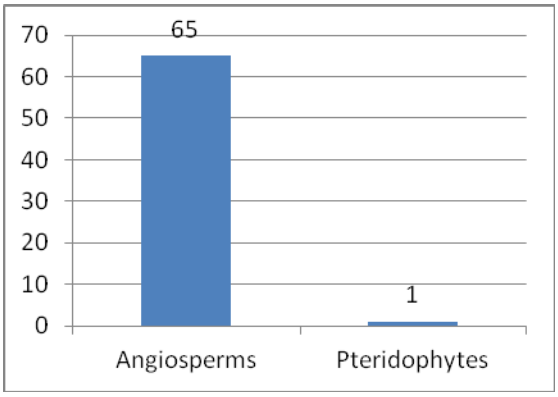


Figure 6.28: Number of species recorded under different taxonomic groups

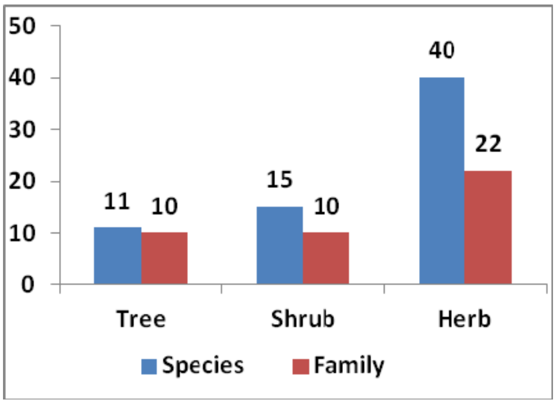
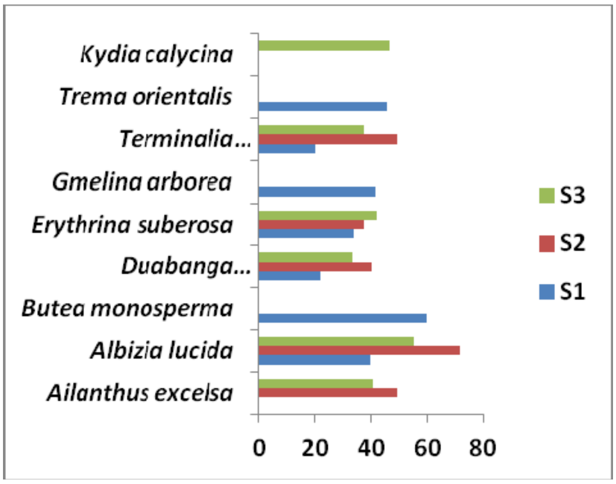
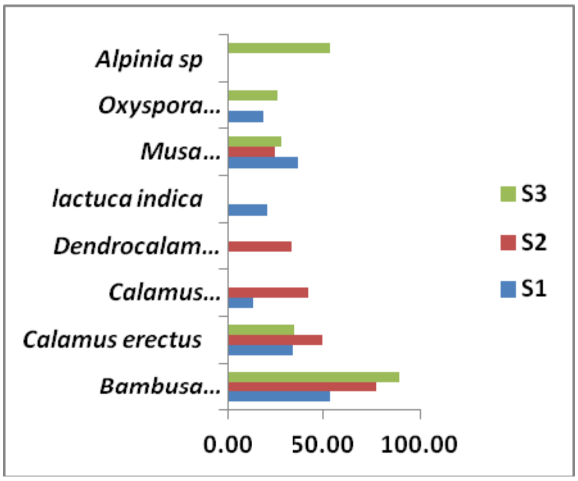


Figure 6.29: Number of Species and Families recorded

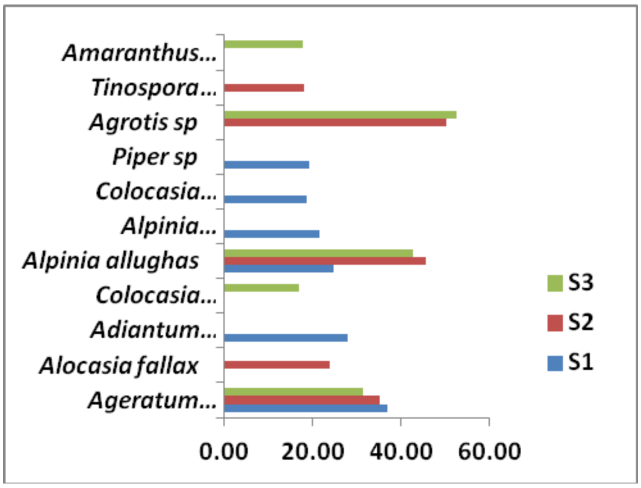
Importance Value Index (IVI)
Erythrina suberosa, Albizia lucida, Gmelina arborea, Trema orientalis, Butea monosperma were the dominant flora in tree layer. Dominant shrub flora was recorded as *Calamus erectus*, *Bambusa pallida*, and *Musa acuminata* while the dominant herb species were recorded as *Ageratum conyzoides, Alpinia allughas*, and *Agrostis sp.* **(Figure 6.30)**



Tree



Shrub



Herb

Figure 6.30: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

Tree density of study area ranged between 350 trees ha^{-1} to 400 trees ha^{-1} (S2, near Dam Site) whereas the maximum Shannon Diversity (2.34) as well as evenness (0.99) for tree species was recorded highest in upstream area. Highest species richness (3.03) for tree species was also recorded near Dam site. Shrub density (6500 plants/ha), diversity (2.51), evenness (0.98) and species richness (2.47) has been recorded highest in downstream area of dam site. Density (99000 plants/ha), diversity (3.04), evenness (0.93) and species richness (4.73) values for herbaceous flora were also recorded highest around downstream of dam site. **(Table 6.36)**

Table 6.36: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3
Density (plants/ha)	375	350	400
Diversity (H')	2.12	2.01	2.34
Evenness (E)	0.96	0.91	0.99
Species Richness (SR)	2.95	3.03	2.89
Shrub			
Density (plants/ha)	6500	4900	5850
Diversity (H')	2.51	2.08	1.92
Evenness (E)	0.98	0.95	0.87

Tree	S1	S2	S3
Species Richness (SR)	2.47	1.74	1.68
Herb			
Density (plants/ha)	99000	85500	90000
Diversity (H')	3.04	2.80	2.87
Evenness (E)	0.93	0.89	0.90
Species Richness (SR)	4.73	4.28	4.43

Detailed phytosociological characters of vegetation given in **Annexure 6.11.**

SITE 9: NABA

Sampling locations

Sampling has been carried out at following sampling points.

Site Code	Site Description
S1	Downstream of damsite
S2	Dam site
S3	Upstream of damsite

Taxonomic Diversity

In the primary vegetation survey, a total of 56 angiospermic species has been recorded. Beside these angiosperms, 4 pteridophytes was also recorded from the study area. **(Figure 6.31)**

Species and Family

Among higher plants, a total of 11 trees, 15 shrubs and 34 herbs species were recorded in this project area. Tree species belong to 10 families, shrub to 9 families whereas the herbaceous flora represented by 18 families. **(Figure 6.32)**

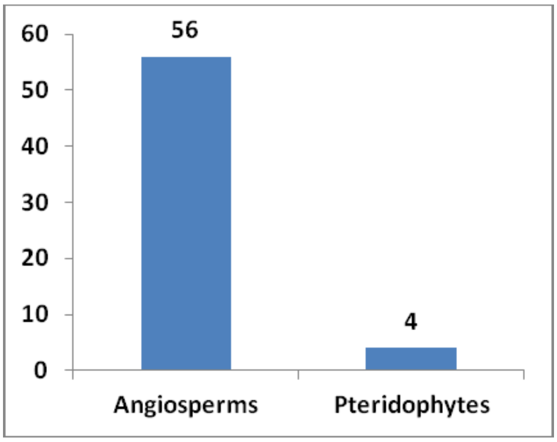


Figure 6.31: Number of species recorded under different taxonomic groups

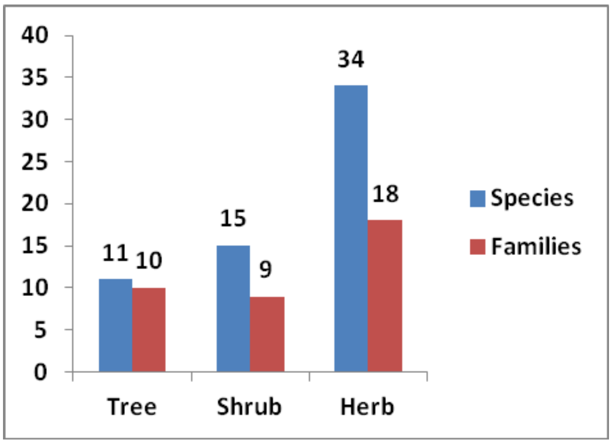
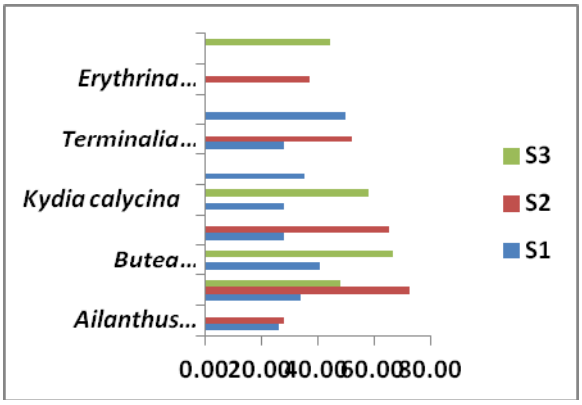


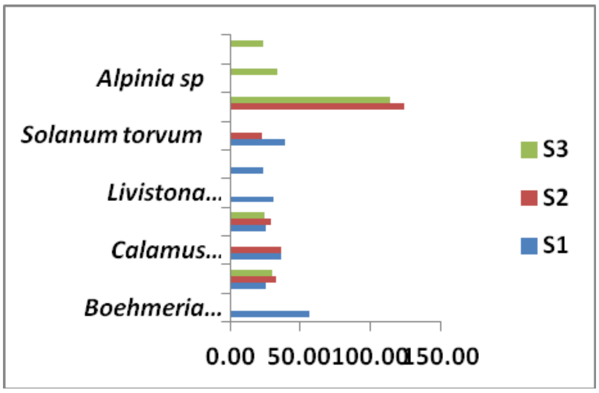
Figure 6.32: Number of Species and Families recorded

Importance Value Index (IVI)

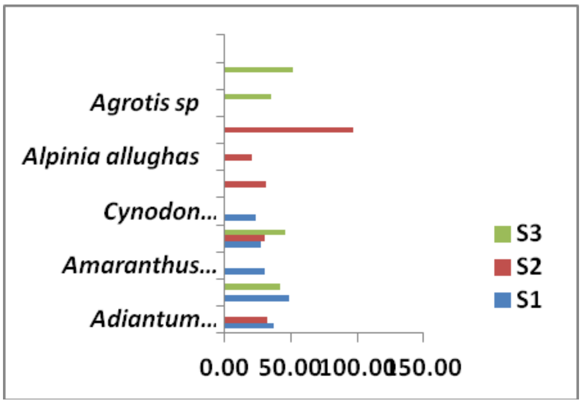
Albizia lucida, *Gmelina arborea*, *Trema orientalis*, *Butea monosperma* and *Terminalia myriocarpa* were the dominant flora in tree layer. Dominant shrub flora was recorded as *Calamus erectus*, *Bambusa pallida*, and *Dendrocalamus hamiltoni* whereas the dominant herb species found in the study area were *Ageratum conyzoides*, *Amaranthus spinosus* and *Adiantum caudatum*. **(Figure 6.33)**



Tree



Shrub



Herb

Figure 6.33: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

Tree density in the studied area was recorded highest (300 plants/ha) near to dam site, shrub density was highest (6050 plants/ha) around upstream area of dam whereas the herb diversity (86000 plants/ha) has been recorded highest near dam site. Shannon diversity Index for tree and herb species was found highest (2.16 for tree and 2.63 for herb) around downstream of dam site whereas the highest diversity (2.41) for shrub flora was recorded around dam site. Tree and herb species richness was also highest around downstream area while richness of shrub species was found highest (3.13) near to dam site. **(Table 6.37)**

Table 6.37: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3
Density (plants/ha)	250	300	325
Diversity (H')	2.16	1.86	1.38
Evenness (E)	0.98	0.96	0.71
Species Richness (SR)	3.47	2.41	2.34
Shrub			
Density (plants/ha)	5550	5850	6050
Diversity (H')	2.34	2.41	2.00
Evenness (E)	0.97	0.85	0.87
Species Richness (SR)	2.12	3.13	1.88
Herb			
Density (plants/ha)	76000	86000	83500
Diversity (H')	2.63	2.39	2.41
Evenness (E)	0.91	0.83	0.85
Species Richness (SR)	3.38	3.30	3.13

Detailed phytosociological characters of vegetation given in **Annexure 6.11.**

SITE 10: NIARE

Sampling locations

Sampling has been carried out at following sampling points.

Code	Site Description
S1	Downstream of damsite
S2	Dam site
S3	Upstream of damsite

Taxonomic Diversity

A total of 54 plant species has been recorded during the primary survey conducted for baseline study of floristics. Among these species, 52 belongs to Angiosperms whereas two species of Pteridophytes were also recorded. **(Figure 6.34).**

Species and Families

Higher plants of the project area were represented by a total of 11 trees (10 families), 14 shrubs (9 families) and 29 herbs (16 families) species **(Figure 6.35).**

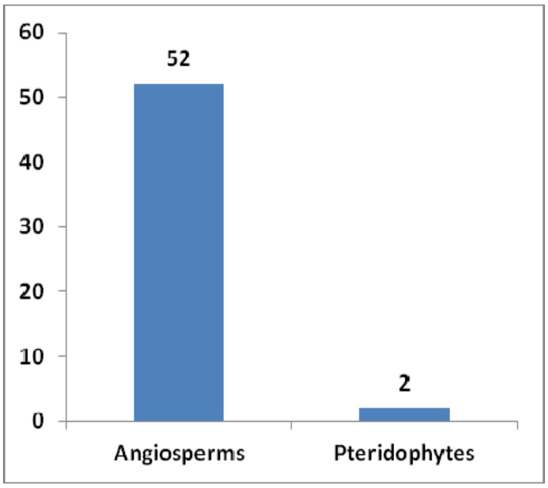


Figure 6.34: Number of species recorded under different taxonomic groups

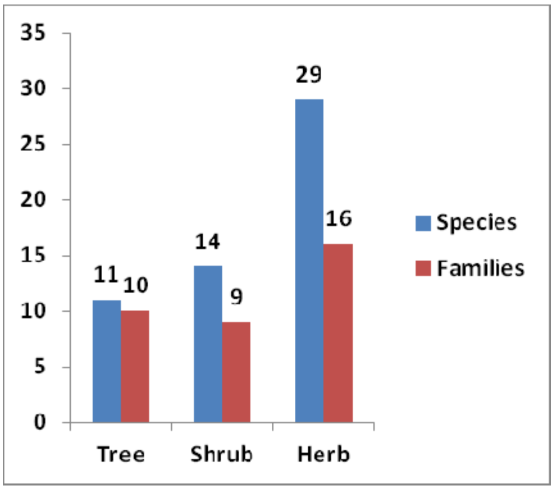
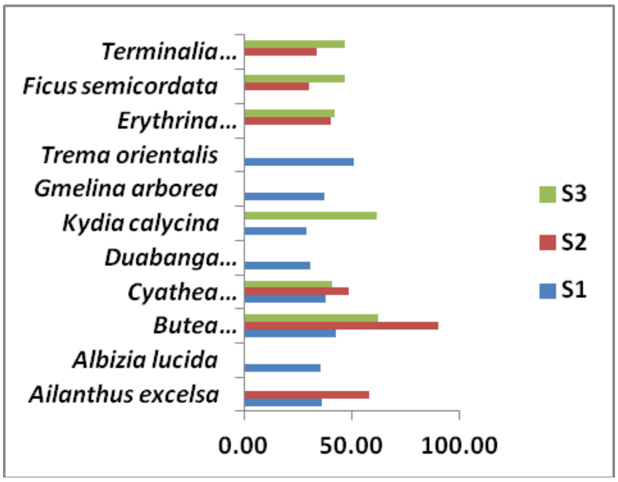


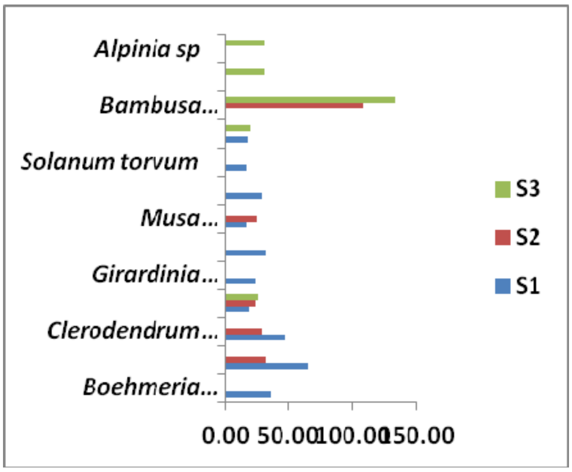
Figure 6.35: Number of Species and Families recorded

Importance Value Index (IVI)

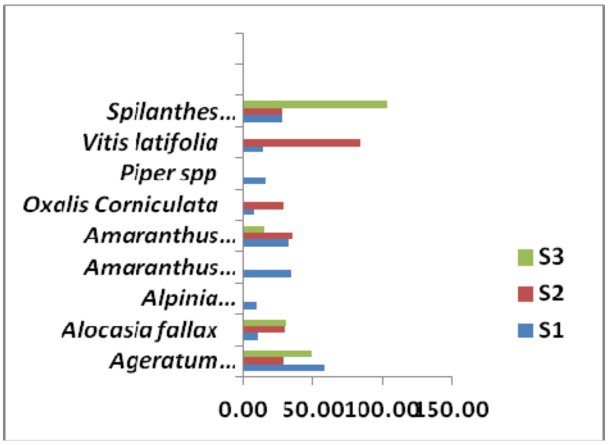
Butea monosperma, *Cyathea spinulosa*, *Terminalia myriocarpa* were the dominant trees in tree layer, *Bambusa pallida*, *Dendrocalamus hamiltonii*, and *Calamus flagellum* in shrub layer whereas *Spilanthes paniculata* and *Amaranthus viridis* were dominant herb species. **(Figure 6.36)**



Tree



Shrub



Herb

Figure 6.36: Importance Value Index (IVI) of Dominant plant species at different sampling locations

Density, Diversity, Evenness and Species Richness

Tree density was recorded from 225 to 300 plants/ha and it was recorded highest in upsream area of dam. Shannon diversity for tree species recorded highest (2.02) in downsream area of dam whereas the tree species richness was found highest (2.92) around downstream area. Density of shrub flora was recorded highest (8450 plants/ha) in upstream area, diversity of shrub was found highest (2.23) in downstraem area and Margalef species richness has been recorded highest (1.99) also in downstream of dam. Herb's density has been recorded highest (108500 plants/ha) at dam site, herb's diversity, evenness and species richness values were recorded highest in downstream area of proposed dam. **(Table 6.38)**

Table 6.38: Density, diversity, evenness and species richness at different sampling locations

Tree	S1	S2	S3
Density (plants/ha)	275	225	300
Diversity (H')	2.02	1.74	1.79
Evenness (E)	0.97	0.97	1.00
Species Richness (SR)	2.92	2.28	2.01
Shrub			
Density (plants/ha)	4500	5800	8450
Diversity (H')	2.23	2.04	1.67
Evenness (E)	0.97	0.93	0.72
Species Richness (SR)	1.99	1.68	1.75
Herb			
Density (plants/ha)	63500	108500	77000
Diversity (H')	2.42	2.26	2.09
Evenness (E)	0.98	0.83	0.81
Species Richness (SR)	2.89	2.60	2.83

Seasonal Variation in herbaceous flora

Tago: A notable seasonal variation has been recorded in herbaceous flora. Maximum (37) species has been recorded in monsoon season followed by summer (21) and winter seasons (17). Maximum stand density was also recorded during rainy season in all the sampling locations. **(Table 6.39)**

Table 6.39: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)			
		S1	S2	S3	S4
Winter	17	78000	47500	50500	46000
Summer	21	101000	72500	71000	67000
Rainy	37	166500	137500	119000	104000

Nyepin: In Nyepin HEP area, highest number of herb species (34) was recorded during rainy season whereas only 17 species of herbs were present during winter season. As far as the density of herb flora is concerned, highest density has been recorded during the monsoon season in all the sampling locations. **(Table 6.40)**

Table 6.40: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)			
		S1	S2	S3	S4
Winter	17	56700	50500	52000	36500
Summer	18	82000	52000	52000	44500
Rainy	34	145000	96000	93500	88000

Hiya: A total number of 19, 25 and 39 herb species has been recorded during winter, summer and rainy seasons respectively. Highest density (177500 plants ha^{-1}) was recorded at Site-I in rainy season whereas the minimum herb density (85500 plants ha^{-1}) was recorded at Site-3 during winter season. **(Table 6.41)**

Table 6.41: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)		
		S1	S2	S3
Winter	19	102500	88500	85500
Summer	25	114000	101500	100500
Rainy	39	177500	166000	176500

Dengsar: In proposed Dengser HEP area, a total number of 33 herb species has been recorded and all the species were present during monsoon season. Only 16 and 19 species were found during primary survey in summer and winter season respectively. Highest herb density (129000 plants ha^{-1}) was found at Site-I during rainy season whereas the lowest stand density (31000 plants ha^{-1}) has been recorded at Site-3 during summer season. **(Table 6.42)**

Table 6.42: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)		
		S1	S2	S3
Winter	19	60500	53500	35000
Summer	16	50700	39500	31000
Rainy	33	129000	114000	66500

Middle Subansiri (Kamala HEP): A total of 16, 15 and 30 herb species has been recorded during winter, summer and rainy seasons respectively. The highest stand density was recorded at Site-I (119000 plants ha^{-1}) during rainy season while the lowest stand density (27000 plants ha^{-1}) was found at Site-4 during summer season. **(Table 6.43)**

Table 6.43: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)			
		S1	S2	S3	S4
Winter	16	62500	39000	29000	29000
Summer	15	56500	39000	25500	27000
Rainy	30	119000	93500	49500	52500

Upper Subansiri: During primary study around proposed Upper Subansiri HEP area, a total of 37 herb species has been recorded. Among these 37 species, all the species were present in rainy season whereas only 19 and 21 species were recorded during winter season and summer seasons respectively. Stand density was found highest (110500 plants ha^{-1}) around Site-I during monsoon season whereas the lowest density of herb species (44500 plants ha^{-1}) was recorded at Site-4 in winter season. **(Table 6.44)**

Table 6.44: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)			
		S1	S2	S3	S4
Winter	19	69500	48000	50500	44500
Summer	21	76000	51500	52500	46000
Rainy	37	110500	79500	83000	76000

Lower Subansiri: 32, 19 and 17 herb species has been recorded during rainy, summer and winter season respectively. Maximum herb density (92500 plants ha-1) was recorded during rainy season at Site-4 whereas the lowest herb density (24700 plants ha-1) was found at Site-4 during summer season. **(Table 6.45)**

Table 6.45: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)			
		S1	S2	S3	S4
Winter	17	34500	33500	47000	39500
Summer	19	35600	33500	43100	24700
Rainy	32	80500	74500	78500	92500

Nalo: 21, 22 and 40 herb species has been recorded in winter, summer and rainy season respectively. Highest number of herbaceous species has been found in this area. Highest density of herb flora has been recorded during monsoon season whereas the lowest density of herb flora was found during winter season. **(Table 6.46)**

Table 6.46: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)		
		S1	S2	S3
Winter	21	47500	53000	65500
Summer	22	59000	53000	65500
Rainy	40	99000	85500	90000

Naba: Around this proposed HEP area, a total of 20, 19 and 34 herb species has been recorded in winter, summer and rainy season respectively. Highest density values were recorded during rainy season at all the sampling locations. **(Table 6.47)**

Table 6.47: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)		
		S1	S2	S3
Winter	20	57000	36500	61500
Summer	19	51000	35000	61500
Rainy	34	76000	86000	83500

Niare: A total of 17, 17 and 19 herb species have been recorded in winter, summer and rainy season respectively. The highest density of herb flora was recorded during rainy season in all the sampling locations. Among all the studied HEP's area, lowest number of herb species around this area. **(Table 6.48)**

Table 6.48: Number of species and stand density recorded in different seasons

Season	No. of Species	Density (Plants/ha)		
		S1	S2	S3
Winter	17	41500	56500	43500
Summer	17	44500	54500	33000
Rainy	17	63500	108500	77000

Lower plants:

Beside higher plants, the study area was also inventorised for minor floral species such as lichens, fungi, bryophytes and pteridophytes. Although these plants area under-utilized but ecologically equal important. During the primary survey, nine floral species were registered as pteridophytes form which proved a diverse growth in the study area and the lavish growth of pteridophytes contribute greatly to above ground greenery. Fungi flora included a total of two species dominated with Agaricaceae, a saprobic fungi grow mostly on organic debris, such as woodchip mulch. Three species of Bryophytes and two species of lichens were also recorded in this survey. **(Table 6.49)**

Table 6.49: Presence (*) of lower plants at different locations during the primary study

SN	Lower plants	Tago	Nypin	Hiya	Dengser	Middle Subansiri	Upper Subansiri	Lower Subansiri	Nalo	Naba	Niare
Pteridophytes											
1	*Adiantum caudatum*						*		*	*	*
2	*Adiantum philippense*		*					*			
3	*Adiatum sp*	*		*	*						
4	*Nephrolepis cordifolia*				*		*				
5	*Pteridium aquilinum*		*					*			

SN	Lower plants	Tago	Nypin	Hiya	Dengser	Middle Subansiri	Upper Subansiri	Lower Subansiri	Nalo	Naba	Niare
6	*Pteridium sp*	*		*		*		*			
7	*Pteris quadriaurita*	*	*	*	*		*				*
8	*Pteris vittata*				*						
9	*Selaginella sp*		*	*	*						
Bryophytes											
1	*Marchantia sp*	*					*				
2	*Riccia sp*			*		*					
3	UND		*								
Lichen											
1	*Physcia sp*		*	*			*				
2	*Usnea sp*		*		*						
Fungi											
1	*Agaricus sp.*	*			*		*				
2	UND					*					

UND= Unidentified

Seasonal variation

Seasonal variation in herbaceous flora in all three seasons has been assessed for sampling sites. The phytosociological data is given in **Annexure 6.11.**

Photographs

Spilanthes paniculata

Ageratum conyzoides

***Musa Forest* (Left bank of Upper Subansiri)**

***Oxalis* sp**

Thick growth of Pteridophytes

Orange orchards

6.11 Natural Resource Use in the Basin

Firewood and bamboo are the major natural resource utlised by communities in Lower Subansiri District and Timber, cane and bamboo in Upper Subansiri District. Details of quantity and value of major forest products in Subansiri basin during 2010-2011 is given in **Table 6.50**. [33]

Table 6.50: Quantity and value of major forest products in Subansiri basin during 2010-2011

District	State forest quantity			State forest quantity		Total Value of Quantities under col. 6&7 (In Rs.)
	Timber (cum)	Fire Wood (cum)	Total Value of Firewood (In Rs.)	Cane (Kaps)	Bamboo (no.)	
1	2	3	4	5	6	7
L/Subansiri	NA	721	23,25,062	-	300	354
Kurung Kumey	-	-	-	-	-	-
U/Subansiri	222	-	3,74,267	1850	2060	23,456

Details of distribution and uses of various economically important species in Subansiri basin is given below:

Table 6.51: Species and varieties of Dioscorea found in Subansiri Basin, Arunachal Pradesh

Sr.No	Species	Locations
1.	*Dioscorea oppositfolia*, *D. oppositifolia* *D. assamica*	Subansiri
2.	*D. pentaphylla*, *D. rumphii*, *D. suli*.	Between 450-1066 m.s.l. Subansiri

Table 6.52: Distribution of Bamboo in Subansiri Basin, Arunachal Pradesh

[33] Source: Principal Chief Conservator of Forests, Arunachal Pradesh, Itanagar

Sr. No.	Name of the species	Distribution
1	*Bambusa balcooa*	Lower Subansiri
2	*B. nutans*	Lower Subansiri
3	*B. pallida*	Lower Subansiri
4	*B. polymorpha*	Lower Subansiri
5	*B. tulda*	Lower Subansiri
6	*Dendrocalamus giganteus*	Upper Subansiri
7	*D. hamiltonii*	Lower Subansiri
8	*D. sahnii*	Lower Subansiri
9	*Phyllostachys bambusoides*	Lower Subansiri
10	*Pleioblastus simonii*	Lower subansiri

Table 6.53: Distribution of Canes in Subansiri Basin, Arunachal Pradesh

Sr. No.	Name of the species	Distribution
1.	*Calamus leptospadix*	Lower Subansiri
2.	*C. floribundus*	Lower Subansiri
3.	*C. flagellum*	Lower Subansiri
4.	*C. erectus*	Lower Subansiri
5.	*C. gracilis*	Lower Subansiri
6.	*C. inermis*	Upper Subansiri
7.	*C. latifolius*	Upper Subansiri and Lower Subansiri
8.	*C. khasianus*	Lower Subansiri and Upper Subansiri
9.	*Plectocomia assamica*	Lower Subansiri
10.	*P. himalayana*	Lower Subansiri

Lower and Upper Subansiri districts

The forest is a store house of a large number of timbers, medicinal herbs, fruits and other life support species. Species of *Piper*, *Terminalia, Alpinia, Clerodendrum, Houttuynia, Alstonia, Oroxylum, Hedychium,* etc., are commonly used for medicinal purposes. Likewise, the NTFPs are of great use to the local inhabitants. The Palms and Bamboos play an important role in the indigenous tribe's daily use.

Non Timber Forest Produce etc

From the survey, it was observed that most of the Non Timber Forest Produce (NTFPs) viz Housing materials, vegetables, wild fruits, mushrooms, medicinal plants, food items etc is collected by the people from their adjoining jungles. The bamboos and canes are a part of the culture. The local people not only use these bamboos and canes for fencing but as major materials for fuel wood and house construction. They utilize the same as house hold utensils such as for making furniture, handicraft, decorative items, agriculture implements, musical instruments, fighting weapons, baskets and even baby carriers. Bamboo shoots are essential cooking ingredients of the local inhabitants. The common names along with their botanical names are tabulated in **Table 6.54**.

Housing Material

Cane is used to tie the pieces of bamboo and timber together. The roof is thatched with dry Palm (*Livistona jenkinsiana*) and ammung (*Erianthus* sp.). The houses have extensive use of bamboo and wood as bamboo sheets form the floor and the wall and the wooden logs serve as the main pillars over which the structure of the house is raised. Almost all the houses are made in rectangular form having two or three doors according to the individual will and fashion. The doors have wooden ladder, which leads to the ground. The most important feature is the fire place (meram). Over the fire hearth (perap) hangs a square-shaped bamboo shelf used to dry meat, fish, etc. Meram is prepared with the help of bamboo, wood, soil and cane. Some of the varieties of bamboos viz. *Dendrocalamus hamiltonii, Arundinaria* sp., *Bambusa tulda*, and *B. pallida* are used for wall, floor and ropes for binding the poles. House is decorated with skulls of mithuns, jaws of pigs and wild boars on the wall.

Table 6.54: List of bamboo and cane species used for house construction

Local Name	Common name	Scientific name	Family
Bamboo			
Bash	Jati Mistenga	*Bambusa tulda*	Poaceae
Shim	Bhaluka bah	*Bambusa balcooa*	Poacea
Epo	Kako bah	*Dendrocalamus hamiltonii*	Poaceae
Kite bash	Kata bah	*Arundinaria bamboosa*	Poaceae
Rattans/canes			
	Lejai	*Calamus floribundus*	Arecaceae
	Raidang	*Calamus flagellum*	Arecaceae
	Sundi	*Calamus guruba*	Arecaceae
	--	*Calamus tenuis*	Arecaceae
Trees			
	Hollock	*Terminalia myriocarpa*	Combretaceae
	Gamari	*Gmelina arborea*	Verbenaceae
Himoru	Shemal	*Bombax ceiba*	Bombacaceae
	Khokon	*Duabanga grandiflora*	Sonneratiaceae
	Jutuli	*Altingia excelsa*	Hamamelidaceae

Medicinal Plants

Due to remote location, the surveyed villages had minimal usage to the modern medicines. The health centres are concentrated in far off town areas. For these unavoidable circumstances, these locals opt to their traditional healing practices. They largely depend on the nature to cure and take care of them. They practice *Shamanism* and spirit prayers through the Priests. Apart from it, they use the local flora and fauna to treat their ailments. The commonly used medicinal plants in the study sites are *Houttuynia cordata, Spilanthes acmella, Bidens pilosa, Clerodendrum colebrookianum*, etc. **Table 6.55**. The use of medicinal plants is from various plant parts. They are from whole plants to root, rhizome, leaves, bark, stem, flowers, petioles, buds, shoots, etc. These are used to cure from common cold, fever to least cure diseases, such as cancer, pneumonia, diabetes to dog bites.

Table 6.55: Locally used plants for medicinal purposes

Sr. No.	Scientific Name	Local name	Family	Disease	Plant part used
Herbs					
1.	*Ageratum conyzoides*	Namninyn	*Asteraceae*	Cuts and burns	Leaves
2.	*Alpinia galanga*	Talang	*Zingiberaceae*	Fractured bones	Rhizomes
3.	*Azadirachata indica*	Neem	*Meliaceae*	Skin allergy	Leaves
4.	*Alocasia macorrhiza*	Kotchu	*Araceae*	Pain reliever of insect bite	Leaves
5.	*Bidens pilosa*	Bayap	*Asteraceae*	Antiburns and cuts	Leaves
6.	*Centella asiatica*	Mani	*Apiaceae*	Stomach disorder	Whole plant
7.	*Clerodendrum colebrookianum*	Oign	*Verbenaceae*	Checks High BP	Leaves

Sr. No.	Scientific Name	Local name	Family	Disease	Plant part used
8.	*Houttuynia cordata*	Elo	*Saururaceae*	Appetizer	Whole plants
9.	*Hydrocotyle sibthorpoides*	Mani	*Apiaceae*	Stomachic	Whole plants
Shrubs					
1.	*Datura stramonium*	Yayu	*Solanaceae*	Dog bite, burnt skin	Flower
2.	*Osbeckia nepalensis*	Onkuk	*Melastomataceae*	Liver pain and constipation	Fruit & leaves
Tree					
1.	*Bauhinia purpurea*	Hoingchangne	*Caesalpiniaceae*	Dysentry	Bark
2.	*Oroxylum indicum*	Bhatgila	*Bignoniaceae*	Jaundice & diarrhea	Bark
3.	*Syzygium cumini*	Jamun	Myrtaceae	Asthma, constipation	Fruit/ flower buds

Vegetables: From the survey it was found that wild vegetables played a major role to feed their routine diet. Plants such as *Amaranthus, Spilanthes, Houttuynia cordata* are eaten wholly while stem and rhizome of *Colocasia esculentus* are cooked. *Clerodendrum, Pouzolzia bennettiana, Hydrocotyle* sp., etc. are usually boiled with fermented bamboo shoot and some are used as raw salads.

Wild Edible Plants: From our recent first survey in the site, few wild fruits consumed by the locals were known to us. They were identified as *Citrus medica, Artocarpus, Ficus* sp., *Terminalia bellirica*, etc. **Table 6.56**.

Table 6.56: Wild edible Fruits

Sr.No.	Botanical Name	Local Name	Family	Edible parts
1.	*Artocarpus lakoocha*	Malang	Moraceae	Ripened Fruits
2.	*Castanopsis indica*	Kora	Fagaceae	Nuts
3.	*Citrus medica*	Narang	Rutaceae	Fruits
4.	*Mahonia napaulensis*	Tamin	Berberidaceae	Fruits
5.	*Musa* sp.	Kopak	Musaceae	Fruits
6.	*Rosa* sp.	Ningkhe	Rosaceae	Fruit
7.	*Rhus semialata*	Amashi	Rosaceae	Berry
8.	*Rubus* sp.	Endum Kurum	Rosaceae	Berry

Dye Yielding Species: Tribal communities are using dyes for various purposes such as Dyeing, tattooing, etc., for which *Rubia cordifolia* was the dominant dye yielding species in the study area.

Flowers: Many beautiful wild flowers like *Osbeckia octandra*, *Osbeckia chinensis*, *Morinda angustifolia*, orchids such as *Vanda* sp., *Eria* sp. and *Rhynchostylis retusa*, *Begonia* sp., *Impatiens* sp. etc were encountered in the region during the field studies.

Kurung Kumey district

Edible plants: The use of wild plants as food is very common in the district, the local inhabitants knew about the use of wild plants in a traditional method. During the study it revealed that about 40 plant species that are used as food or have a potential for food value. The details are given in the **Table 6.57**.

Table 6.57: Edible plants of present in the study area

Sr. No.	Name of the Species	Family	Mode of Use
1.	*Diploknema butyraceoides*	Sapotaceae	Ripened seeds are edible

Sr. No.	Name of the Species	Family	Mode of Use
2.	*Alternanthera sessilis*	Amaranthaceae	Tender shoots and leaves eaten at pot herb or soup
3.	*Amomum subulatum*	Zingiberaceae	Seeds eaten raw
4.	*Arenga obtusifolia*	Arecaceae	The stem pith powder is eater and commonly known as Tache.
5.	*Bambusa balcooa*	Poaceae	Young shoots are edible after boiling
6.	*Calamus erectus*	Araceae	Young stems boiled and used as vegetable
7.	*Cardamine hirsuta*	Brassicaceae	Young shoots as leafy vegetable
8.	*Castanopsis indica*	Fagaceae	Roaster seeds eaten
9.	*Cayratia trifolia*	Vitaceae	As leafy vegetable
10.	*Clerodendron colebrookianum*	Verbenaceae	Young leaves boiled and used as vegetable
11.	*Colocasia fallax*	Araceae	Spathe boiled and fried.
12.	*Colocasia esculenta*	Araceae	Young leaves and petioles are edible.
13.	*Debregeasia longifolia*	Urticaceae	Roasted fruits eaten
14.	*Dendrocalamus hamiltonii*	Poaceae	Young shots are eaten after boiling
15.	*Dillenia indica*	Dilleniaceae	Fruits as vegetable
16.	*Dioscorea bulbifera*	Dioscoreaceae	Tubers Bulbils are eaten after through boiling
17.	*Dioscorea pentaphylla*	Dioscoriaceae	Tuber often eaten after through boiling.
18.	*Elatostemma platyphylla*	Urticaceae	Young leaves as vegetable.
19.	*Ficus hispida*	Moraceae	Unripe fruits as vegetable
20.	*Fragaria nubicola*	Rosaceae	Ripen fruits are edible
21.	*Girardinia diversifolia*	Urticaceae	Leaves & young shoots Edible after through boiling
22.	*Girardinia diversifolia*	Euphorbiaceae	Young shoots as leafy vegetable
23.	*Houttuynia cordata*	Piperaceae	Young shoots as leafy vegetable
24.	*Hydorcotyle himalaica*	Apiaceae	Young shoots as leafy vegetable
25.	*Musa balbisiana Colla*	Musaceae	Pith eaten after cooking
26.	*Musa ornata*	Musaceae	Pith and flowers edible.
27.	*Mussaenda roxburghii*	Rubiaceae	Leaves as leafy vegetable
28.	*Natsiatum herpeticum*	Icacinaceae	Leaves and slender shoots are edible after cooking
29.	*Oenanthe thomsonii*	Apiaceae	Leaves
30.	*Piper sylvaticum*	Piperaceae	Young leaves edible.
31.	*Phlogacanthus curviflorus*	Acanthaceae	Leaves as leafy vegetable
32.	*Polygonum chinensis*	Polygonaceae	Young shoots as leafy vegetable
33.	*Rhynchotechum ellipticum*	Gesneriaceae	Leaves as veg.
34.	*Rubus sumatranse*	Rosaceae	Ripen fruits are edible
35.	*Saurauia armata*	Actinidiaceae	Raw fruits eaten to control thirsty
36.	*Solanum indicum*	Solanaceae	Young fruits fried and eaten raw
37.	*Solanum nigrum*	Solanaceae	Young leaves as vegetable.
38.	*Spilanthes acmella*	Asteraceae	Young shoots edible
39.	*Spilanthes calva*	Asteraceae	Leaves are used as leafy vegetable
40.	*Toddalia asiatica*	Rutaceae	Fruits & Leaves

Timber valued plants: Table 6.58 show the timber valued plants and their potential uses.

Table 6.58: Timber valued trees present in Kurung Kumey district

Sr. No.	Name of the Species	Uses
1.	*Acer thomsonii*	Beams, pole, fuel wood
2.	*Actinodaphne angustifolia*	House construction, poles and embankment.
3.	*Pterospermum acerifolium*	Cabinet, Planks
4.	*Alnus nepalensis*	Cabinet, Planks, commercial purpose.
5.	*Altingia excelsa*	Beams, pole, fuel wood
6.	*Artocarpus heterophylla*	Furniture, house construction
7.	*Bischofa javanica*	Miscellaneous work, fuel
8.	*Bridelia retusa*	Cabinet, poles, embankment, fuel wood.

Sr. No.	Name of the Species	Uses
9.	*Castanopsis lancefolia*	Miscellaneous work
10.	*Castanopsis indica*	House constriction
11.	*Cinnamomum bejolghota*	Beams, pole
12.	*Cinnamomum tamala*	Cabinet, poles
13.	*Dillenia indica*	Beams, pole
14.	*Dipterocarpus retusus*	Beams, pole, House construction, Commercial purpose
15.	*Dysoxylum binectariferum*	Beams, fuel wood
16.	*Elaeocarpus floribundus*	House construction
17.	*Exbucklandia populnefolia*	House construction
18.	*Ficus* sp.	Miscellaneous work
19.	*Lindera neesiana*	Miscellaneous work, House construction
20.	*Lithocarpus elegans*	Cabinet, Planks
21.	*Macaranga denticulata*	Poles and beams
22.	*Magnolia pterocarpa*	Furniture, house construction
23.	*Mangifera sylvatica*	Beams, pole, planks
24.	*Mesua ferrea*	Furniture, house construction,
25.	*Michelia doltsopa*	Furniture
26.	*Phobe attenuata*	Beams, pole
27.	*Schima wallichi*	House construction, poles, planks
28.	*Abies densa*	Furniture, house construction
29.	*Sterculia villosa*	Beams, pole, fuel wood
30.	*Sterculia hamiltonii*	Cabinet, Planks
31.	*Sterculia villosa*	Furniture, house construction, commercial purpose
32.	*Terminalia alata*	House construction, commercial purposes
33.	*Terminalia chebula*	Beams, pole
34.	*Terminalia myriocarpa*	Furniture, house construction, commercial purpose
35.	*Toona ciliata*	Furniture, house construction, commercial purpose
36.	*Trewia nudiflora*	Furniture, house construction,

Species of horticultural importance: The rich and diverse flora of the district harbors a large number of wild horticulture important species. These include specie like *Begonia aborensis, Begonia palmatum*, *Colocasia fallax*, *Arenga obtusifolia, Erythrina suberosa*, *Gonatanthus pumilus, Globba multiflora*, *Hedychium coccineum*, *Hedychium rubrum*, *Hedychium stenopetalum*, *Hitchenia careyana, Hoya spp., Luculia gratissima*, *Mastersia assamica, Raphidophora glauca, Schefflera venulosa, Sauropus trinervius, Thunbergia grandiflora, Mussaenda incana, Silvianthus bracteatus, Tacca integrifolia etc.*

***Non-timber forest products*:** Non-timber forest products (NTFP) were collected by the local inhabitants from time to time depending upon the requirement. NTFPs are generally collected for the own consumption and use. They use it for different purposes such as food, house construction/ repair, preparation of domestic household materials, medicine, beverage etc. The surplus collection is occasionally sold in the markets which fetch a good amount of money to the local people

Bamboo: The most commonly available bamboo species of the district are *Bambusa balcooa, Bambusa pallida, Bambusa nutans, Chimonobambusa callosa, Chimonobambusa grifithiana, Dendrocalamus giganteus, Dendrocalamus hamitonii, Dendrocalamus hookeri,* and *Schizostachyum polymorpha*. Demand of bamboo is high in the paper and pulp industries; however no commercial extraction of the bamboo is reported from the district.

Canes: During the study, it revealed that, five species of canes viz. *Calamus erectus, Calamus flagellum*, *Calamus floribundus*, *Calamus gracilis*, *Calamus leptospadix* are of maximum use in the district. All the canes are having high commercial importance. The canes are in great demand in the furniture industry in the state as well in the other parts of our country. Besides their traditional use of furniture, basket making, canes are also used profusely house construction in the district.

Medicinal Plants: Traditional use of plants is a part of the cultural heritage of the people of Kurung Kumey. Due to non availability of easy modern drugs, the local inhabitants are fully depends upon the plants or plants product to cure different ailment. The district harbours a wide range of important medicinal plants which have tremendous commercial value. The important species that are being used in the folklore system are *Alpinia nigra* (for rheumatic pain), *Aconitum ferox* (Rheumatism), *Ainsliaea latifolia* (Stomachache), *Ajuga bracteosa* (Urinary disorder, Purgative), *Ammomum subulatum* (Cold & cough.), *Begonia sikkimensis* (Febrifuge), *Berberis wallichiana* (antidotes), *Buddleja asiatica* (Headache, fore head pain), *Callicarpa arborea* (Gastric trouble), *Cinnamomum tamala* (Diarrhoea), *Clinopodium umbosum* (Antiseptic), *Coelogyne fuscescens* (Stomach ailment), *Coix lachryma-jobi* (Urinary disorder), *Colocasia affinis* (Febrifuge), *Costus speciosus* (Breast swelling, Health tonic), *Dendrocalamus hamiltonii* (Menstrual disorder), *Ephedra gerardiniana* (Bronchitis, respiratory problems), *Eurya acuminata* (Rheumatic pain, Insect antidote), *Ficus semicordata* (Purgative)**,** *Globa multiflora* (sprain or swelling),*Gynocardia odorata* (Epilepsy), *Hedyotis scandens* (eye ailment, conjunctivitis) *Morinda angustifolia* (general bodyache), *Neopicrorhiza scruphulariiflora* (Blood dysentery), *Rhaphidophora glauca* (Body ache), *Rubia cordifolia* (Leucorrhoea), *Rubus ellipticus* (Dysentery, Jaundice).

6.12 Endemic Flora of Subansiri Basin

Endemic species reported from Subansiri basin, Arunachal Pradesh: An inventory of 62 endemic species (of which 12 are also threatened species namely 5 Endangered, 2 Vulnerable, 3 Rare and 2 Indeterminate) reported from Subansiri basin is given in **Table 6.59.**

Table 6.59: Endemic species reported from Subansiri basin

Sr. No.	Botanical Name	Location	Local Name	Status (IUCN) & Remarks
RANUNCULACEAE				
1.	*Aconitum assamicum*	Arunachal Pradesh, 3900-4300 m		Endemic
2.	*Anemone howellii*	Subansiri, 1500-2500 m		Endemic
3.	*Caltha palustris var. palustris*	Arunachal Pradesh		Endemic
4.	*Trollius farreri*	Arunachal Pradesh		Endemic
MAGNOLIACEAE				
5.	*Magnolia caveana*	Subansiri, 400-800 m	Pan-sopa; Phul-sopa (Asm.)	Endemic
6.	*Magnolia gustavii*	Subansiri, 300-1000 m	Khorokia-sopa (Asm.)	Endemic
7.	*Michelia doltsopa*	Subansiri, 1300-1700 m		Endemic
8.	*Michelia wardii*	Arunachal Pradesh		Endemic
ILLICIACEAE				
9.	*Illicium cambodianum*	Subansiri, 1600-1800 m		Endemic
SCHISANDRACEAE				
10.	*Schisandra propinqua*	Arunachal Pradesh		Endemic
FUMARIACEAE				
11.	*Dicentra roylei*	Subansiri, 1400-1600 m		Endemic
12.	*Capparis acutifolia*	Subansiri, 500-1300 m	Keta-har (Asm); Dieng-sning-sning (Kh)	Endemic

Sr. No.	Botanical Name	Location	Local Name	Status (IUCN) & Remarks
13.	*Garcinia acuminata*	Subansiri, 500-1200 m	Kuji thikera (Asm)	Endemic
14.	*Eurya arunachalensis*	Subansiri, 1500-3100 m		Endemic
15.	*Pyrenaria barringtonifolia*	Subansiri, 100-500 m	Gunbang (Abor); Bon madhuri (Asm)	Endemic
		BALSAMINACEAE		
16.	*Impatiens laevigata*	Subansiri, 200-1000 m		Endemic
17.	*Impatiens latiflora*	Subansiri, 300-1200 m		Endemic
18.	*Impatiens porrecta*	Subansiri, 300-1500 m		Endemic
		VITACEAE		
19.	*Cissus assamica*	Subansiri, 600-1500 m		Endemic
		HYDRANGEACEAE		
20.	*Pileostegia subansiriana*	Subansiri, ca. 1800 m		Endemic
		MYRTACEAE		
21.	*Syzygium aborense*	Subansiri, 640-762 m	Pon-kar (Abor); pankala-sing (Adi)	Endemic
		BEGONIACEAE		
22.	*Begonia aborensis*	Subansiri, 400-1200 m		Endemic (Rare)
23.	*Begonia scintillans*	Lower Subansiri District, in the submergence area of Lower Subansiri HEP Abor Hills. It is also recorded from Lohit and Dibang Valley district), Dibang Valley, Siang, Tirap at an altitude of 500-2000m in Arunachal Pradesh		Endemic (Indeterminate)
24.	*Begonia tessaricarpa*	Lower Subansiri District, in the submergence area of Lower Subansiri HEP and Assam		Endemic (Indeterminate)
		RUBIACEAE		
25.	*Mycetia listeri*	Subansiri, 250-1200 m		Endemic
26.	*Ophiorrhiza talevalliensis*	Subansiri, 2500-3000 m		Endemic
27.	*Polyura geminata*	Subansiri, 1000-1500 m		Endemic
28.	*Psychotria burkillii*	Subansiri, 300-1000 m		Endemic
		ERICACEAE		
29	*Agapetes atrosanguinea*	Near Pange, Manipolyang to Pange, Talley Valley Wildlife Sanctuary, Lower Subansiri district		Endemic (Vulnerable)
30	*A. refracta*	Near Lebbya Penggo Pass, Talley Valley, Lower Subansiri district		Endemic (Vulnerable)
31	*Gaultheria seshagiriana*	Pange to Talley Valley-Lower Subansiri, West Kameng, and Siang districts		Endemic

Sr. No.	Botanical Name	Location	Local Name	Status (IUCN) & Remarks
32	*Rhododendron falconeri* subsp. *eximium*	Subansiri and Kameng, 2700-3000 m and 3000-3500 m		Endemic (Endangered)
33	*R. nuttallii*	Subansiri, 1200-3650		Endemic (Rare)
34	R. santapauii	Subansiri, 1600 metres		Endemic (Endangered)
35	*R. subansiriense*	Subansiri, 2550-2800		Endemic, known only from type collection (Endangered)
36	*Vaccinium dendrocharis* ssp. *talle*	Lebya-Penggo Pass, Talley Valley, Wildlife Sanctuary Lower Subansiri, 2725 m. and West Kameng, district		Endemic (Endangered)
		MYRSINACEAE		
37	*Maesa arunachalensis*	Subansiri 800-1200 metres in primary forests		Endemic
		GESNERIACEAE		
38	*Aeschynanthus parasiticus*	Subansiri		Endemic
39	*Loxostigma griffithii*	Subansiri		Endemic
40	*Rhynchoglossum lazulinum*	Subansiri		Endemic
		PEDALIACEAE		
41	*Phlogacanthus tubiflorus*	Subansiri		Endemic
		VERBENACEAE		
42	*Clerodendrum lasiocephalum*	Subansiri		Endemic
		EUPHORBIACEAE		
43	*Baliospermum micranthum*	Subansiri		Endemic
		URTICACEAE		
44	*Pilea insolens*	Subansiri		Endemic
		ORCHIDACEAE		
45	*Coelogyne arunachalensis*	Lower Subansiri		Endemic
46	*Dendrobium cathcartii*	Subansiri		Endemic
47	*Dendrobium hookerianum*	Subansiri		Endemic
48	*Dendrobium sulcatum*	Subansiri		Endemic
49	*Epipogium indicum*	Subansiri		Endemic
50	*Eria clausa*	Subansiri		Endemic
51	*Eria ferruginea*	Subansiri		Endemic
52	*Eria jengingensis*	Subansiri		Endemic
53	*Eria sharmae*	Subansiri		Endemic
54	*Liparis assamica*	Subansiri		Endemic
55	*Liparis distans*	Subansiri		Endemic
56	*Liparis plantaginea*	Subansiri		Endemic
57	*Pholidota pygmaea*	Subansiri		Endemic
58	*Pholidota wattii*	Subansiri		Endemic (Rare)
		AGAVACEAE		
59	*Peliosanthes teta* ssp. *humilis*	Subansiri		Endemic
		ARACEAE		
60	*Lagenandra undulata*	Subansiri		Endemic
		ARECACEAE		
61	*Livistona jenkinsiana*	Upper and Lower Subansiri districts		Endemic to North East India
		CYPERACEAE		
62	*Mapania arunachalensis*	Subansiri		Endemic

Source: Red Data Book Plants of India Volume 1-3, Edited by M P Nayar & A R K Sastry 1987-88; Flora of Arunachal Pradesh Vol.1-3, 1996-2009; Biodiversity Characterisation at Landscape Level in

North-East India using Satellite Remote Sensing and Geographic Information System, Indian Institute of Remote Sensing, 2002; Ashish Paul, M. L. Khan, A. Arunachalam and K. Arunachalam: Biodiversity and conservation of Rhododendrons in Arunachal Pradesh in the Indo-Burma biodiversity hotspot, Current Science, vol. 89, no. 4, 25 August 2005.

The Table 6.59 indicates that 62 endemic species (12 of which are threatened) representing 23 families are reported from Subansiri Basin. Orchidaceae family has 14 species (1 threatened) , Ericaceae has 8 species (7 threatened), followed by 5 species of Fumariaceae, 4 species each of Ranunculaceae, Magnoliaceae and Rubiaceae, 3 each of Balsaminaceae, Begoniaceae (3 threatened) and Gesneriaceae and 1 species each of family Illiciaceae, Schisandraceae, Vitaceae, Hydrangeaceae, Myrtaceae, Myrsinaceae, Pedaliaceae, Verbenaceae, Euphorbiaceae, Urticaceae, Agavaceae, Araceae, Arecacecae (1 threatened)and Cyperaceae. Further, 5 species namely *Rhododendron falconeri* subsp. *eximium, R. santapauii*, *R. subansiriense, Vaccinium dendrocharis* ssp. *talle* and *Livistona jenkinsiana* are assessed as Endangered, 2 species namely *Agapetes atrosanguina* and *Agapetes refracta* are assessed as Vulnerable, 3 species namely *Begonia aborensis, Rhododendron nutalli* and *Pholidota wattii* are assessed as Rare and 2 species namely *Begonia scintillans* and *Begonia tessaricarpa* are assessed as Indeterminate species in Subansiri basin[34]. Further, *5* endemic and threatened species namely *Begonia aborensis, Begonia scintillans, Begonia tessaricarpa, Pholidota wattii,* and *Livistona jenkinsiana* are recorded from submergence areas of Lower Subansiri HEP, Lower Subansiri district.

238 endemic species has been listed from Arunachal Pradesh, out of which Subansiri Basin has 62 endemic species which accounts for 26% of the State's endemic flora. This is indicative of high endemism in the Subansiri Basin. 7 endemic species of Ericaceae, 3 endemic species of Begoniaceae and 1 species each of Orchidaceae and Arecaceace are threatened as well.

Statistics of 62 Endemic and threatened endemic species is given in **Table 6.60**:

Table 6.60: Statistics of Endemic Species and number of threatened endemic species

Sr. No.	Family	No of Endemic species	No. of Threatened endemic species
1	*Ranunculaceae*	4	
2	*Magnoliaceae*	4	
3	*Illiciaceae*	1	
4	*Schisandraceae*	1	
5	*Fumariaceae*	5	
6	*Balsaminaceae*	3	
7	*Vitaceae*	1	
8	*Hydrangeaceae*	1	
9	*Myrtaceae*	1	
10	*Begoniaceae*	3	3
11	*Rubiaceae*	4	
12	*Ericaceae*	8	7
13	*Myrsinaceae*	1	
14	*Gesneriaceae*	3	
15	*Pedaliaceae*	1	
16	*Verbenaceae*	1	
17	*Euphorbiaceae*	1	
18	*Urticaceae*	1	

34 Materials for the Flora of Arunachal Pradesh, Volume I, 1996, Volume II, 2008 and volume III, 2009, ArunachalPradesh, H J Chowdhery in Floristic diversity and conservation strategies in India , 1999 and Red Book of Indian Plants (Volume I-III, edited by M P Nayar and A R K Sastry , 1990), Materials for the Flora of Arunachal Pradesh, Volume I, 1996, Volume II, 2008 and volume III, 2009.

Sr. No.	Family	No of Endemic species	No. of Threatened endemic species
19	*Orchidaceae*	14	1
20	*Agavaceae*	1	
21	*Araceae*	1	
22	*Arecaceae*	1	1
23	*Cyperaceae*	1	
	Total	62	12

The endemic species reported to occur in Subansiri basin is shown in **Figure 6.37**.

6.13 Threatened plants reported from Subansiri Basin of Arunachal Pradesh

An inventory of 36 threatened species (including 12 endemic species) reported from Subansiri basin has been prepared[35] [36] [37].Distribution and altitude details of 36 plants (6 Endangered, 15 Vulnerable, 13 Rare and 2 Indeterminate) reported to occur in Subansiri Basin are given below.

Category: Endangered

1. *Agapetes miranda* is reported near Lebbya-Penggo Pass, Talley Valley Wildlife Sanctuary, Lower Subansiri district at 2725 m.
2. *Rhododendron falconeri* ssp. *eximium* is also an Endemic species reported from Subansiri and Kameng in the altitudinal range of 2700-3000 m and 3000-3500 m
3. *R. santapauii* is also an endemic species reported from Subansiri on open slopes.
4. *R.subansiriense* is also an Endemic reported from Subansiri at 2600-2800 m
5. *Vaccinium dendrocharis* ssp. *talle* is reported near Lebya-Penggo Pass, Talley Valley, Wildlife Sanctuary Lower Subansiri district at 2725 m. The species is also Endemic to Lower Subansiri district and West Kameng District (Arunachal Pradesh)
6. *Livistona jenkinsiana* is reported in moist forests upto 1000 metres from mountain valleys of Lohit and Tirap Districts and Lower and Upper Subansiri Districts (Arunachal Pradesh). This palm is among the commonly met with palms in the forests of Arunachal Pradesh. However, the species has been assessed as Endangered. It is also an Endemic species to North East India and is assessed as Endangered due to extensive deforestation and degradation.

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[35] *Red Book of Indian Plants (Volume I-III, edited by M P Nayar and A R K Sastry, 1990), and Materials for the Flora of Arunachal Pradesh, Volume I, 1996, Volume II, 2008 and volume III, 2009.*
Wildlife in a Changing World - An Analysis of the 2008 IUCN Red List of Threatened Species. Gland, Switzerland, 180pp.
[37] *Ashish Paul, M. L. Khan, A. Arunachalam and K. Arunachalam Biodiversity and conservation of Rhododendrons in Arunachal Pradesh in the Indo-Burma biodiversity hotspot, Current Science, vol. 89, no. 4, 25 August 2005.*

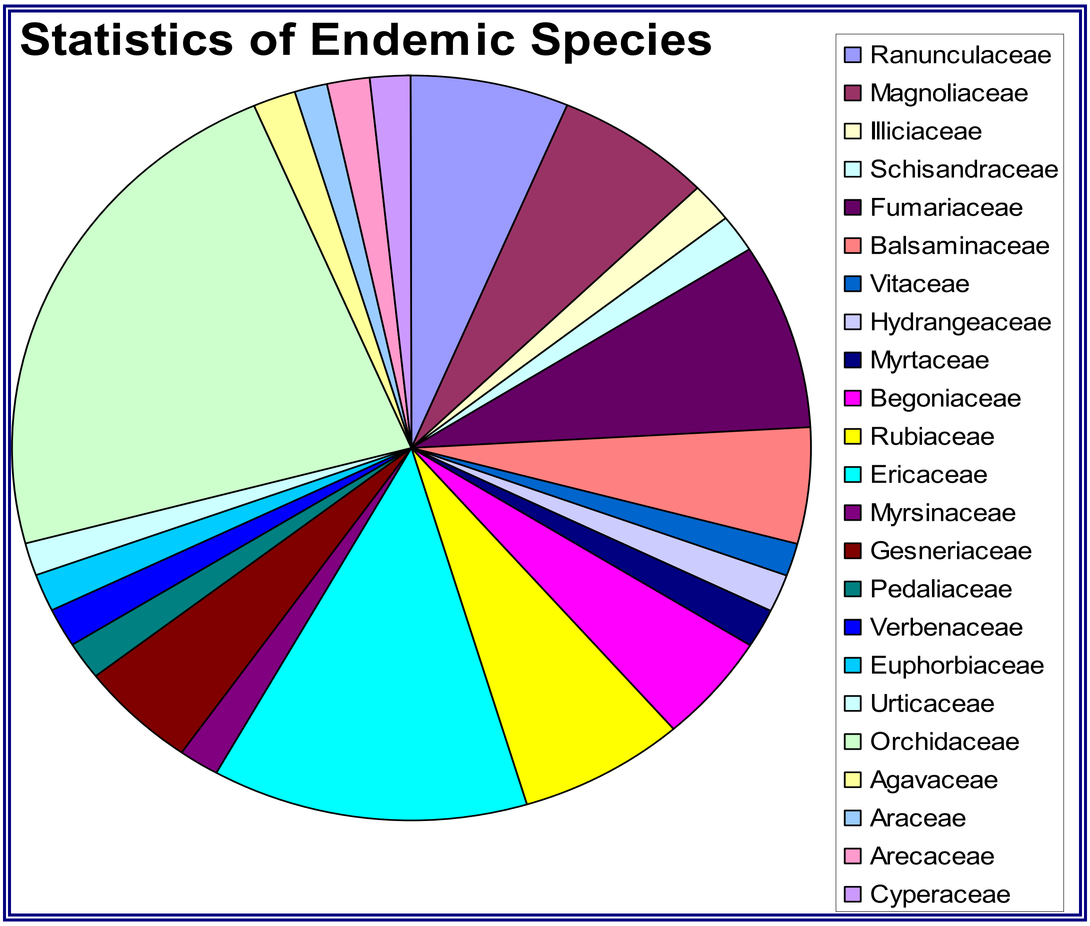

Figure 6.37: Endemic species in Subansiri Basin

Category: Vulnerable

1. Agapetes atrosanguinea is reported near Pange, Manipolyang to Pange, Talley Valley Wildlife Sanctuary, Lower Subansiri district at 1800 m. The species is also Endemic to Arunachal Pradesh.

2. *A. buxifolia* is reported near Manipolyang to Pange, Talley Valley Wildlife Sanctuary, Lower Subansiri district at 2725 m 1700-1800 m.

3. *A. praestigiosa* is reported near Pange to Lebbya-Penggo Pass), Talley Valley Wildlife Sanctuary, Lower Subansiri district at 1900-2000 m.

4. *A. refracta* is reported near Lebbya Penggo Pass, Talley Valley Wildlife Sanctuary, Lower Subansiri district at 2732 m. The species is Endemic to Arunachal Pradesh.

5. *A. smithiana* var *major* is reported near Lebbya Penggo Pass, Talley Valley Wildlife Sanctuary, Lower Subansiri district at 2725 m.

6. *Coptis teeta* is reported from upper reaches of Upper Subansiri district at 2500-3000 m

7. Leucothoe griffithiana is reported near Pange to Talle Valley, Talley Valley Wildlife Sanctuary, Lower Subansiri district at 2400-2800 m.

8. Panax pseudo-ginseng is reported from Subansiri at 1500-2000 m.

9. *Rhododendron arboreum* ssp. *delavayi* is reported near Pange to Lebbya – Penggo Pass, Talley Valley Wildlife Sanctuary, Lower Subansiri district at 2000 m.

10. R. boothii is reported in Talley Valley, Talley Valley Wildlife Sanctuary, Lower Subansiri district.

11. *R.vaccinioides* is reported from Talley valley at 2432 metres, Talley Valley Wildlife Sanctuary, Lower Subansiri district.

12.Vaccinium dunalianum var. *brevifolium* is reported in Talley Valley, Talley Valley Wildlife Sanctuary, Lower Subansiri District at 2000 m.

13. V dunalianum var. *megaphyllum* is reported in Talle Valley, Talley Valley Wildlife Sanctuary Lower Subansiri District.

14.V. nuttallii is reported in Pange to Tale Valley, Talley Valley Wildlife Sanctuary Lower Subansiri District at 2200-2500 m.

15.V. subdissitifolium is reported Pange to Talle Valley, Talley Valley Wildlife Sanctuary Lower Subansiri District at 1600 – 2800 m.

Category: Rare

1. *Alniphyllum fortunei* is reported from Begi –Amjee, Subansiri at 1600 m.
2. *Begonia aborensis* is also an endemic species reported from Abor Hill and Subansiri at 400-1200 m.
3. *Bulleyia yunnanensis* is reported from Subansiri at 1600-2000 m.
4. *Pholidota wattii* is also an endemic species reported from Subansiri at 500-1500 m.
5. *Huodendron biaristatum* is reported from Subansiri at 1700 m.
6. *Rhododendron exasperatum* is reported from Subansiri and Dibang valley at 3000-3700 m
7. *Rhododendron kendrickii* is reported from Subansiri, Kameng and Siang at 2300-3300 m
8. *Rhododendron maddenii* ssp. *crassum* is reported from Subansiri and Kameng at 2000-3000 m
9. *Rhododendron micromeres* is reported from Subansiri at 2400-3400 m
10. *Rhododendron nuttalli* is also an endemic species reported from Subansiri at 1500-2000 m and 1200-3650 m.
11. *Rhododendron pemakoense* is reported from Subansiri at 1500-1800 m.
12. *Rhynchoglossum lazulinum* is reported from Subansiri at 500-1500 m.
13. *Vanda coerulea* in different sites in the submergence areas of Lower Subansiri HEP, Lower Subansiri district.

Category: Indeterminate

1. Begonia scintillans is also an Endemic species reported from Abor Hills (Lohit and Dibang Valley district), Dibang Valley, Siang, Tirap at an altitude of 500-2000m in Arunachal Pradesh. It is recorded from the mountain of Bapus, both on the south face and towards Wotung, between 1200-2000 m alititudes.
2 Begonia tessaricarpa is apparently rare and not collected since 1862 in Assam (no specific location) and Endemic. This species has been collected from Upper Subansiri District, and Changlang District (Namdapha National Park), Arunachal Pradesh as well.

The family wise threatened species, location details and their conservation status is given in **Table 6.61**.

Table 6.61: Species, location details and their threatened status

Sr. No.	Botanical Name	Location	Local Name	Threatened Conservation Status (IUCN) & Remarks
RANUNCULACEAE				
1	*Coptis teeta*	Upper reaches of Upper Subansiri District, 2500-3000 metres	Mishmee teeta	Vulnerable (Herb)
BEGONIACEAE				
2	*Begonia aborensis**	Subansiri, 400-1200 m Changlang, Dibang Valley, Lohit, and Siang		Rare (Herb) and Endemic (found in more illuminated clearings)
3	*Begonia scintillans*	Abor Hills (Lohit and Dibang Valley district), Dibang Valley, Siang, Tirap at an altitude of 500-2000m in Arunachal Pradesh. It is recorded from the mountain of Bapus, both on the south face and towards Wotung, between 1200-2000 m alititudes		Indeterminate and Endemic (Herb)
4	*Begonia tessaricarpa*	It is apparently rare and not collected since 1862 in Assam (no specific location). It is recorded from Upper Subansiri District, and Changlang District (Namdapha National Park)		Indeterminate and Endemic (Herb)
ARALIACEAE				
5	*Panax pseudo-ginseng*	Subansiri, 1500-2000 m		Vulnerable (herb)
ERICACEAE				
6	*Agapetes atrosanguinea*	Lower Subansiri district at 1800 m		Vulnerable (Ephiphyte) Endemic)
7	*A. buxifolia*	Lower Subansiri district at 2725 m 1700-1800 m.		Vulnerable (Ephiphyte)
8	*A. praestigiosa*	Lower Subansiri district at 1900-2000 m.		Vulnerable (Ephiphyte)
9	*A. miranda*	Lower Subansiri district at 2725 m.		Endangered (Ephiphyte)
10	*A. refracta*	Lower Subansiri district at 2732 m		Vulnerable (Ephiphyte) Endemic
11	*A. smithiana* var. *major*	Lower Subansiri district at 2725 m.		Vulnerable (Ephiphyte)
12	*Leucothoe griffithiana*	Lower Subansiri district at 2400-2800 m.		Vulnerable (Shrub)
13	*Rhododendron arboreum* ssp. *delavayi*	Lower Subansiri district at 2000 m.		Vulnerable (Treelet to medium sized tree)
14	*R. boothii*	Talley valley; Lower Subansiri district, 1800-2500 m.		Vulnerable (Treelet)
15	*R. exasperatum*	Subansiri, Dibang valley, 3000-3700 m, in forests.		Rare

Sr. No.	Botanical Name	Location	Local Name	Threatened Conservation Status (IUCN) & Remarks
16	*R.falconeri* ssp. *eximium*	Subansiri, Kameng in the altitudinal range of 2700-3000 m and 3000-3500 m.		Endangered (Shrub/Small Tree) Endemic
17	*R. kendrickii*	Subansiri, Kameng; Siang, 2300-3300 m, in mixed forests		Rare (shrub/small tree)
18	*R. maddenii* ssp. *crassum*	Subansiri, Kameng, 2000-3000 m		Rare
19	*R. micromeres*	Subansiri; 2400-3400 m		Rare
20	*R. nuttalli*	Subansiri on cliffs, ledges and rocky slopes in open forests in the altitudinal range of 1500-2000 m and 1200-3650 m.		Rare (Tree or shrub) Endemic
21	*R. pemakoense*	Subansiri; 1500-1800 m.		Rare
22	*R. santapauii*	Subansiri; on open slopes		Endangered (Epiphytic shrub) Endemic
23	*R.subansiriense*	Subansiri, 2600-2800 m in mossy rain forest		Endangered (Erect shrub or small Tree) Endemic
24	*R. vaccinioides*	Talley Valley, 2432 m. Lower Subansiri District		Vulnerable (Ephiphytic)
25	*Vaccinium. dunalianum* var. *brevifolium*	Lower Subansiri District		Vulnerable (Ephiphyte)
26	*V. dunalianum* var. *megaphyllum*	Lower Subansiri District		Vulnerable (Ephiphyte)
27	*V. nuttallii*	Lower Subansiri District		Vulnerable (erect shrub, Sometimes epiphyte)
28	*V. dendrocharis* var. *talle*	Lower Subansiri district at 2725 m.		Endangered (erect Ephiphytic shrub) Endemic
29	*V. subdissitifolium*	Lower Subansiri District at 1600 – 2800 m.		Vulnerable (erect shrub)
		STYRACACEAE		
30	*Alniphyllum fortunei*	Subansiri		Rare (Tree)
31	*Huodendron biaristatum*	Subansiri		Rare (Shrub)
		ORCHIDACEAE		
32	*Bulleyia yunnanensis*	Subansiri		Rare (Herb)
33	*Pholidota wattii**	Subansiri		Rare (Herb) and Endemic
34	*Rhynchoglossum lazulinum*	Subansiri		Rare (Herb)
35	*Vanda coerulea**	Lower Subansiri District		Rare (Epiphytic) Herb)
		ARECACEAE		
36	*Livistona jenkinsiana**	Upper and Lower Subansiri District and Tirap	Assam Fan Palm	Endangered (Palm) Endemic to N E India.

* ➔ Reported to occur in different sites in the submergence areas of Lower Subansiri HEP, Lower Subansiri district.

Table 6.61 indicates that out of 7 families having 36 threatened species (including 12 Endemic species) reported from Subansiri basin, family Ericaceae has 24 threatened species (5 Endangered and 13 Vulnerable and 6 Rare), Arecaceae has 1 Endangered species, Ranunculaceae has 1 Vulnerable species, Orchidaceae has 4 species assessed as Rare and Styracaceae has 2 Rare species. Begoniaceae has 3 species (1 Rare and 2 Indeterminate) and Araliaceae has 1 Rare species. Out of 36 threatened species, 12 species namely *Agapetes atrosanguinea, A. refracta, Begonia aborensis, Begonia scintillans, Begonia tessaricarpa, Rhododendron falconeri* ssp. *eximium, Rhododendron nuttalli, R. santapauii, R.subansiriense, V. dendrocharis* var. *talle, Pholidota wattii* and *Livistona jenkinsiana* are also reported to be Endemic species. It is important to note that out of 6 Endangered species, 5 are also endemic species. Further, 6 threatened species namely *Begonia aborensis, Begonia scintillans, Begonia tessaricarpa, Pholidota wattii, Livistona jenkinsiana* (all endemic) and *Vanda coerulea* are recorded from submergence areas of Lower Subansiri HEP, Lower Subansiri district.

Moreover, three threatened plant species *viz. Heritiera acuminata* (a tree species), *Bambusa mastersii* (a bamboo species) and *Cyathea spinulosa* (a fern species) were found in the submergence area/construction site of the Lower Subansiri dam. One species of endangered plant, i.e. *Heritiera acuminata* and two rare species, i.e. *Bambusa mastersii* and *Cyathea spinulosa* have been reported in the project area. These species are observed in the nearby forests also, and only a very small proportion of the total forest area in the region is being acquired, hence, no major impacts are anticipated during the construction phase of Lower Subansiri project. It may be noted that these species are not listed in Red Data Book of Indian Plants (Vol 1-3.), BSI. However, these species are listed in EIA/EMP report of Lower Subansiri Project and Preservation plans and project cost was also suggested in the EIA/EMP report.

Species listed in Schedule of Wildlife Protection Act (1972), amended 2003: The Blue Vanda Orchid, *Vanda coerulea* is listed in Section 2, Schedule VI of Wildife Protection Act (1973) amended 2003 is reported to occur in different sites in the submergence areas of Lower Subansiri HEP, Lower Subansiri district.

Species listed in Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES):

The Blue Vanda Orchid *Vanda coerulea* is included in the Appendix I of CITES and its trade is banned. The species is under *ex situ* conservation in the National Orchidaria of the Botanical Survey of India at Shillong, Barapani, Yercaud, and in some private nurseries and Orchidarium of the Arunachal Pradesh at Tipi.[38]

36 species by their threatened status is given in **Figure 6.38**.

[38] Red Book of Indian Plants (Volume III, edited by M P Nayar and A R K Sastry , 1990)

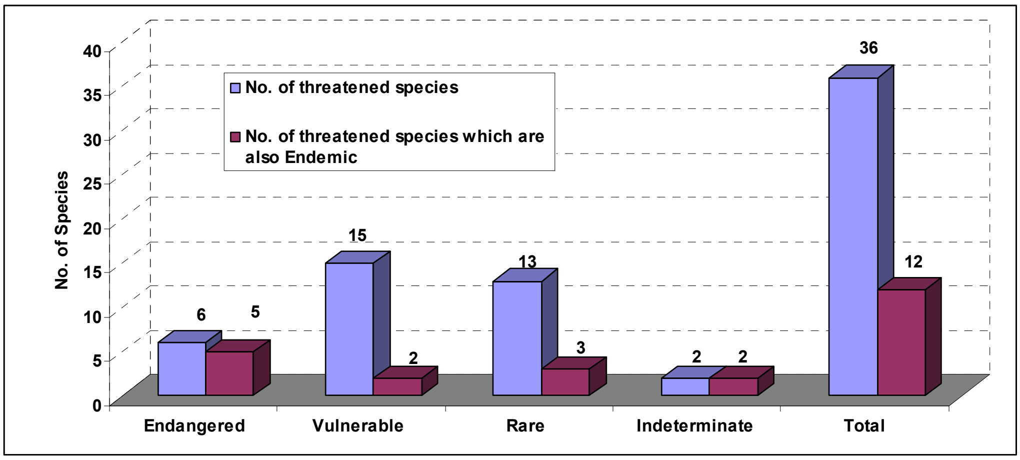

Figure 6.38: Species by their Threatened Status

36 threatened species by their family is given in **Figure 6.39**.

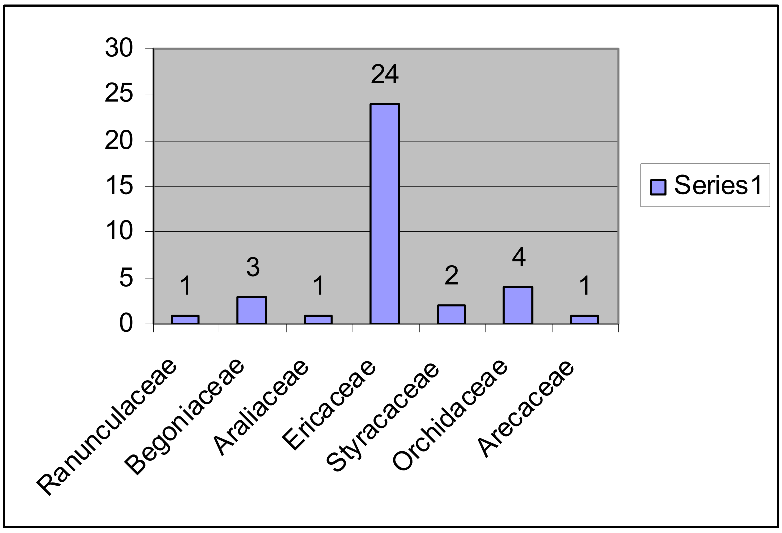

Figure 6.39: Statistics of Threatened Species by their Family

36 threatened species by their genus is given in **Figure 6.40**.

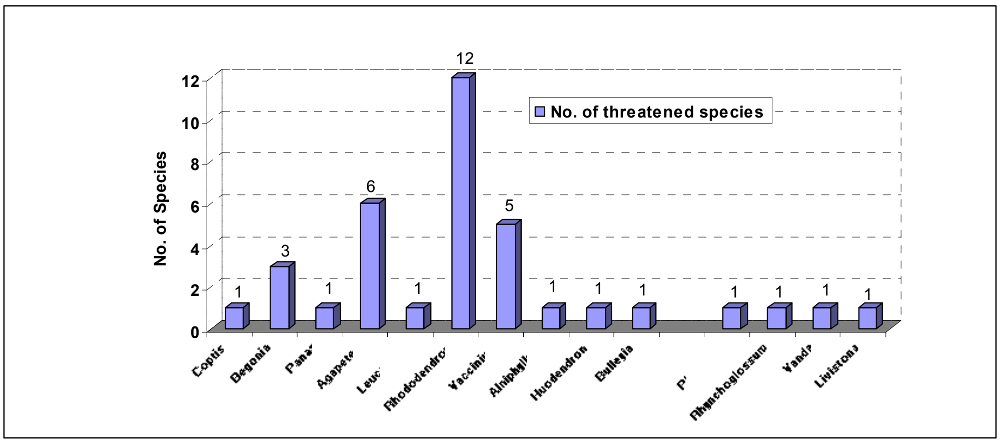

Figure 6.40: Statistics of Threatened Species by their Genus

6.14 Faunal Diversity of Arunachal Pradesh

Biogeographically Arunachal Pradesh occupies a prominent place in the eastern Himalaya harboring various animal forms. Such unparalleled occurrence of life forms can be attributed to the particular location of the state which is at the juncture of paleoarctic, Indo-China and Indo – Myanmar biogeographic regions. The following section describes the diversity of vertebrates and invertebrates reported to occur in Arunachal Pradesh/Subansiri Basin.

Vertebrate Diversity

Arunachal Pradesh forms a complex hill system of Siwalik and Himalayan origin and is criss-crossed by six major rivers and streams flowing from west to east. Besides, a good number of beels in the lower belt and lakes in the middle and higher belts and lakes in the middle and higher belts add up to the natural resources of the state. The state has 7000 ha and 2000 km of lentic and lotic water resource respectively. Of which, 30-40% is falling in the cold water zone of the state. 213 fish species are reported in Arunachal Pradesh[39].

Cold Water fishery-especially the Trout fishery both Brown and Rainbow Trout variety being cultured for stocking.The occurrence of certain fish species which are traditionally not found in the area are mainly due to the Fish Breeding through Echo-hatcheries for the Indian major Carps (Rohu, Mrigal, Catla and Gonius) & Exotic Carps (Silver Carp & Grass Carp) at Emchi, Papumpare District and Lathao in Lohit District and Trout Breeding (Brown & Rainbow) in West Kameng & Tawang districts. The state fisheries have also resorted to Composite Fish Culture of six species, the combination has been very successful in foot-hill area of the State through beneficiary participation in many of the district viz. Balijan, Doimukh & Kimin Circle in Papumpare district; Ziro & Raga in Lower Subansiri district, East & West Siang district, Namsai & Jairampur in Changlang district etc. The state fisheries also conduct International Angling Festival of sport fishes especially the Mahaseer for furthering the tourism.

Amphibian: 39 species belonging to 11 genera, 6 families and 2 orders are recorded in the state, in comparison to the earlier record of 24 species by Boulenger (1920), Smith (1929), Sarkar and Sanyal (1985) and Chanda (1994). A new species of Amphibia from the state viz., *Philautus sahai* (sp.nov.) is reported and five new records viz., *Megaphrys lateralis, Rana erythraea, Rana nicobarensis, Rana keralensis and Rana andersonii* for the first time from India. It is interesting to note that the Salamander (*Trilotriton verrucosus)* was also recorded previously from the Daphabum Scientific Survey Expedition (1969-70) by the scientists of Zoological Survey of India at an altitude of 1248 m in the Lohit district in a hibernating condition. District wise distribution indicates the maximum diversity in Tirap (21 species), East Siang (20 species), West Kameng (9 species), Lower Subansiri (7 species), East Kameng (4 spp.), West Kameng and Changlang (3 species each). As in the case of several other groups such as fishes, the diversity is low in higher stretches and highest in the areas adjacent to Myanmar, Assam and Nagaland i.e., Tirap and East Siang districts. Species such as *Bufo macrotis, Mycrohyla berdmorei, Microxalus borealis, Theloderma moloch, Chiraxalus shyamrupus, chiraxalus doriae and Racophorus naso* is restricted to Arunachal Pradesh. As many as 14 species share in common with the distribution in eastern Himalayan states.

Reptilian: 78 species under 46 genera and 12 families of reptiles are reported in Arunachal Pradesh. Of this two species viz. *Ophites laoensis* and *Xenochrophis punctulata* are the first

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[39] *Kenjam Bagra, et al. 2009: Ichthyological survey and review of the checklist of fish fauna of Arunachal Pradesh, India Check List 5(2): 330–350, 2009, ISSN: 1809-127 X).*

records to the country. Distribution of snake (*Boiga gokool*) is restricted to the eastern Himalayas and *Trimeresurrs monticola* is widely distributed in Southeast Asian countries extending upto Malaysia. The systematic list includes 4 species of testudines, 19 species of lizards and 55 species of snakes.

Among the four testudines recorded, *Pyxidia mouhoutii* is a Malayan element distributed in the state, *Kachuga tecta* becoming vulnerable due to over exploitation, *Kachuga sylhetensis,* endemic to northeastern India distributed in north and south of Brahmaputra River. Species such as *Kachuga smithi, Kachuga dhongoka and Cyclymys dentata* are on record from the state. Among the order squamata, the family Gekkonidae includes *Cyrtodactylus khasiensis, Cosymbotus platyurus, Ptyctolaemus gularis, Mictopholis austeniana, Oriocalotes paulus, Japalura andersoniana, Calotes jerdoni, Sphaenomorhpus indicum, S.machlatum, S.courcyanum, Scincella sikkimensis, Tarkydromus sexlineatus khasinensis,* which are the eastern Himalayan representative distributed in the state. Among snakes family Typhlopidae represented by 3 species, Boidae (1 species), Colubridae (42 Species), Elapidae (5 species) and Viperidae (4 species).

Species of snakes such as *Pareas monticola, Elaphae taeniura, E cantoris, E porphyracea, E prasina, Ptyas korros, Zaocys nigromarginatus, Leopeltis frenatus, L stoliczkae, Ologodon albocinctus, O melanozotus, O erythrocharis, Dendolaphis ahaetulla, D. cyanochloris, D. gorei, Ahaetulla prasina, Pseudoxenodon macrops, Amphiesma modesta, Trachyschium monticola, T. tenuiceps, Thabdophis himalayanus, R bicolor, Blythia reticulate, Boiga ochracea, B gokool, B. quincuciata, B cyanodon, Psammodynastes pulverulentus, Bungarus niger, Trimeresurus mucrosquamatus, T monticola, T stejnegeri* are the eastern Himalayan representative distributed in the state of Arunachal Pradesh. Out of 55 species of snakes, nearly 33 species (60%) are the eastern Himalayan representative distributed in the state. Besides above, *Elaphae mandarina* is restricted to Arunachal Pradesh. *Ophites jara and Xenochrophis punctulata* recorded for the first time from Indian subcontinent from the study. *Oligodon (Prox) cinereus* is the other species exclusive to Arunachal Pradesh.

Of the 19 species of lizards recorded from the state, distribution in East Siang (17 species) followed by Changlang (9 species), Lohit, East and West Kameng (3 each), Lower Subansiri (2 species) and a lone speices form Tirap districts. In contrast, of the 55 species of snakes distributed in the state, again East Siang dominates (26 species), Lower Subansiri (21 species), Changlang (15 species), East Kameng (10 species), Papumpare (9 species), West Siang (6 species), West Kameng (5 species), Lohit (2 species) and a lone species of *Trimeresurus monticola* (Blotched pit viper) from the district of Tirap. In conclusion, it may be said that the distribution of snakes are in the southern and lower elevations along the Brahmaputra River and its tributaries.

Aves (Birds): 964 species and subspecies of birds from the state of Arunachal Pradesh, divided into four parts the first one includes 473 species authentically collected and reliably sighted in the field, out of this 416 are resident, 42 are winter visitors, 3 species are partly resident and partly winter visitor, 1 species each of winter vagrant and summer visitor birds.

The third list includes 43 species and subspecies of birds which are likely to occur in the state of Arunachal Pradesh (Distribution doubtful, needs confirmation). Of these 5 birds are winter visitors, 32 are residents, lone species of straggler and passage migrant, 4 are uncertain species of birds. The last list includes 157 species and subspecies of birds of birds of these 97 are residents, 51 are winter visitors, 2 partly resident and partly winter visitor and 7 birds have uncertain status. Most of these birds are from the adjacent countries of Bhutan, Myanmar and China, however, a few of them are also from the Western Himalayan country (Pakistan). The study enumerates the distribution pattern of birds in different ecologically significant areas, wildlife sanctuaries and other protected areas of the state.

Mammals: The order carnivore in India is represented by 7 families, 26 genera and 55 species; of this the state has a share of nearly 13 species under 10 genera. The family Felidae represented by 15 species, of which the state of Arunachal Pradesh has 9 species thus constituting nearly 60% of the total India species. Among them *Panthera tigris* and *Panthera pardus* are found in the lower elevations and foot hills and are common in Namdapha National Park, Dihang-Dibang Biosphere Reserve, Itanagar WLS, Pakke and Tale WLS. Stray cases in other parts of the state are also on record. The alluvial grasslands, delineated as the Terai-Duar Savanna and Grassland ecoregions of northeast India, support some of the highest densities of tigers in the world. Same is true in case of *Panthera pardus* also. *Neofelis nebulosa* and *Uncia uncia* has a wide distribution across the Himalayas range, and into the Trans-Himalaya, the population in the Eastern Himalayas especially form Arunachal Pradesh is very important because this high-altitude predator occurs at low densities. Cats such as *Prionilurus bengalensis* (subspecies *charltoni* occurs in India), *Felis chaus* (subspecies *affinis* found in Arunachal Pradesh), *Pardofelis viverrinus* is comparatively rare and found in marshy areas. Family Canidae is represented by 3 genera and 5 species in India, while the state of Arunachal Pradesh accounts for all the five species, thus the representation is 100% in the state. The Indian wolf is represented by *Canis lupus pallipes* the common jackal, *Canis aureus* a scavenger survive on smaller prey and the Indian wild dog or Dhole (*Cuon alpinus*) distributed in the scrub jungles of the state. According to Johnsingh (1985), the wild dog of Arunachal Pradesh is believed to be *Cuon alpinus adjustus*, as this subspecies is found in northern Mayanmar. Of the two species of genera *Vulpes, Vulpes bengalensis* are found in the foot hills and at elevations above 2500m.

The family Ursidae represented by 4 genera and 4 species in India. The state is represented by all the two species viz., *Melursus ursinus* (Sloth bear), *Selenarctos thibetanus* (*Ursus thibetanus* according to Corbet and Hall, Himalayan Black bear) and *Helarctos malayanus* (Malayan Sun bear) distributed in Tirap & Changlang adjoining Burma.

The monotypic family Ailuridae represented by the Red Panda is a Himalayan species (*Ailurus fulgens*) found in altitude varying from 2800-3500m, records of this are available in old growth subalpine conifer and mixed forests with a bamboo understory and *Rhododendron* and Oak forests. The family Mustellidae represented by 7 genera and 15 species are included under 4 subfamilies. The amphibious Otters under subfamily Lutrinae includes *Lutra perspicillata, Lutra lutra* and *Amblyonyx cinerus (Aonyx cinera)* but represented by the latter two species in the state. The subspecies of *Amblyonyx cinerus* reported from Arunachal is *concolor.* The subfamily Mustellinae includes martens, weasels and pole cats and represented by 8 species under 3 genera. Arunachal Pradesh has the distinction of having 2 genera and 2 species (*Martes flavigula* (Indian moninate subspecies is *flavigula*) keeps to forest limits and are not found above tree line, *Mustela strigidirosa* in temperate forests above 1500m. *Mustela altaica and Martes foina* is reported in Tawang and Kameng districts.

The subfamily Melinae includes badgers represented by 2 genera and 3 species. In Arunachal Pradesh it is fully represented by two species viz., *Arctonyx collaris* (subspecies present in Arunachal is *collaris) and Melogale moschata* (The Indian subspecies in *millsi*). The subfamily Mellivorinae represented by a lone species *Mellivora capensis* in India but doubtful in Arunachal. The family Viverridae includes 14 species under 7 genera and 3 subfamily and the state is represented (50%) by 5 species viz., *Viverra zibetha* (Arunachal Pradesh subspecies *zibetha*), *Viverricula indica, Pardoxurus hermophroditus, Paguma larvata* and *Arctictis binturong.* The subfamily Herpestrinae includes only one genus *Herpestes* with 6 species. The state represented by *Herpestes urva* and *Herpestes javanicus.*

The order Proboscidia represented by the lone species *Elephas maximus indicus,* the elephant population present in small habitat patches along the north bank of the Brahmaputra River in Arunachal Pradesh is very important from the point of distribution. The eventoed Artyodactyles are represented by four families in Arunachal Pradesh; the family Suidae represented by *Sus scrofa cristatus*; the family Cervidae represented by *Muntiacus muntjak* (subspecies *vaginalis*), *Axis porcinus (*subspecies *porcinus* in Arunachal Pradesh and the genus *Axis* and *Cervus unicolor* are important prey species distributed in the lower elevations of the state. The family bovidae represented by *Bos frontalis* (a domesticated stock especially in northeastern Chittagong, Bangladesh. *Bubalis bubalis* and the *Budorcas taxicolor* especially distributed in the Mishmi hills of Arunachal Pradesh, *Naemorhedus goral* and *Naemorhedus sumatrensis* are extensively distributed in the state.

There are large herbivores of Eastern Himalayas especially Arunachal Pradesh which play critical ecological roles in maintaining the integrity of the ecosystem. The landscape includes a variety of ecosystems, from the wetlands and riverine habitat along the Brahmaputra River and alluvial grasslands and subtropical broadleaf forests, to temperate broadleaf forests, mixed conifer forests and even alpine habitats in Arunachal Pradesh the species diversity is high. Some of the juvenile and sub-adult mammals show seasonal migration especially the tigers disperse from natal areas to establish territories elsewhere and elephants exhibit seasonal movements along the length of the mountains. In the higher up the mountain landscape, blue sheep and Takin undertake seasonal migrations from the alpine meadows in the summer to the mixed conifer forests below in the winter.

The order Pholidota represented by two species in India viz., *Manis pentadactyla, Manis crassicaudata,* the former is well distributed in the state. The order Rodentia is the largest order next to Chiroptera, characterized by chisel like incisors in each jaw and in Arunachal Pradesh they are represented by three family, 19 genera and 31 species. The Order includes the lone endemic species Namdapha flying squirrel (*Biswamoyopterus biswasi*) restricted to the temperate broadleaf forests of the Eastern Himalayas. The family Sciuridae includes 10 species including *Biswamoyopterus biswasi;* the family Muridae represented by 19 species and the family Hystricidae represented by 2 species. Among the members of the order Sciuridae, *Ratufa bicolor gigantia* lives on high trees in dense forests and never comes to ground. The monotypic genus *Belomys* includes only one species *Belomys pearsoni.* The subfamily Arvicolinae under the family Muridae includes *Eothenomys melanogaster*. Among the subfamily Murinae, *Berlymys bowersi* is a nocturnal fossorial species commonly found in the primary forests and in the highlands above 600m. *Vandeleuria oleracea* is distributed in Arunachal Pradesh. The Bamboo rats in Arunachal Pradesh in particular and northeastern Himalayan states very important as they are related to the flowering seasons of the bamboo shoots belongs to the subfamily Rizomyinae of Muridae. These rats are heavily built provided with strong claws for digging and have adapted for fossorial habits in the hilly terrains of the state. The family Hystricidae commonly includes porcupines includes two genera and two species viz., *Atherurus macrourus* and *Hystrix brachyuran subcristata.*

Insectivores are small with pointed snout with body covered with closely set fur and short limbs. The family represented by two family soricidae which includes *Suncus murinus soccatus* and *Suncus murinus griffithi.* The other one is a monotypic genus represented by *Anourosorex squamipes.* The family Talpidae includes animals with short velvety fur represented by a lone species *Euroscaptor micrura.* The family Scandentia represented by a lone species *tupaia belangeriassamensis.* The state of Arunachal Pradesh is known for the distribution of flying mammals under the order Chiroptera which includes 14 genera and 22 species out of 112 species known from India.

Primates: 7 species and subspecies of primates are reported from Arunachal Pradesh. The family Loricidae is represented by the *Nycticebus coucang bengalensis*; the family

Cercopithicidae represented by *Macaca assamensis, Macaca arctoides, Macaca mulatta, Macaca nemestrina,* the genus *Trachypithecus* represented by *T. pileatus pileatus.* The family Hylobatidae is represented by the lone species of *Bunopithecus hoolock (Hylobates hoolock).*

Altogether, the mammalian fauna of the state is represented by 106 species and subspecies under 58 genera, 25 families and 9 orders. Of these 4 species are new records to the state and also includes the lonely endemic species The mammals includes *Platanista gangetica, Golunda ellioti, Hemitragus jemlachicus, Taphozous nudiventris, Episticus tatei, Tylonycteris pachypus, Ursus arctos, Psedois nayaur, Caprolagus hispidus, Mustela Kathiah, Manis crassicaudata, Sus salvinus* and a few others.

Invertebrate Diversity

There are 72 species (43 species of free living, 20 parasites and 9 species are symbionts) distributed in 11 districts, of which 3 species are new records to the country and 62 species are new records to the state. Distribution pattern of protozoans indicates the preponderance of free living in Dibang valley, parasitic in Changlang and symbionts in Tirap districts. In comparison to the above, Lower Subansiri dominates in species distribution followed by West Siang, East Siang, Debang Valley, Lohit, Tirap and moss plant, parasitic ones are in frogs, toads, birds, livestock and man while the symbionts occur on the termite hosts.

Leeches constitute the major group of annelids recorded from the state which include 7 species. The trematode fauna of the state consists of 8 species distributed under 6 genera and 6 sub-families parasitizing the amphibians distributed in 9 districts.

Arthropods are represented by members belonging to Crustacea, Arachnida and Insecta. The present study includes seven species of palemnoid prawns and six species of potamonid crabs, of which 8 species are first records from the state. Three new species of scorpions from Namdapha Biosphere Reserve have been reported. Besides the distribution of 3 species from the lower foothills of the state, a new species of scorpion (*Chaerilus dibangvalleycus sp.nov.*) from the family Chelicerilidae and a new species from Scorpiopsidae (*Euscorpios kamengensis sp.nov.*) are reported. From among the family Thalyphonidae, distribution of *Uropoctus asssamensis* from 4 districts of the state is reported. Report of a new species of Schizomidae (*Schizomus arunachalicus sp.nov.*) and a species of Opalinida (*Gnomulus roingii* sp. Nov.) from the state gives a total of 4 new additional species of arachnida. 58 species of spiders are presently found distributed in the state, under 28 genera and 11 families of which 4 species belonging to 4 genera are new to the science (*Storena dibagensis sp.nov., Phidippus tirappensis sp nov., neoscona bomdilaensis sp. Nov.* and *Nephila dirangensis* sp. nov) and 25 species are first records from the state and 15 species exclusively from eastern Himalayan state. 21 species of Ixodid mites belonging to 8 genera of a single family are reported . Of the 21 species, 2 species are new records to the state, 7 are restricted to Northeastern state, one exclusive restricted to Arunachal Pradesh and the rest are widely distributed in the country. Among the Oribatid mites, 35 species are known from the state belonging to 30 genera and 20 families. All species are reported for the first time from the state of Arunachal Pradesh, besides 3 species which are likely to be new species. Of the 35 species, 21 are restricted to the eastern Himalayan foothills.

Insects: The eastern Himalayas and hills of Assam and Arunachal Pradesh in the northeast India with tropical evergreen forests from a paradise of maximum number of species and populations of species. 27 species under 15 genera and 3 families are reported. Of these, several of them are widely distributed (*Xenylla obscura, Dicranocentrus simplex, Siera indica, Cyphoderus javanus, Tomocerus mitrai Dicranocentroides flaviscens, D.*

Fasciculatus, Salina indica, S. Montana, Isomurus balteatus), a few of them are exclusively known from Northeast India state (*Lobella kraeplini, Lepidocyrtus caudatus , L. magnificus, L. Heterolepis, L. Cyaneus, Lepidosira unguserrata, Sinella curviseta, Homidia cingula, Dicranocentroides salmon, Salina striata, Callyntrura Japonica, while Lepidocyrtus curvicollis*) is known exclusively from Arunachal Pradesh

92 species and subspecies distributed over 50 genera, 11 families and 2 suborders are reported. Of these, 65 species are widely distributed, 24 species are having records from Northeast India and 3 species are exclusively recorded from Arunachal Pradesh and are known by types. An interesting pattern of distribution of odonates recorded in the present study, a maximum number of species found in Subansiri district followed by Siang, West Kameng and Dibang valley districts. Among these districts the middle reaches of tree line show maximum diversity than the lower reaches of the state. Another interesting pattern of distribution recorded is as many as 25 species from Tirap district which as adjacent to Myanmar, Assam and Nagaland trijunction.

Acridid insects totaling 47 speceis belonging to 33 genera and 2 families are reported. Among them 29 species are widely distributed, 12 species are restricted to Northeastern India while 3 genera and 3 species are recorded from Arunachal Pradesh only. Acridid distribution further indicates greater diversity in West Siang (16 species) followed by Upper Subansiri and Debang Valley (15 species each), Lower Subansiri (13 species), West Kameng (11 species), East Siang (4 species), Upper Siang (3 species), East kameng, Tirap, Papumpare 2 species each and no records from the districts of Tawang and Changlang. Of the 47 species recorded from different districts, *Xenocatantops humilis* is distributed in 6 districts, *Stenocatantops splendens* and *phlaeoba infumata* are distributed in 5 districts, *P attenuata* and *Trilophidia annulata* in 4 districts, 10 species in 3 districts, 2 species in 9 districts, 23 species distributed either alone or in places where other have been recorded.

Distribution of 20 species under 14 genera and 6 families, of the 6 species are reported and the rest are cosmopolitan in their distribution. The distribution of blattids indicate that they are recorded from ten districts of which East Siang and Papumpare dominate followed by Dibang Valley, West Siang, Lower Subansiri, Tirap, Lohit, Upper Subansiri and Changlang districts.

73 species belonging to 14 genera of Scarabaeid beetles of the subfamily coprinae are reported. The distribution pattern of dung beetles indicates maximum number of speices at Changlang, the district adjacent to Myanmar, followed by Papumpare (17 species), Dibang Valley, the Lower Dibang showing better distribution than the Upper Dibang Valley. The East Siang, West Siang and the Lower Subansiri shows the same pattern of distribution, equally true in case of Upper Siang, Tawang, Lohit and Tirap districts in respect of the species distribution. Least number of species recorded is from East Kameng followed by West Kameng and Upper Subansiri districts.

Dipteran includes 6185 species under 1091 genera and 87 families from India and the largest group of insects next to coleopteran. 19 families out of 87 families known from the country, consisting of Syrphidae with 50 species, Bombylidae (9 species), Stratyomyidae (10 species), Tabanidae (24 species), Ailidae (15 species), Empidae (1 sp.), Dolichopodidae (1 sp.), Pipunculidae (2 species), Sciomyzidae (1 sp.), Sepsidae (6 sp.), Calliphoridae (15 sp.), Sarcophagidae (15 sp.), Culicidae (19 species), Simulidae (6 species), Bibionidae (8 species), Sciaridae (5 species) are reported thus totaling 269 species of Dipterans from the state.

It may be concluded that the generic representation of the family is nearly 28% which the species representation is only 5.19 from the known dipteran insects and hence a large scope exist for the inrepresented families of the order Diptera. It is interesting to know four species of syrphids are distributed in the adjacent southeast Asian countries such as Myanmar, Borneo, Jawa and Malaya, 16% of the species are confined to India, 20% to the Oriental Region, 32% extends beyond up to Palaearctic 10% each to Ethiopian and Australian and only one species appears to be cosmopolitan in distribution. The distribution of Bombylids appears to be related to the wet and hilly areas of the Himalayan state of Arunachal Pradesh. Among the 51 species under 5 families of Brachycera, 13 species are confined to Arunachal Pradesh, 4 species to India, 33 species extend up to the boundary of the Oriental Region and a lone species extend beyond up to Japan and Korea. Among the 68 species distributed in 7 families of Cyclorrhapha, a maximum number of species (26) distributed in the district of Tirap which is adjacent to Myanmar, Assam and Nagaland trijunction. 15 species are restricted to Arunachal Pradesh, 49 species are found in Oriental Region and 19 species extend their distribution to Palaearctic region. Of the 32 species of Muscids, 6 species are recorded for the first time from the state, only on e species restricted to the Indian soil and the rest extend to Oriental, Palaearctic, Australian, Ethiopian, regions of the world. Of the 61 species under five families of Nematocera, 7 species are confined to India and nearly 44 species extend their range in the Oriental Region and 10 species beyond Oriental Region. It is also interesting to note the families Similiidae and Bibionidae are fully represented at the generic level in the state.

Two families of Hymenoptera viz., Formicidae and Sphaecidae are represented in Arunachal Pradesh. 63 species of Formicidae (ants) under 30 genera and 7 subfamilies; 33 species under 20 genera, 8 subfamilies are included in the family Sphaecidae (Commonly known as mud daubers and hunting wasps), of which 23 species are recorded for the first time from the state. Among the members of Formicidae, 5 species are exclusively known from Arunachal Pradesh, 12 species from eastern Himalayan states, 4 species share with Andaman and Nicobar group of Islands and the rest are widely distributed in India. District wise distribution indicates maximum in Lower Subansiri (18 species) followed by Papumpare (17 species), West Kameng (12 species), Lohit (11 species), Tirap (6 species), Upper Subansiri and East Siang with 5 species each and lowest recorded is from East Kameng with a lone species. Distribution of 33 species of Shpaecids indicate that 3 species are exclusive to Arunachal Pradesh, 9 species share with the Eastern Himalayan states and the rest are common and widely distributed and some of them extend their range in the Oriental Region, besides India[40].

6.15 Faunal diversity in Subansiri basin, Arunachal Pradesh

A total of five hundred and seventy five species belonging to 8 faunal groups is reported to occur in Subansiri basin. Insecta group is the most diverse faunal group with 207 species, followed by aves (175), mammals (106), pisces (213), protozoa (27), reptilia (19), amphibia (6) and trematodes of amphibia (4) which is shown in **Figure 6.41**.

[40] Fauna of Arunachal Pradesh, Zoological Survey of India (ZSI), 2006 (No. 13 Part 1&2)

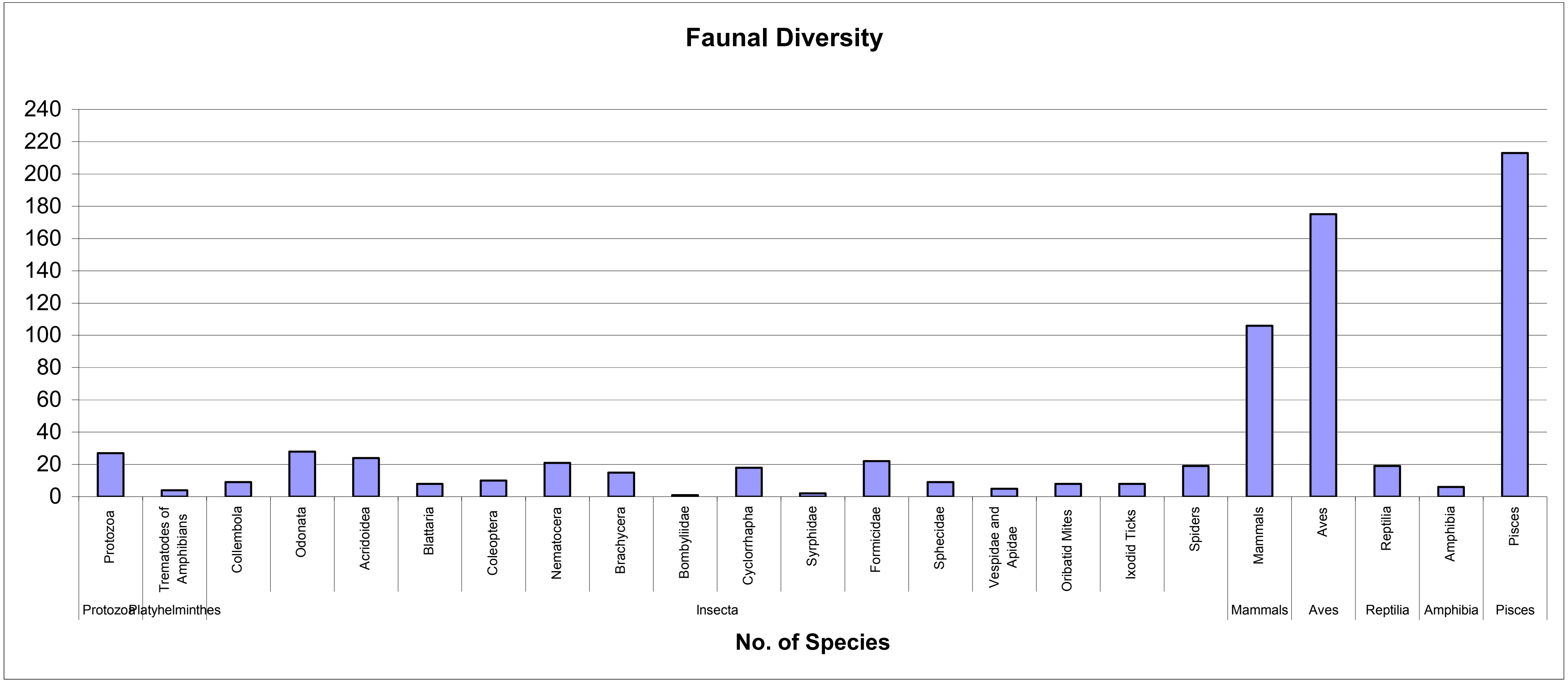

Figure 6.41: Faunal diversity in Subansiri basin

A summary of faunal groups and no. of species reported to occur in Subansiri basin[41] is given in **Table 6.62**.

Table 6.62: Faunal groups reported to occur in Subansiri basin

Sr. No.	FAUNA GROUP	NO. OF SPECIES
1	Protozoa	27
2	Platyhelminthes	
2.1	Trematodes of Amphibians	4
3	Insecta	
3.1	Collembola	9
3.2	Odonata	28
3.3	Acridoidea	24
3.4	Blattaria	8
3.5	Coleoptera	10
3.6	Nematocera	21
3.7	Brachycera	15
3.8	Bombyliidae	1
3.9	Cyclorrhapha	18
3.10	Syrphidae	2
3.11	Formicidae	22
3.12	Sphecidae	9
3.13	Vespidae and Apidae	5
3.14	Oribatid Mites	8
3.15	Ixodid Ticks	8
3.16	Spiders	19
		Insecta Sub total: 207
4	Mammals	106
5	Aves	175
6	Reptilia	19
7	Amphibia	6
8	Pisces	213[42]
Total		757

A detailed inventory of fauna reported to occur in Subansiri Basin has been done. A total of 757 faunal species belonging to 8 faunal groups are reported to occur in Subansiri basin. Pisces is the most diverse faunal group with 213 species, followed by 207 species of Insecta, Aves (175), Mammals (106), Protozoa (27), Reptilia (19), Amphibia (6) and Trematodes of Amphibia (4). A number of authors have reported presence of varying number of fish species in Subansiri basin from time to time ranging from 48 species (Das *et al*, 2011), 87 species (Das et al, 2013), 213 species (Bagra *et al*, 2009), 137 species (Sharma *et al*, 2008) etc to maximum 204 species as reported by latest study (Bakalilal *et al*, 2014). Consideration of total fish species as 213- highest reported till date by any author (Bagra et al, 2009) has been made which substantially covers a number of upstream rivers and Subansiri in particular, which are in the study area. Latest paper by Bakalilal et al, 2014 has reported 204 species of fishes but are mainly inventorised for Lower Subansiri area. The inventory includes details of distribution of species in Subansiri Basin and remarks (**Annexure 6.12)**.

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[41] *Fauna of Arunachal Pradesh, Zoological Survey of India (ZSI), 2006 (No. 13 Part 1&2)*

[42] *Kenjam Bagra, et al. 2009: Ichthyological survey and review of the checklist of fish fauna of Arunachal Pradesh, India Check List **5**(2): 330–350, 2009, ISSN: 1809-127 X).*

Lepidoptera (butterflies) of Arunachal Pradesh

No account of Lepidoptera is given in Fauna of Arunachal Pradesh, 2006, Zoological Survey of India. However, M J Gogoi, 2012 listed 294 butterfly species belonging to 156 genera from Mishmi Hills, Arunachal Pradesh **Annexure 6.13**. This includes 33 species of Papilionidae, 26 species of Pieridae, 59 species of Lycaenidae, 115 species of Nymphalidae and 61 species belonging to Hesperiidae. An account of Lepidoptera has been given for understanding of representation and possible occurrence in Subansiri basin.

Butterflies reported in Subansiri basin are given in **Table 6.63**.

Table 6.63: Lepidoptera (Butterflies) reported in Subansiri basin

Sr. No.	Scientific name	Common name
1.	*Antheraea* sp.	
2.	*Atlas* sp.	
3.	*Eurema hecabe*	Common Grass Yellow
4.	*Graphium* sp.	
5.	*Heliophorus* sp.	
6.	*Lethe margaritae*	The Bhutan Treebrown
7.	*Luna* sp.	
8.	*Naptis* sp.	
9.	*Papilio demoleus*	Lime Butterfly
10.	*Papilio helenus*	Red Helen
11.	*Pathysa* sp.	
12.	*Parides* sp.	
13.	*Phalanta phalantha*	Common Leopard
14.	*Pieris* sp.	
15.	*Princeps* sp.	

6.16 Threatened species in Subansiri Basin, Arunachal Pradesh

100 species belonging to Mammals (out of 106 reported species), 57 species belonging to Aves (out of 175 reported species), 1 Reptilian (out of 19 reported species), 2 Amphibians (out of 6 reported species), 28 fishes (out of 94 reported species), 25 species belonging to Odonata of Insecta fauna group (out of 28 reported species) are reported to be assessed as per IUCN's threatened categories. No species belonging to faunal groups namely, Protozoa, Trematodes of Amphibian found in Subansiri Basin, Arunachal Pradesh are assessed as per IUCN's threatened category. The list of threatened faunal species and their status is given in **Annexure 6.14**.

6.17 Species listed in various schedules of Indian Wildlife Protection Act, 1972 (as amended till date)

As per WPA, 1972, no person shall hunt any wild animal specified in Schedule, I, II, III and IV except as provided under section 11 and section 12 of WPA,1972 (chapter 13). 63 species belonging to Mammals (out of 106 reported species), 50 Aves (out of 175 reported species) and 2 amphibians (out of 6 reported species) in Subansiri Basin are listed in Schedules of Wildlife Protection Act, 1972 (as amended till date). 60 Lepidopteran (butterflies) species are listed in various schedules of WPA. Faunal groups namely Pisces, Protozoa, Trematodes of Amphibian and Insecta found in Subansiri Basin, Arunachal Pradesh are not listed in any Schedules of Wildlife Protection Act. The list of species as mentioned in various schedules of Wildlife Protection Act, 1972, as amended till date is given in **Annexure 6.15.**

6.18 Endemic species

Namdapha Flying Squirrel *(Biswamoyopterus biswasi* Saha) is the only endemic species of India in Arunachal Pradesh among its 106 species and subspecies of mammals. However, this species is reported from Namdapha National Park, Tirap, which is outside Subansiri Basin[43].

6.19 Primary survey results

Methodology: During ecological survey, identification of faunal species was carried out simultaneously. Indirect observations of mammals were carried out by identification of tracks, droppings (scat), claw marks and calls, etc. The listing of faunal species is done by direct observation techniques. Linear transects of 1 km each was carried out. Each transect was trekked for 1 hour for sampling for animals. Sampling methodology for faunal groups is summarized in **Table 6.64**.

Table 6.64: Sampling methodologies used for different taxon

Sr. No.	Taxa	Sampling Method
1	Butterflies	Pollard Walk (Random Walk), Opportunistic observations
2	Amphibians	Visual Encounter Survey (search)
3	Reptiles	Visual Encounter Survey (search)
4	Birds	Random Walk, Opportunistic observations
5	Mammals	Tracks and signs, and Visual Encounter Survey

Butterflies of the area were documented using direct observations during Random Walks, Opportunistic Observations and Standardized Transect Counts during morning hours. Butterfly surveys were carried out by searching 5 m distance on either side of transect.

The avifauna of the study site documented through Direct Observations, Random Walks and Opportunistic Observations, during early morning and evening using a pair of binoculars.

Visual Encounter Method (all out search) followed during the survey for amphibians and reptiles. Visual Encounter Survey (VES) is one in which field personnel walk through a chosen area for a prescribed time period systematically searching for animals. This is an appropriate technique for inventory and monitoring studies. During the search leaf litter, fallen logs, trees (bark, buttress, root, shrubs, boulders, rocks and rock crevices were examined.

For, Mammals both direct and indirect observation is applied to sample mammals present in the study site. Indirect evidences like tracks and signs (e.g. footprints/pugmarks, calls, signs and scats) along with Visual Encounter Surveys were used. Night surveys were conducted for sampling nocturnal mammals and chiropterans

Bos frontalis, Felis bengalensis, Felis marmorata, Sus scrofa, Muntiacus muntjack, Macaca assamensis, Vulpes bengalensis, Vandeleuria oleracea, Talpa micrura, Rattus rattus, Coracias benghalensis, Alcedo atthius, Vanellus indicus, Dicrurus aeneus, Acridotheres fuscus, Passer domesticus, Pycnonolus jocosus, etc. are species observed in the project sites in Subansiri Basin.

[43] *Fauna of Arunachal Pradesh, Zoological Survey of India (ZSI), 2006 (No. 13 Part 1)*

Site specific faunal species which occur in and around proposed HEPs are described below:

Upper Subansiri District - Nalo

Mammalia (Mammals)
Talpa micrura (Himalayan Mole), *Suncus murinus* (House Shrew), *Sus scrofa*, (Wild boar), *Capra aegagrus hircus, Pteropus giganteus* (Indian Flying Fox), *Macaca mulatta* (Rhesus Monkey), *Canis aureus* (Golden Jackal), *Vulpes vulpes* (Red Fox), *Viverra zibetha* (Large Indian Civet), *Felis chaus* (Jungle Cat), *Prionailurus bengalensis* (Leopard Cat), *Ratufa bicolor* (Malayan Giant Squirrel), *Presbytes entellus* (Common Langur), *Macaca assamensis* (Assamese Macaque), *Panthera pardus* (Leopard), *Panthera tigris* (Tiger), *Vulpes bengalensis* (Indian Fox), *Viverricula indica* (Small Indian Civet), *Herpestes edwardsi* (Common mongoose), *Bos frontalis* (Mithun), *Bubalus bubalis* (Wild buffalo), *Cervus unicolor* (Sambor), *Muntiac muntjak* (Barking Deer), *Manis crassicaudata* (Indian Pangolin), *Selenarctos thibetanus* (Himalayan black bear), *Lepus nigricollis* (Rufous talled hare), *Hystrix indica* (Indian Porcupine).

Aves (Birds)
Acridotheres grandis (Great Myna), *Picus canus* (Grey- Headed Woodpecker), *Upupa epops* (Eurasian Hoopoe), *Ninox scutulata* (Brown Hawk-Owl), *Venellus indicus* (Red Wattled Lapwing), *Gracula religiosa* (Hill Myna), *Corvus brachyrhynchos, Acridotheres tristis, Dendrocitta vagabunda, etc., Psittacula krameri* (Parakeet), *Nectarinia asiatica* (Sunbird), *Pycnonotus cafer* (Bulbul), *Corvus macrorhynchos* (Jungle Crow), *Motacilla alba* (Wagtail), *Dicrurus macrocercus* (Black Drongo), *Chalcophaps indica* (Emerald Dove), *Megalaima virens* (Great Barbet), *Dinopium javanense* (Wood Pecker), *Coracias benghalensis* (Blue Jay), *Eudynamys scolopacea* (Koel), *Butorides striatus* (Little Heron), etc.

Amphibia (Frogs)
Rana danielli, Amolops gerbillus, Microhyla rubra, etc.

Reptilia (Snakes)
Bungarus fasciatus, Elaphe radiata, Ptyas korros, Xenohrophis piscator, Oligodon albocinectus, Naja naja naja, Ophiophagus hannah, Bungarus niger, Trimeresurus spp. Vipera ruselli, Boiga trigonata, Rhabdophis bicolor, Amphiesma isolata.

Lepidoptera (Butterflies)
Phalanta phalantha (Common Leopard), *Papilio helenus* (Red Helen), *Papilio demoleus* (Lime Butterfly), *Eureuma hecabe* (Common Grass Yellow), *etc*.

Upper Subansiri District - Niare

Mammals
The mammalian species present in the area are *Bos frontalis* (Mithun), *Felis bengalensis* (Leopard Cat), *Felis marmorata* (Marbled Cat), *Sus scrofa* (Wild Pig), *Sus scrofa ,Capra aegagrus hircus ,Muntiacus muntjak* (Barking Deer), *Suncus murinus, Macaca assamensis* (Assam Macaque), *Vulpes bengalensis* (Indian fox), *Talpa micrura* (Eastern Mole), *Canis aureus* (Jackal), *Viverra zibetha* (Large Civet), *Paradoxurus hermaphroditus* (Palm Civet), *Apodemus sylvaticus* (Common field Mouse), *Rattus rattus* (House Rat), *Bos primigenius, Malayan Giant Squirrel, Ratufa bicolor (Sparrman, 1778), Hoary-bellied Himalayan Squirrel Callosciurus pygerythrus (I. Geoffroy Saint-Hillaire, 1831) etc*

Amphibia (Frogs & Toads)
The area represents amphibian species like *Polypedates leucomystax, Rhacophorus maximus, Rana cyanophlycitis, Rana limnocharis, Rana tigrina and Bufo melanostictus, etc.*

Reptila (Snakes, Lizards & Gecko)
The dense forest covers and different ecological condition in the area harbours snakes like *Python molurus bivittatus*, *Lycodon jara, Rhabdophis himalayanus, Ophiophagus hannah*, *Elaphe radiata*, *Calotis versicolar* and Gecko *Hemidactylus brookii* and *Cosymbotus platyurus, etc.*

Lepidoptera (Butterflies)
Some beautiful butterflies usually seen in the area are *Kallima inachus inachus*, *Papillio helenus helenus*, *lxias pyvrene*, *Euploea mulciber mulciber*, *Danaus agela*, *Troides helena*, *Cethosia cyane, etc.*

Aves (Birds)
Some common birds species observed in the Upper Subansiri district areas are *Dicrurus aceneus* (Bronzen Drongo), *Pyecnonotus jocosus* (Red Vented Bulbul), black crested bulbul (*Pycnonotus melanicterus*) *Copsychus saulartis* (Magpie Robin), *Coracias benghalensis* (Indian Roller), *Tringa nebularia* (Green Shank), *Ducula aenea* (Green Iperial Pigeon), *Streptopelia chinensis* (Spotted dove), *Cuculus canorus* (Cuckoo), *Ceryle atthis* (Common Kingfisher), *Halcyon smyrnensis* (White Breasted Kingfisher), *Dicrurus renifer* (Lesser Racket tailed Drongo) and *Pellorneum ruficeps* (Spotted Babbler), *Acridotheres tristis, Dendrocitta vagabunda,* Hill myna *(Gracula reliqiosa*), Jungle myna (*Acridotheres fuscus*) etc.

Insecta (Insects)
Small & large size Beetles, Grass Hoppers, Spiders, Mantids, Roaches, Scorpions, White ants, *etc.*

Upper Subansiri District - Dengser

Mammalian (Mammals)
Talpa micura (Himalayan Mole), *Suncus murinus* (House Shrew), *Bubalus arnee, Capra aegagrus hircus, Pteropus gigantceus* (Indian Flying fox), *Macaca mulatta* (Rhesus Monkey), *Canis aureus* (Golden Jackal), *Vulpes vulpes* (Red Fox), *Bos primigenius, Sus scrofa, Viverra zibetha* (Large Indian Civet), *Felis chaus* (Jungle Cat), *Prionailurus bengalensis* (Leopard Cat), *Ratufa bicolor* (Malayan Giant Squirrel), *Suncus murinus, etc.*

Aves (Birds)
Acridotheres grandis (Great Myna), *Picus canus* (Grey–headed Woodpecker), *Upupa epops* (Eurasian Hoopoe), *Ninox scutulata* (Brown Hawk-Owl), *Venellus indicus* (Red Wattled Lapwing), *Gracula religiosa* (Hill Myna), *Acridotheres tristis, Dendrocitta vagabunda,* Jungle myna, Black drongo, White wagtail, Forest wagtail, Great hornbill etc.

Amphibian (Frogs)
Rana danielli, Amolops gerbillus and *Microhyla rubra*

Reptilian (Snakes)
Banded Krait *(Bungarus fasciatus), Copperhead rat snake (Elaphe radiata)*, Indo-chinese rat snake (*Ptyas korros)*, Checkered keelback (*Xenohrophis piscator)* light-barred kukri snake *(Oligodon albocinctus*), *etc.*

Lepidoptera (Butterflies)

Phalanta phalantha (Common Leopard), *Papilio helenus* (Red Helen), *Papilio demoleus* (Lime Butterfly), *Eureuma hecabe* (Common Grass Yellow), *etc*.

Upper Subansiri District - Upper Subansiri
The major mammal species reported in the study area include *Panthera pardus*, *Bubalus arnee, Felis bengalensis*, *Felis marmorata*, *Arctictis binturong*, *Capra aegagrus hircus, Sus scrofa*, *Bos frontalis*, *Cervus unicolor*, etc.

The Himalayan keelback, checkered keelback, Indo-Chinese rats, snakes, striped trinket snake etc.

The observed bird species in the area include *Phalacrocorax carbo*, *Corvus brachyrhynchos, Suncus murinus, Passer domesticus, Anas gibberifrons*, *A. acuta*, *Avicaeda jendoni*, Emerald dove, Crested Bunting, yellow breasted bunting etc.

Lower Subansiri District

Middle Subansiri (Kamala HEP)

Mammals: *Panthera pardus, Felis bengalensis, Bubalus arnee, Arctictis binturong, Capra aegagrus hircus, Bos frontalis*, etc are reported in this area. 'Mithun' or *Bos frontalis* are the bovines symbolising prosperity and status among the locals. These animals, although found in the wild, are domesticated as well.

Reptiles: The Himalayan Keelback (*Natrix himalayana*), Checkered keelback *Xenochropis piscator*), Indo-Chinese rat snake (*Ptyas korros*), Cobra (*Naja naja*), Krait (*Bungarus* sp.), Python, rattle snake and various species of Lizards are found in the area.

Aves: The commonly observed birds in the area are *Phalacrocorax carbo, Anas gibberifrons, Passer domesticus, A. acuta, Aviceda jerdoni, Acridotheres tristis,* Hornbill, Cuckoo, Dove, Owl*,* Woodpecker, Indian bulbul, Sparrow, Eagle, Jungle crow, little Swift, Small minivet, Treepie, Long tailed minivet, Indian roller and various species of Pigeon. The fowls are domesticated by the locals

During field study a number of animals were observed in February-March 2013 (winter season). The observations on species seen along with their conservation status are given below:

Table 6.65: Faunal species observed in the Subansiri Sub-basin

S. No	Taxa	Record/ Observation		Conservation status
		Common Name	Scientific Name	
1	Mammals	Jungle Cat	*Felis chaus*	LC
		Mithun	*Bos frontalis*	LC
		Wild boar	*Sus scorofa*	LC
		Leopard Cat	*Prionailurus bengalensis*	LC
		House Shrew	*Suncus murinus*	LC
		Rhesus macaque	*Macaca mulatta*	LC
		Small Indian mongoose	*Herpestes auropunctatus*	LC
		Himalayan striped squirrel	*Tamiops macclellandi*	LC
2	Reptiles	Indo-chinese rat snake	*Ptyas korros*	LC

S. No	Taxa	Record/ Observation		Conservation status
		Common Name	Scientific Name	
		The banded krait	*Bungarus fasciatus*	--
		Copperhead Snake	*Elaphe radiata*	--
		Rat snake	*Ptyas mucosa*	--
		Banded wolf snake	*Lycoden fasciatus*	--
		Asian vine snake	*Ahaetulla prasina*	--
3	Amphibians	-	*Rana danieli*	*LC*
		-	*Amolops gerbillus*	*LC*
		-	*Microhyla rubra*	--
4	Birds	Jungle Crow	*Corvus brachyrhynchos*	LC
		Common Mynah	*Acridotheres tristis*	LC
		House Sparrow	*Passer domesticus*	LC
		Black Bulbul	*Hypsipetes leucocephalus*	LC
		Indian tree pie	*Dendrocitta vagabunda*	LC
		Great hornbill	*Buceros bicornis*	NT
		Yellow breasted bunting	*Emberiza aureola*	VU
		White-eared bulbul	*Pycnonotus leucotis*	LC
		Red-whiskered bulbul	*Pycnonotus jocosus*	--
		Red-vented bulbul	*Pycnonotus cafer*	LC
		Hoopoe	*Upupa epops*	LC
		Grey Treepie	*Dendrocritta formosae*	---
		Verditer Flycatcher	*Eumyias thalassina*	--
		Black drongo	*Dicrurus macrocerus*	--
		Oriental magpie-robin	*Copsychus saularis*	LC

LC: Least Concern

Inventory of Fauna at HEPs locations

Primary survey conducted at various proposed HEPs showed presence of following fauna (**Figure 6.42** / **Table 6.66**):

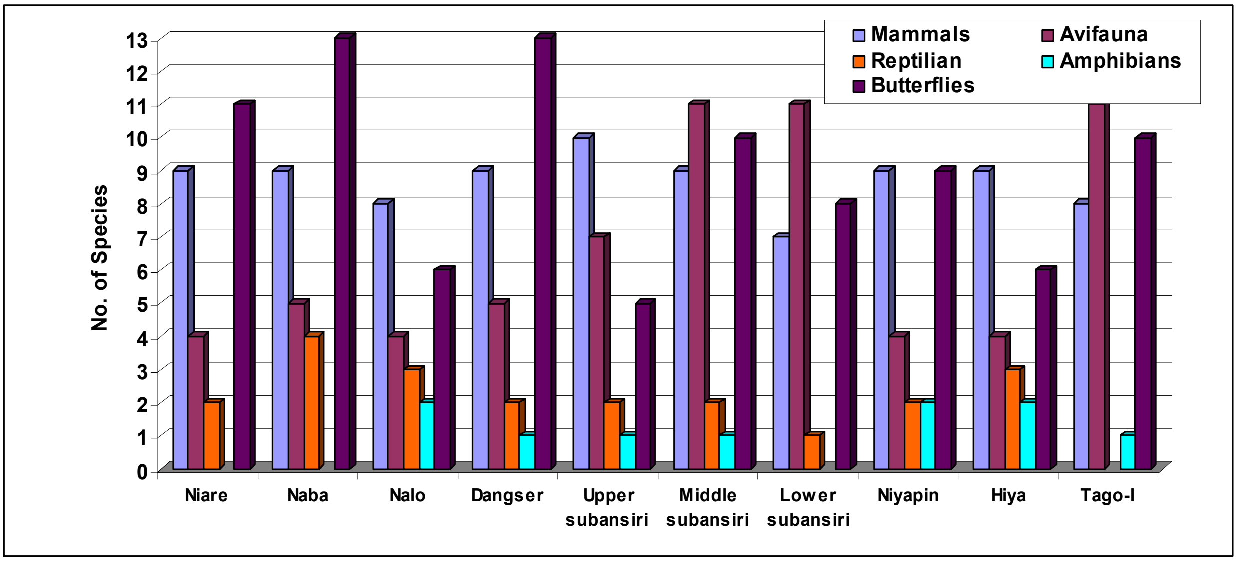


Figure 6.42: Number of species observed at various proposed HEPs in Subansiri basin

Table 6.66: Number of species observed at various proposed HEPs in Subansiri basin

Fauna	Niare	Naba	Nalo	Dengser	Upper Subansiri	Middle Subansiri	Lower Subansiri	Nyepin	Hiya	Tago-I
Mammals	9	9	8	9	10	9	7	9	9	8

Fauna	Niare	Naba	Nalo	Dengser	Upper Subansiri	Middle Subansiri	Lower Subansiri	Nyepin	Hiya	Tago-I
Avifauna	4	5	4	5	7	11	11	4	4	11
Reptilian	2	4	3	2	2	2	1	2	3	
Amphibians			2	1	1	1		2	2	1
Butterflies	11	13	6	13	5	10	8	9	6	10
Total	26	31	23	30	25	33	27	26	24	30

As per figure 6.42, highest number of faunal species were observed at Middle Subansiri (Kamla) followed by Naba, Dengser and Tago-I. Among all, butterflies were dominant overall followed by mammals and avifauna which is shown in **Table 6.67.** Moreover various species of insects and butterflies, ants, bees, wasp, centipede belonging to different classes are observed in the sampling locations.

Table 6.67: Consolidated faunal species observed at various HEPs in the study area.

Fauna Name	Animals	Middle Subansiri	Nalo	Dengser	Naba	Niare	Tago-I	Subansiri Upper	Subansiri Lower	Nyepin	Hiya
Mammals	*Capra aegagrus hircus*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Bos frontalis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Felis catus	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Canis lupus familiaris	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		
	Bos primigenius	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Prionailurus bengalensis	Yes	-	-	-	-	-	Yes	-	-	-
	Macaca mulatta	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes
	Herpestes auropunctatus	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Hystrix indica	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
	Sus scrofa	No	No	No	No	No	No	No	No	Yes	Yes
	Tamiops macclellandi	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Avifauna	*Corvus brachyrhynchos*	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes		
	Acridotheres tristis	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes		
	Passer domesticus	-	-	-	Yes	-	-	Yes	Yes	-	-
	Hypsipetes leucocephalus	Yes	-	Yes	Yes	-	Yes	-	Yes	Yes	Yes
	Dendrocitta vagabunda	-	-	Yes	-	-	-	-	Yes	-	-
	Pycnonotus leucotis	Yes	-	-	-	-	Yes	-	Yes	-	-
	Pycnonotus jocosus	Yes	-	-	-	-	Yes	-	Yes	-	-
	Pycnonotus cafer	Yes	-	-	-	-	Yes	Yes	-	-	-
	Upupa epops	Yes	-	-	-	-	Yes	-	-	-	-
	Dendrocritta	-	-	-	-	-	-	-	Yes	Yes	Yes

Fauna Name	Animals	Middle Subansiri	Nalo	Dengser	Naba	Niare	Tago-I	Subansiri Upper	Subansiri Lower	Nyepin	Hiya
	formosae										
	Eumyias thalassina	Yes	-	-	-	-	Yes	Yes	-	-	-
	Corvus macrorhynchos	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Dicrurus macrocerus	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Copsychus saularis	Yes	-	-	-	-	Yes	-	Yes	-	-
Reptiles	*Bungarus fasciatus*	-	-	-	Yes	-	-	Yes	-	-	Yes
	Elaphe radiata	Yes	-	-	-	-	-	-	Yes	Yes	Yes
	Ptyas korros	-	Yes	-	Yes	-	-	Yes	-		
	Ptyas mucosus	-	Yes	Yes	Yes	-	-	-	-	-	yes
	Lycodon fasciatus	Yes	-	-	-	Yes	-	-	-	-	-
	Aenatulla prasina	-	Yes	Yes	Yes	Yes	-	-	-	Yes	-
Amphibians	*Rana danieli*	-	Yes	-	-	-	Yes	-	-	Yes	Yes
	Microhyla rubra	-	Yes	Yes	-	-	-	-	-	Yes	Yes
	Amolops gerbillus	Yes	-	-	-	-	-	Yes	-	-	-
Butterflies	*Phalanta phalantha*	Yes	-	-	-	-	Yes	Yes	-	-	-
	Papilio helenus	-	Yes	Yes	Yes	--	-	-	Yes	=	-
	Eureuma hecabe	Yes	Yes	Yes	Yes	Yes	-	-	-	=	=
	White and yellows										
	Dellias belladonna	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Appias libythea	-	-	Yes	Yes	Yes	-	-	-	-	
	Pieris canidia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Ixias pyrene	-	-	Yes	Yes	Yes	-	-	-	-	
	Swallowtails										
	Papilio polyctor	-	Yes	Yes	Yes	-	-	-	Yes	-	-
	Graphium agetes	-	-	Yes	Yes	Yes	-	-	-	-	-
	Graphium sarpedon	-	-	Yes	Yes	Yes	Yes	-	-	Yes	-
	Graphium cloanthus	Yes	-	-	Yes	Yes	Yes	-	-	-	-
	Nymphalids Sumalia daraxa	-	-	-	-	-	-	-	-	Yes	Yes
	Paraaspra dudu	_	-	-	-	-	Yes	-	-	-	-
	Cirrochroa aoris	Yes	-	Yes	Yes	Yes	-	-	-	-	
	Acraea issoria	-	-	-	-	-	-	-	Yes	Yes	-
	Polyura eudmippus	-	-	-	-	-	-	-	-	Yes	Yes
	Junonia orithiya	Yes-	-	-	-	-	Yes	-	Yes	-	-

Fauna Name	Animals	Middle Subansiri	Nalo	Dengser	Naba	Niare	Tago-I	Subansiri Upper	Subansiri Lower	Nyepin	Hiya
	Cyrestis thyodomas	-	-	Yes	Yes	Yes	Yes	-	-	Yes	-
	Hetsina nama	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Junonia orithiya	Yes	-	Yes	-	-	-	Yes	-	-	-
	Graphim chironides	-	-	-	-	-	-	-	-	Yes	Yes
	Blue Acytolepis puspa	Yes	-	-	-	-	Yes	-	Yes	-	-

6.20 Protected Areas in Arunachal Pradesh

There are two National Parks in Arunachal Pradesh State covering 2290.82 sq.kms i.e 2.74% of the total geographical area of the State (83, 743 sq.kms.) respectively. The State has 11 Wildlife sanctuaries spread over 7486.62 sq.kms. i.e. 8.94% of the total geographical area of the State. The protected areas constitute 11.68% of the total geographical area. Arunachal Pradesh has two tiger reserves, namely Namdapha and Pakhui covering 2,847 sq.km. The Dihang-Dibang valley, with an area of 5,112 sq.kms. has been declared a Biosphere Reserve. Map showing locations of National Parks and Sanctuaries in Arunachal Pradesh is given in **Figure 6.43**.

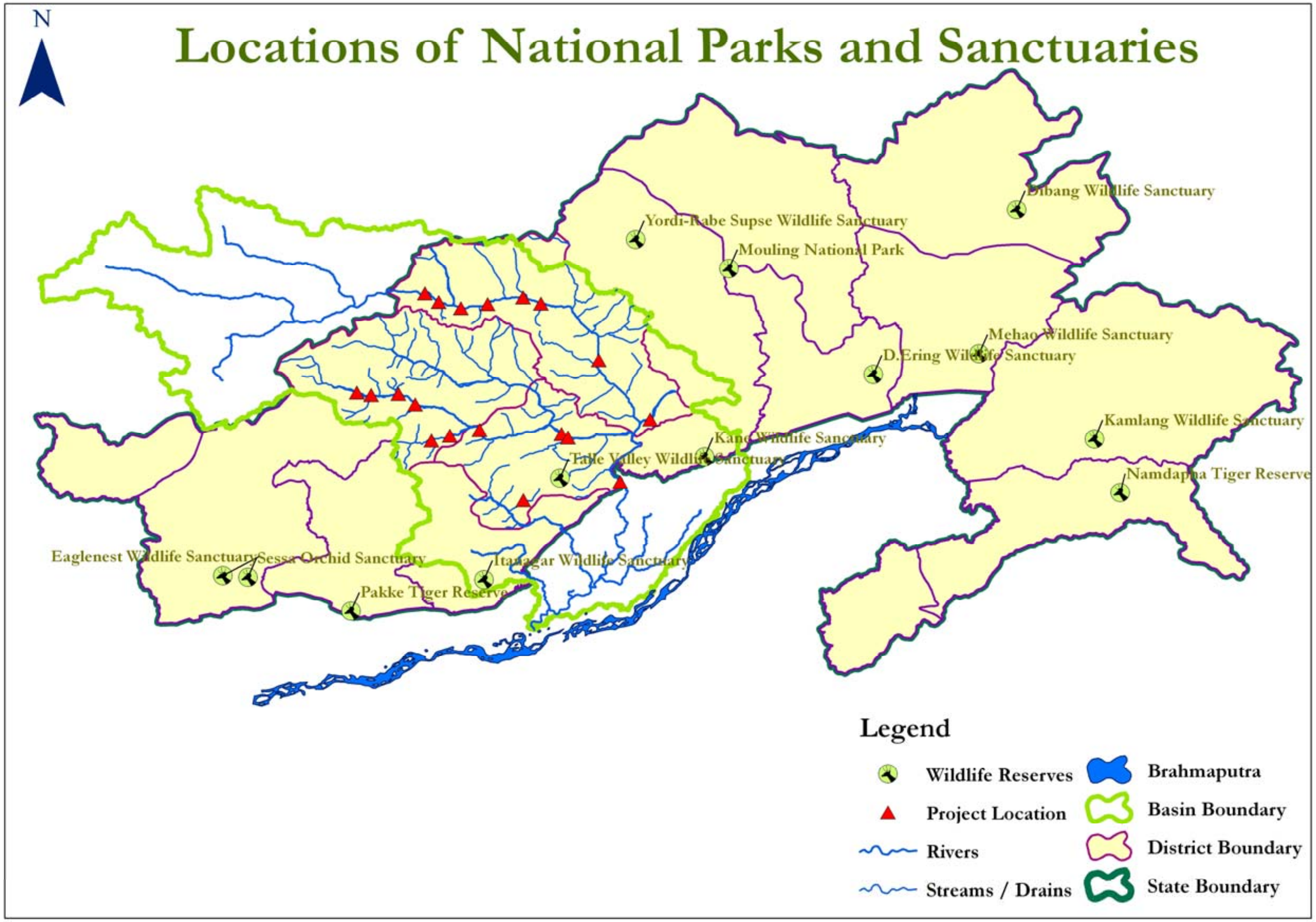


Figure 6.43: Locations of National Parks and Sanctuaries in Subansiri Basin and Arunachal Pradesh

6.21 Protected areas in Subansiri Basin

One Wildlife Sanctuary (WLS) namely Tale Valley Wildlife Sanctuary is located in Lower Subansiri District in an area of 337 sq. km. and lies in between the Subansiri, Sipu and Pange Rivers surrounded by densely forested mountains ranging for 2,000 to 4,000 mtr. altitude. The Wildlife Sanctuary is representative of temperate flora and fauna. Talle Wildlife Sanctuary (TWS) lies approximately between 27°30'–27°39'N and 93°15'–94°2'E with an area of about 55 km^2 and altitudes ranging from 1600–2732 m. It is a part of Tale RF (515.875 Sq.Km) notified during 1976 vides No.FOR.101/71 dt.15.05.76. Tale WLS (337 Sq.Km) notified vide No.CWL / D / 58 / 88 / Pt / 2993-3092 dtd.14.06.95. According to the Apatanese, 'Talle' means an endemic onion not found beyond this valley. Therefore, the name 'Talle' was proposed for this valley by the Apatanese from time immemorial. Map showing location of Talley WLS in Subansiri Basin is given in **Figure 6.44**.

20 species belonging to Mammals, 8 Reptiles and Amphibians, 1 Arthropoda, 10 butterflies and moth, 3 Hymenoptera, 5 Diptera, 1 Dermaptera, 1 Isoptera, 6 Coleoptera, 2 Odonata and 2 Annelida have been reported to occur in Tale Valley Wildlife Sanctuary located in Lower Subansiri district. The checklist of fauna species is given in **Annexure 6.16.** Of these species, threatened and endangered species are:

Mammals: *Presbytis pileatus, Petaurista sp., Manis crassicaudata, Felis bengalensis, Panthera pardus* and Clouded leopard.
Bird: Hornbills
Reptile: *Python molurus*
Butterfly: *Lethe margaritae*

The nearest proposed HEP (Tago 1) site is outside 10 kms radius of Talley Valley Wildlife sanctuary.

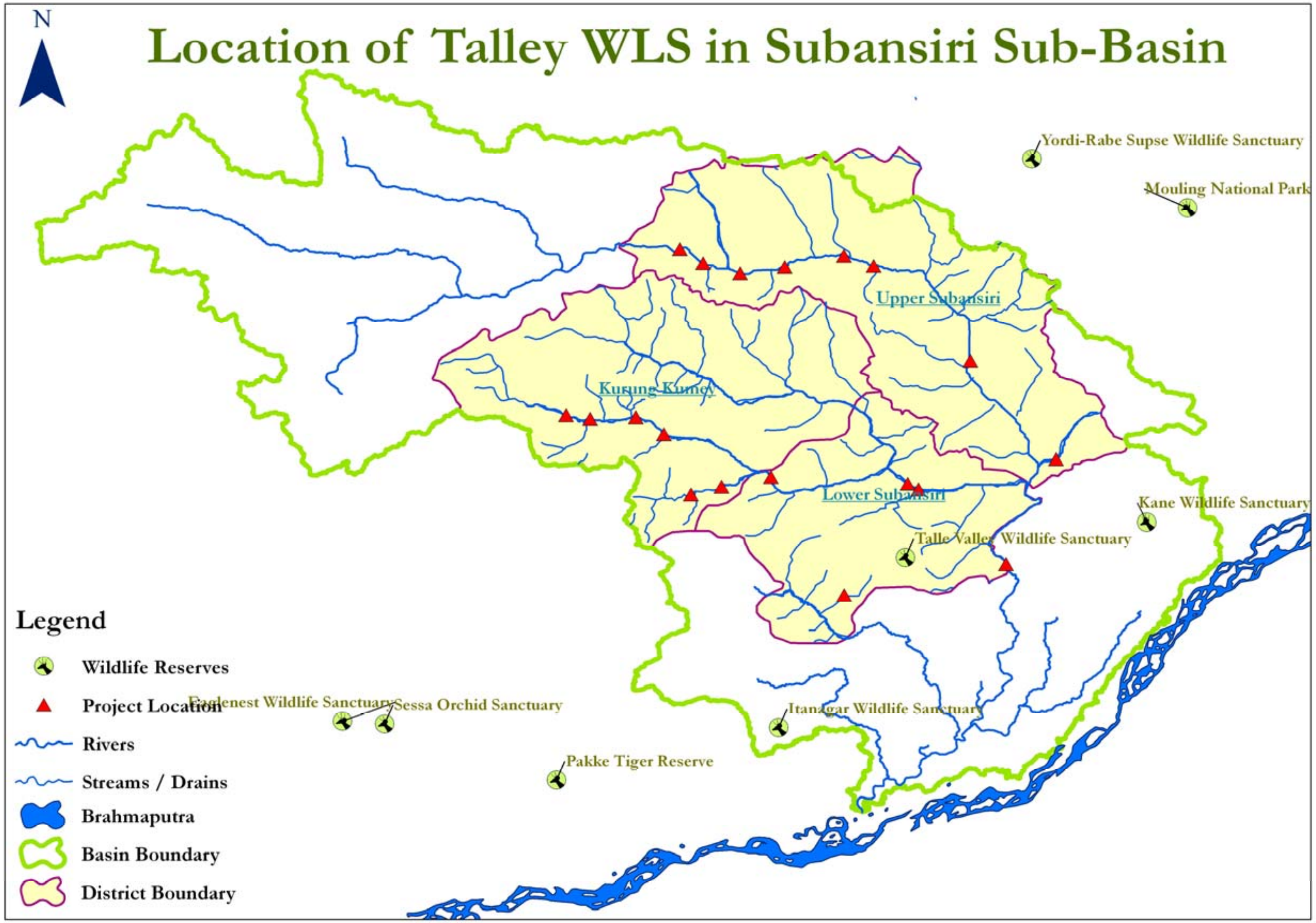


Figure 6.44: Location of Talley WLS in Subansiri Basin

6.22 Important Bird Areas in Arunachal Pradesh

Arunachal Pradesh has the second highest number of IBAs in northeast India. Brief description of IBAs located in Upper Subansiri, Lower Subansiri and Kurung Kumey districts, Subansiri Basin is given below:

1 Nacho-Limeking-Taksing-Majha
Site Code: IN-AR-16
IBA criteria: A1 (Threatened Species), A2 (Endemic Bird Area 130: Eastern Himalayas)
Protection status: Not officially protected
District: Upper Subansiri

2 Koloriang- Sarli-Damin Areas
Site code: IN-AR-10
IBA criteria: A1 (Threatened Species), A2 (Endemic Bird Area 130: Eastern Himalayas)
Protection status: Not officially protected
District: Lower Subansiri

3 Talley Valley Wildlife Sanctuary
IBA Site Code: IN-AR-24
IBA criteria: A1 (Threatened Species), A2 (Endemic Bird Area 130: Eastern Himalayas)
Protection status: Wildlife Sanctuary, established in July 1995
District: Lower Subansiri

Details of three IBAs are given in **Annexure 6.17.** A map showing Important Bird Areas in Subansiri Basin is given in **Figure 6.45**.

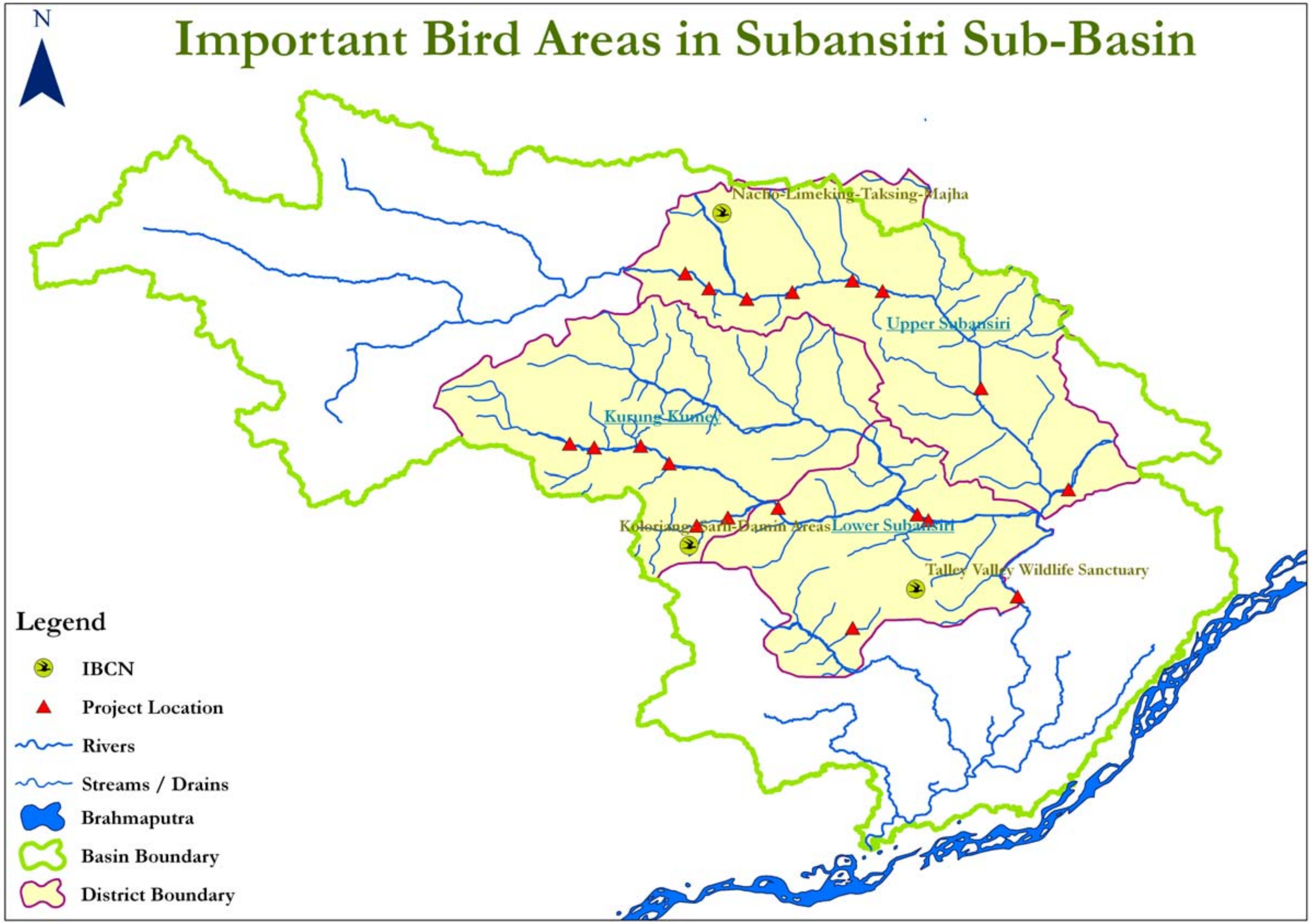


Figure 6.45: Important Bird Areas in Subansiri Basin

Chapter 7: Aquatic Ecology

7.1 Water Quality

The water sampling and its quality analyses provides a broad picture of the parameters that define the aquatic environment as a whole. Biological parameters help to detect the changes in natural water quality that other methods might miss or underestimate. Resident biotic components in their environments are indicators of environmental quality for assessing the impacts that chemical sampling is unlikely to detect due to any modification of river course or flow pattern. Plankton (phytoplankton and zooplankton), benthic macro-invertebrates, aquatic plants, and fish are the most commonly used indicator in assessing biological integrity of any river ecosystem. Therefore the river water quality assessments are best analysed when these are based upon the biological together with physical and chemical assessments. All these together provide a complete picture of the river water quality in general. In the description of physico-chemical and biological parameters the results have been discussed based upon averages of seasonal variations obtained though systematic sampling where all the generated data were collected on monthly basis.

7.1.1 Physico-Chemical Water Quality

Number of sampling locations for water quality assessment and methods of assessment is already given in Chapter 5. The detailed results of all the water quality parameters analysed for water samples collected monthly from April, 2012 to September, 2013 from Subansiri as well as its tributaries at different sampling locations are given in **Annexure-7.2 of Volume-II.**

It can be seen from the results of all the parameters analysed that water quality of Subansiri river as well as its tributaries was excellent and was found well within tolerance limits of inland surface water as per IS: 2296 and falls under Class-A (**Annexure 7.1**) and within limits of prescribed Central Pollution Control Board (CPCB) standards for drinking water (**Annexure 7.1**). In addition the concentration of parameters like Fe, Cd, Hg, Cu, Cr, Zn, Cr and Mn are below the permissible limit. Month wise details of sampling results are given in **Annexure-7.2 of Volume-II.** The number of water sampling locations on HEP's location is given below.

Sr. No.	Name of the project	Number of sampling locations
1	Niare	2
2	Naba	3
3	Kurang I & II	1
4	Tago – I	1
5	Subansiri Lower	3
6	Subansiri Middle (Kamla)	3
7	Subansiri Upper	3
8	Nalo	1
9	Dengser	2
10	Nyepin	1
11	Hiya	1
12	Chauldua Ghat*	1
13	Badodighat*	1
Total		23

Note: * ➔ *Additional locations of CWC's G&D stations*

7.1.1.1 Subansiri River

The pH of at most of the sampling sites was from almost neutral to slightly alkaline. It varied from 7.1-7.9 during the pre monsoon season. Highest pH was recorded at sampling site (S2) near d/s of Niare HEP and lowest at sampling site (S19) d/s / of Subansiri River at Badodighat (**Figure 7.1**). During the post-monsoon season, it varied from 7.5-8.4 and highest pH was at (S19) d/s/ of Subansiri River at Badodighat and lowest at (S16) dam site of Lower Subansiri HEP. During monsoon season pH varied from 7.3-8.5, highest pH was at (S2) at Niare Dam Site while lowest at (S10 & S15) near Dam Site of Upper Subansiri HEP and u/s of Lower Subansiri HEP.

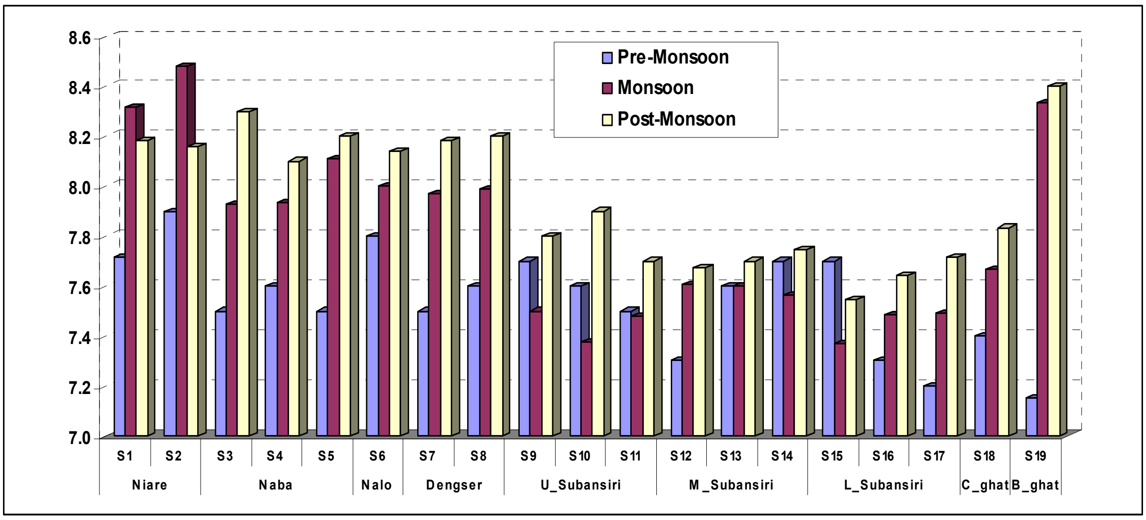


Figure 7.1: pH of Subansiri River

During pre-monsoon season Dissolved Oxygen (DO) values varied from 6.3-8.3 mg/l as highest value of DO was found at sampling site (S9 & 10) u/s and dam site of Upper Subansiri HEP while lowest at sampling site (S3 &4) u/s and dam site of Naba HEP (**Figure 7.2**). In monsoon season DO value varied from 6.9-8.4mg/l, highest value of DO observed at (S12) u/s of Upper Subansiri HEP whereas lowest at (S3) u/s of Naba HEP. Post-monsoon season DO was recorded range from 8.0-8.3 mg/l. highest value of DO observed at (S17) d/s of Lower Subansiri HEP whereas lowest at (S7) Dam site of Dengser HEP.

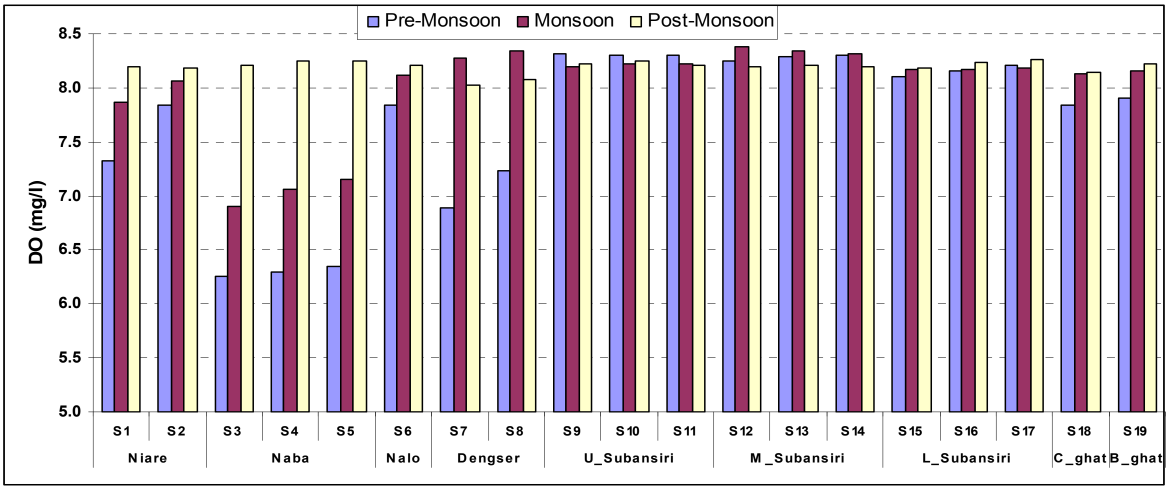


Figure 7.2: Dissolved Oxygen level (mg/L) in Subansiri River during the study period

Total Dissolved Solids (TDS) varied from 87.6- 301.2 mg/l at different sampling locations in Subansiri River during pre-monsoon season (**Figure 7.3**). In monsoon season it ranged from 102.1-314.1 mg/l. During the post- monsoon seasons it was recorded 106.5-368.9 mg/l. TDS was observed highest in both the monsoon and post monsoon season which may be due to inflow of monsoon runoff and soil erosion.

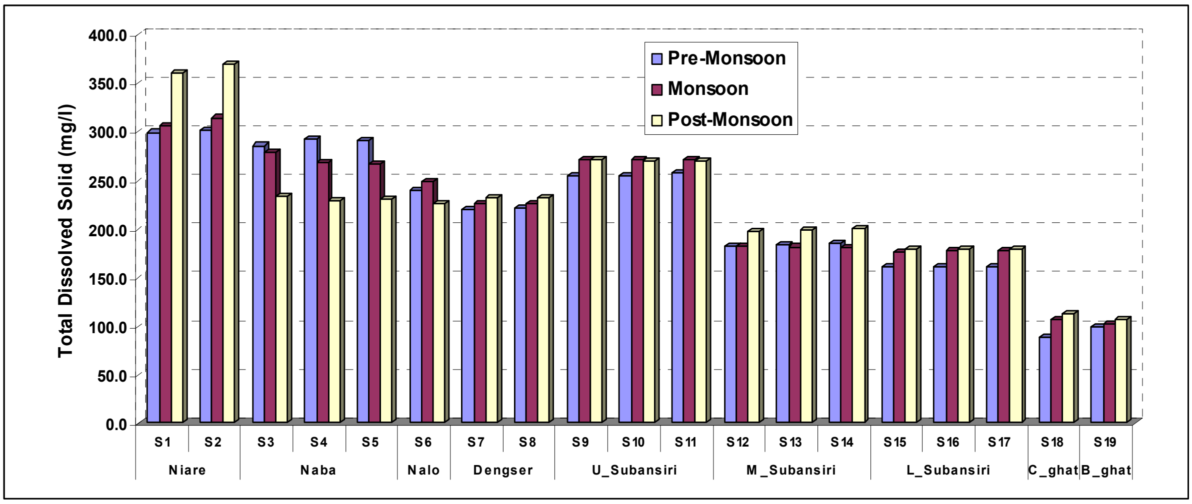


Figure 7.3: Total Dissolved Solids of Subansiri River

Electrical conductivity (EC) was observed highest during the pre-monsoon season as compared to the monsoon and post-monsoon season at Niare and Nalo HEPs (**Figure 7.4**). EC varied from 131.1- 490.1 µS/cm at different sampling locations in Subansiri River during pre-monsoon season. In monsoon season it ranged from 144.3-463.9 µS/cm whereas during post- monsoon seasons it was recorded 146.3-389.1 µS/cm.

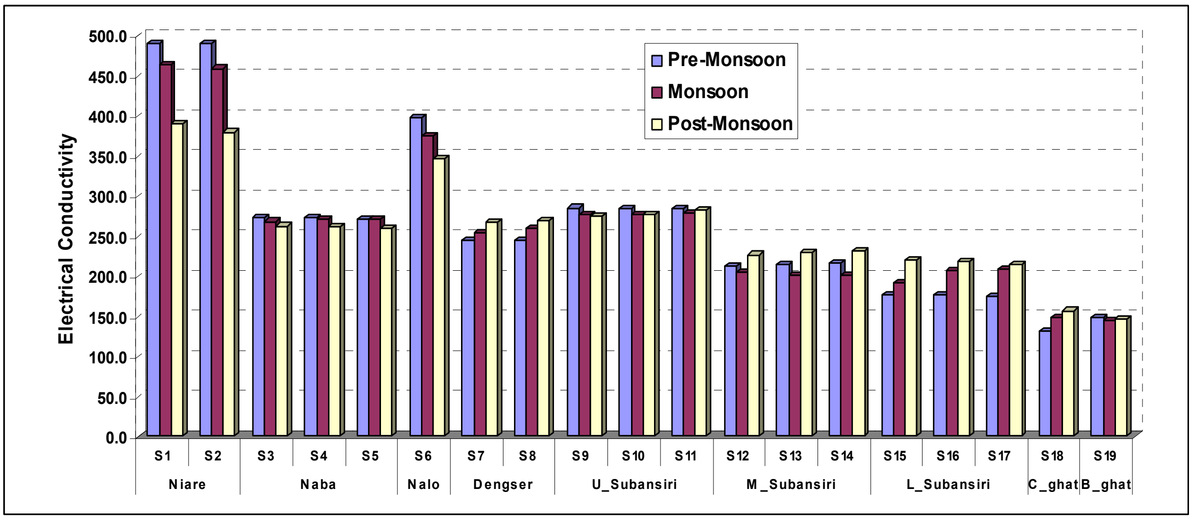


Figure 7.4: Electrical Conductivity of Subansiri River

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values at all sampling sites were very low i.e. <2 and <4 respectively. The Total Coliform level was almost nil (<2) at all the sampling sites, indicating the fact that low pollution load in river. The BOD values were within the permissible limit, which indicates the absence of organic pollution loading. This is mainly due to the low population density and absence of industries in the area. The low COD values also indicate the absence of chemical pollution loading in the area.

Chlorides occur in all natural waters in widely varying concentrations, chlorides is available in natural water, mainly through solvent power of water, which dissolves chlorides from top soil and deeper formations. The chlorides were found more in post-monsoon season followed by monsoon and pre-monsoon season which were well below the desirable limit of 200 mg/l, specified for meeting drinking water requirements (**Table 7.1**). The Sulphates were found more in post-monsoon season followed by monsoon and pre-monsoon season. The sulphate was found well below the desirable limit of 200 mg/l specified for drinking water purposes.

The concentration of nitrates and phosphates at various sampling locations was observed to below <2.0 mg/l during all season which were within the permissible limit. The concentration of various cations, e.g. sodium, potassium, calcium and magnesium was observed below the desirable limit. The concentration of various heavy metals was found well below the permissible limits. Iron was found well below the permissible limit of 1 mg/l specified for drinking water purposes.

7.1.1.2 Kurung River

The pH was from neutral to slightly alkaline. It ranged 7.0 to 7.3 from pre-monsoon season to post monsoon season. Highest pH was recorded in post-monsoon season (**Figure 7.5**) at Kurung-I HEP. Dissolved Oxygen (DO) was also found well in all season which varies between 8.1 to 9.3 mg/l from pre-monsoon season to post-monsoon season. Highest DO was recorded during the post-monsoon season at Kurung-I HEP (**Figure 7.5**).

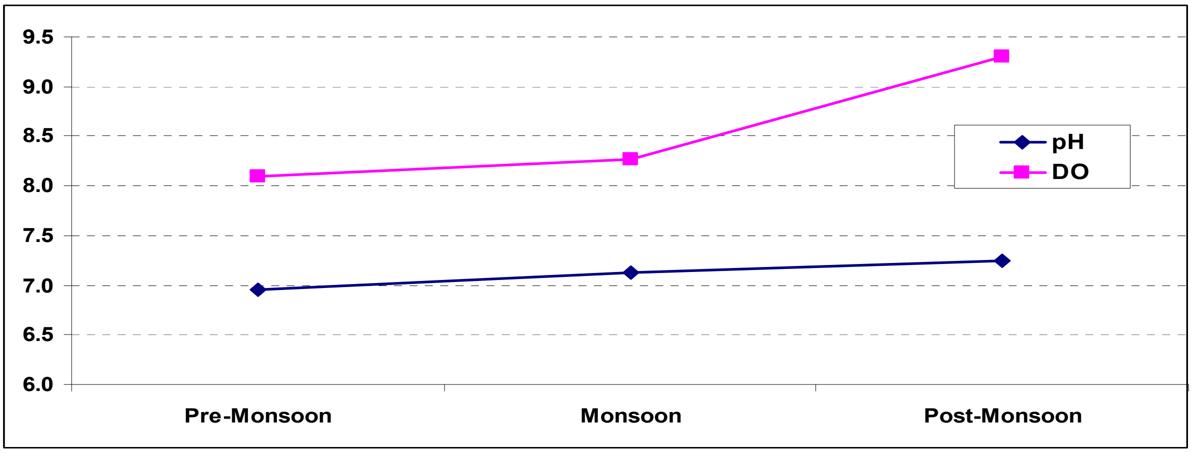


Figure 7.5: pH and Dissolved Oxygen of Kurung River

Table 7.1: Physico-chemical characteristics of Subansiri River

Parameter (mg/l)	Season	Niare		Naba			Nalo	Dengser		Upper Subansiri			Middle Subansiri (Kamla)			Lower Subansiri			Chauldua ghat	Badodi ghat
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19
Sodium	Pre-monsoon	5.6	5.7	4.1	4.3	4.3	3.6	2.6	2.9	1.4	1.2	1.3	0.8	1.0	1.0	0.7	0.8	0.8	0.8	0.7
	Monsoon	6.2	6.8	4.6	4.3	4.2	4.4	4.4	4.8	1.6	2.1	2.3	2.4	2.3	2.4	1.4	1.4	1.2	1.4	2.2
	Post-Monsoon	8.0	8.0	3.2	3.3	3.2	3.7	3.5	3.5	4.0	3.8	3.6	2.7	2.6	2.7	2.1	2.1	2.3	2.7	3.6
Potassium	Pre-monsoon	2.8	2.9	1.4	1.6	1.5	2.4	1.1	1.1	0.9	1.0	0.9	0.8	0.8	0.8	0.7	0.8	0.8	1.0	0.9
	Monsoon	3.5	3.9	2.3	2.2	2.2	2.8	1.9	2.0	1.4	1.7	1.9	1.5	1.5	1.5	1.2	1.2	1.2	1.9	2.1
	Post-Monsoon	8.5	8.6	2.0	2.4	2.4	3.8	1.8	2.3	3.1	3.0	3.2	1.9	1.9	2.1	1.4	1.7	2.0	2.6	3.5
Total Hardness	Pre-monsoon	113.9	116.0	104.2	108.4	108.0	138.1	60.4	58.7	52.6	53.3	54.5	47.1	47.6	48.4	66.4	64.8	64.1	35.7	71.0
	Monsoon	117.0	118.1	108.6	112.3	111.7	138.2	62.8	65.0	58.3	58.2	58.8	52.4	52.5	52.7	62.9	62.8	63.3	43.8	74.9
	Post-Monsoon	123.8	123.8	128.4	128.6	125.4	139.7	71.0	70.8	68.6	69.9	71.4	54.1	54.2	54.0	64.9	65.3	66.2	75.9	79.2
Chlorides	Pre-monsoon	11.6	11.1	9.6	10.2	10.0	12.7	9.9	10.2	14.2	14.9	14.7	14.3	14.8	15.1	13.4	13.0	13.4	15.5	13.1
	Monsoon	14.4	14.7	12.1	13.1	13.7	13.4	14.5	16.0	14.0	13.7	12.7	15.6	15.0	14.5	17.0	16.8	16.0	16.4	18.4
	Post-Monsoon	20.9	20.7	16.8	17.6	17.4	15.2	19.0	20.1	14.0	14.0	14.2	14.0	14.5	14.8	14.2	14.7	14.8	38.2	43.9
Calcium	Pre-monsoon	29.3	29.2	19.9	21.9	20.3	34.1	20.5	20.2	13.9	13.6	13.6	10.2	9.6	9.8	5.9	5.9	6.0	5.1	8.2
	Monsoon	33.2	38.2	23.0	25.7	26.1	36.8	39.6	37.0	15.6	16.1	16.4	15.4	15.1	15.2	9.3	9.1	10.7	8.6	14.8
	Post-Monsoon	48.2	47.8	29.0	30.4	28.6	34.8	35.6	41.1	16.5	16.3	16.1	18.7	18.2	17.9	11.7	11.8	11.9	13.1	18.7
Magnesium	Pre-monsoon	14.4	14.3	12.5	13.3	13.4	7.1	10.9	11.4	13.6	13.6	13.2	8.3	7.7	8.2	5.1	5.6	6.1	4.5	5.7
	Monsoon	18.1	18.8	14.7	14.1	14.6	9.0	14.4	15.6	12.1	12.4	12.2	14.1	13.3	12.5	10.1	9.4	9.5	9.4	9.4
	Post-Monsoon	27.2	28.7	16.6	16.2	17.3	8.9	12.2	14.5	14.0	14.0	14.2	12.9	12.5	12.9	9.4	9.7	11.0	12.1	13.6
Sulphates	Pre-monsoon	<5.0	<5.0	5.4	5.4	5.4	13.6	8.4	8.9	8.1	8.0	8.0	9.4	9.1	8.8	8.8	8.7	8.8	9.5	8.7

Parameter (mg/l)	Season	Niare		Naba			Nalo	Dengser		Upper Subansiri			Middle Subansiri (Kamla)			Lower Subansiri			Chauldua ghat	Badodi ghat
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19
	Monsoon	5.9	6.2	6.3	7.0	7.3	15.1	14.0	14.8	7.7	8.5	8.9	9.3	9.4	9.7	9.7	9.7	9.6	9.0	10.1
	Post-Monsoon	10.9	11.7	7.2	7.4	7.1	15.1	12.7	13.8	9.7	9.7	9.2	9.3	9.4	9.8	9.3	9.3	10.1	16.3	15.5
Nitrates	Pre-monsoon	<0.05	<0.05	<0.05	<0.05	<0.05	1.0	1.0	1.0	0.6	0.5	0.4	0.7	0.6	0.6	0.6	0.6	0.7	0.8	0.8
	Monsoon	<0.05	<0.05	<0.05	<0.05	<0.05	1.0	1.2	1.4	0.2	0.3	0.3	0.1	0.2	0.3	0.6	0.6	0.6	1.0	2.0
	Post-Monsoon	<0.06	<0.05	<0.05	<0.05	<0.05	1.1	1.3	1.7	0.6	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	3.2	3.7
Phosphates	Pre-monsoon	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	Monsoon	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	< 0.01	< 0.01
	Post-Monsoon	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	<0.01	<0.01	< 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	< 0.01	< 0.01
Total Alkalinity	Pre-monsoon	61.9	59.4	45.3	51.8	50.5	71.6	51.1	52.0	37.4	37.0	36.5	50.7	49.2	47.8	35.6	35.5	36.5	27.5	46.2
	Monsoon	61.0	64.7	55.7	56.3	56.1	88.9	70.1	71.3	32.0	32.6	33.7	49.8	50.8	51.6	41.4	42.9	44.2	31.3	58.7
	Post-Monsoon	92.0	97.2	64.7	64.1	64.9	77.7	65.1	65.1	39.5	40.6	41.0	54.5	54.4	54.9	46.2	45.6	45.2	35.6	64.8

Total Dissolved Solids (TDS) varied between 51.1- 69.7 mg/l during pre-monsoon season to post-monsoon season (**Figure 7.6**). Highest TDS was recorded in post-monsoon season followed by monsoon- and pre-monsoon which may be due to erosion of soil. While Electrical Conductivity (EC) was also observed highest during the post-monsoon season as compare to the monsoon and pre-monsoon season (**Figure 7.6**). EC varied between 94.1- 174.0 µS/cm from pre-monsoon to post monsoon season at Kurung-I HEP.

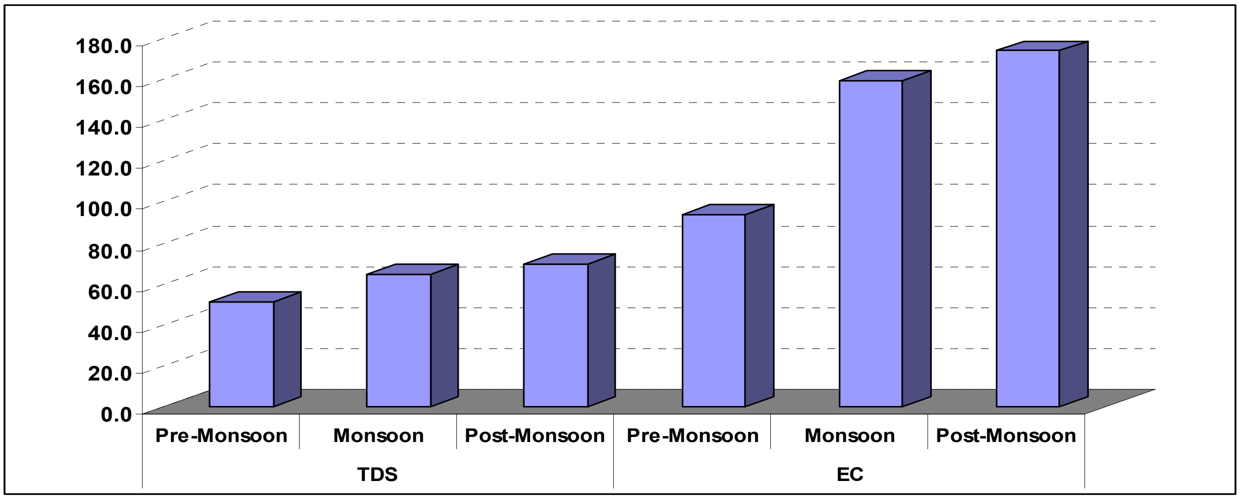


Figure 7.6: Total Dissolved Solids and Electrical Conductivity of Kurung River

Both Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were found within permissible limit in all season. The Total Coliform level was almost nil (<2) at Kurung-I HEP, indicating the fact that low pollution load in river.

The chlorides were found more in post-monsoon season followed by monsoon and pre-monsoon season which were well below the desirable limit of 200 mg/l, specified for meeting drinking water requirements (**Table 7.2**). The Sulphates were found more in post-monsoon season followed by monsoon and pre-monsoon season. The sulphate was found well below the desirable limit. The concentration of nitrates and phosphates was observed to below <1.0 mg/l during all season which were within the permissible limit.

The concentration of various cations, e.g. sodium, potassium, calcium and magnesium was observed below the desirable limit. The concentration of various heavy metals was found well below the permissible limits. Iron was found well below the permissible limit of 1 mg/l specified for drinking water purposes.

Table 7.2: Physico-chemical characteristics of Kurung River

Parameter (mg/l)	Season	Kurung-I
		S22
Sodium	Pre-monsoon	1.4
	Monsoon	1.47
	Post-Monsoon	2.5
Potassium	Pre-monsoon	0.8
	Monsoon	0.9
	Post-Monsoon	1.0
Total Hardness	Pre-monsoon	36.2

Parameter (mg/l)	Season	Kurung-I
		S22
	Monsoon	37.2
	Post-Monsoon	36.9
Chlorides	Pre-monsoon	5.8
	Monsoon	4.8
	Post-Monsoon	6.1
Calcium	Pre-monsoon	8.4
	Monsoon	10.4
	Post-Monsoon	12.5
Magnesium	Pre-monsoon	3.4
	Monsoon	4.5
	Post-Monsoon	4.9
Sulphates	Pre-monsoon	2.5
	Monsoon	3.2
	Post-Monsoon	4.1
Nitrates	Pre-monsoon	<0.1
	Monsoon	<0.1
	Post-Monsoon	<0.1
Phosphates	Pre-monsoon	<1.0
	Monsoon	<1.0
	Post-Monsoon	<1.1
Total Alkalinity	Pre-monsoon	29.7
	Monsoon	31.3
	Post-Monsoon	35.2

7.1.1.3 Page River

The pH was from neutral to slightly alkaline. It ranged 7.2 to 8.5 from pre-monsoon season to post monsoon season at both Nyepin and Hiya HEPs locations. Highest pH was recorded in both monsoon and post-monsoon season (**Figure 7.7**). Dissolved Oxygen (DO) was also found well in all season which varies between 6.8 to 8.3 mg/l from pre-monsoon season to post-monsoon season. Highest DO was recorded during the monsoon season at both HEPs (**Figure 7.7**).

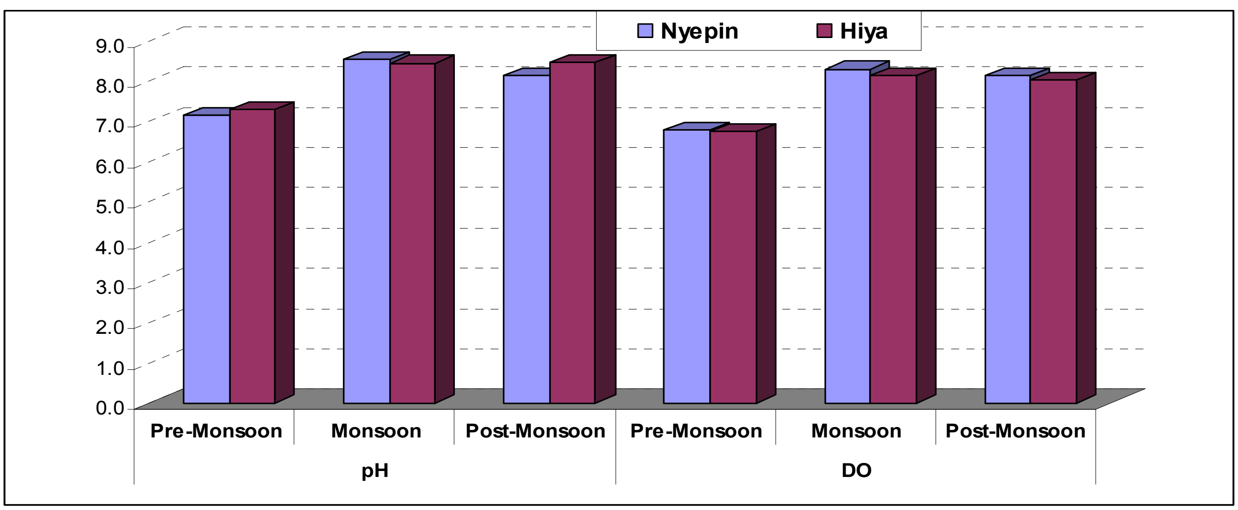


Figure 7.7: pH and Dissolved Oxygen (mg/L) in Page River

Total Dissolved Solids (TDS) varied between 79.1- 221.1 mg/l during pre-monsoon season to post-monsoon season (**Figure 7.8**). Highest TDS was recorded in post-monsoon season followed by monsoon- and pre-monsoon which may be due to erosion of soil. While Electrical Conductivity (EC) was also observed highest during the post-monsoon season as compare to the monsoon and pre-monsoon season (**Figure 7.8**). EC varied between 80.1- 240.0 µS/cm from pre-monsoon to post monsoon season at both HEPs.

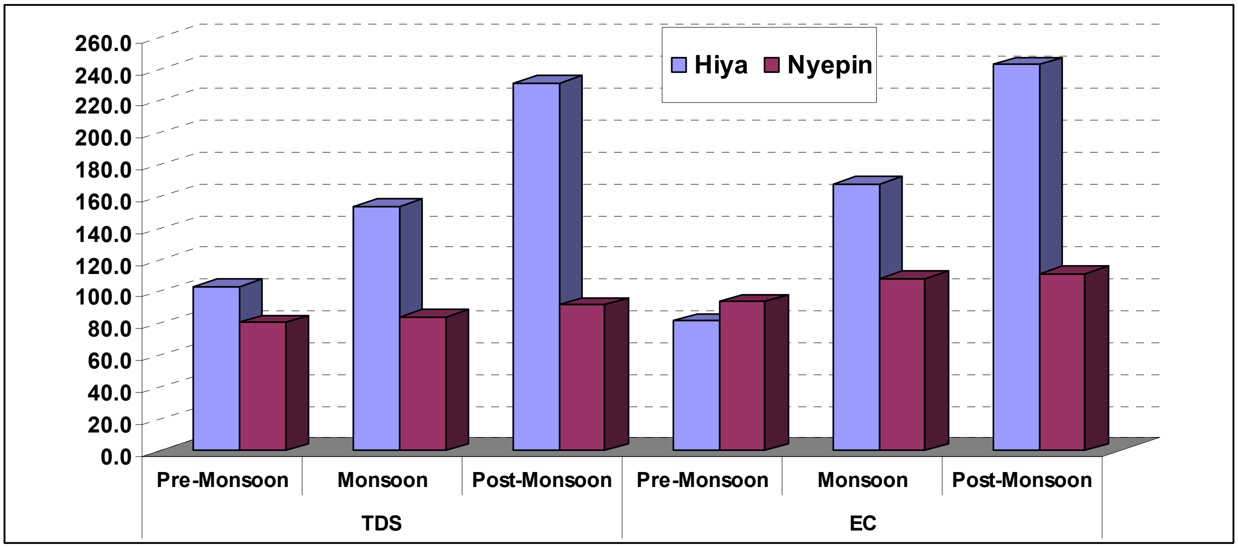


Figure 7.8: Total Dissolved Solids and Electrical Conductivity of Page River

Both Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were found within permissible limit in all season. The Total Coliform level was almost nil (<2) at both HEPs, indicating the fact that low pollution load in river.

The chlorides were found more in post-monsoon season followed by monsoon and pre-monsoon season which were well below the desirable limit of 200 mg/l, specified for meeting drinking water requirements (**Table 7.3**). The Sulphates were found more in post-monsoon season followed by monsoon and pre-monsoon season. The sulphate was found well below the desirable limit. The concentration of phosphates was observed to below <1.0 mg/l during all season which were within the permissible limit.

The concentration of various cations, e.g. sodium, potassium, calcium and magnesium was observed below the desirable limit. The concentration of various heavy metals was found well below the permissible limits. Iron was found well below the permissible limit of 1 mg/l specified for drinking water purposes.

Table 7.3: Physico-chemical characteristics of Page River

Parameter (mg/l)	Season	Hiya	Nyepin
		S20	S21
Sodium	Pre-monsoon	1.9	2.3
	Monsoon	2.6	4.1
	Post-Monsoon	3.6	3.9
Potassium	Pre-monsoon	0.9	0.9
	Monsoon	1.7	1.0

Parameter (mg/l)	Season	Hiya	Nyepin
		S20	S21
	Post-Monsoon	4.1	1.9
Total Hardness	Pre-monsoon	34.3	35.2
	Monsoon	34.9	37.4
	Post-Monsoon	36.2	44.1
Chlorides	Pre-monsoon	8.5	6.5
	Monsoon	16.7	16.7
	Post-Monsoon	26.9	29.6
Calcium	Pre-monsoon	5.8	6.5
	Monsoon	15.1	13.8
	Post-Monsoon	23.4	22.8
Magnesium	Pre-monsoon	5.5	6.3
	Monsoon	14.5	9.8
	Post-Monsoon	13.1	10.4
Sulphates	Pre-monsoon	3.4	2.6
	Monsoon	8.7	8.8
	Post-Monsoon	17.8	16.7
Nitrates	Pre-monsoon	0.1	0.1
	Monsoon	1.1	1.3
	Post-Monsoon	2.8	2.7
Phosphates	Pre-monsoon	< 0.01	< 0.01
	Monsoon	< 0.01	< 0.01
	Post-Monsoon	< 0.01	< 0.01
Total Alkalinity	Pre-monsoon	37.0	37.9
	Monsoon	39.1	44.8
	Post-Monsoon	35.6	64.8

7.1.1.4 Kale River

The pH was from neutral to slightly alkaline. It ranged 7.1 to 8.2 from pre-monsoon season to post monsoon season. Highest pH was recorded in monsoon season (**Figure 7.9**) at Tago-I HEP. Dissolved Oxygen (DO) was also found well in all season which varies between 7.4 to 8.2 mg/l from pre-monsoon season to post-monsoon season. Highest DO was recorded during the post-monsoon season which indicates low pollution in river water (**Figure 7.9**).

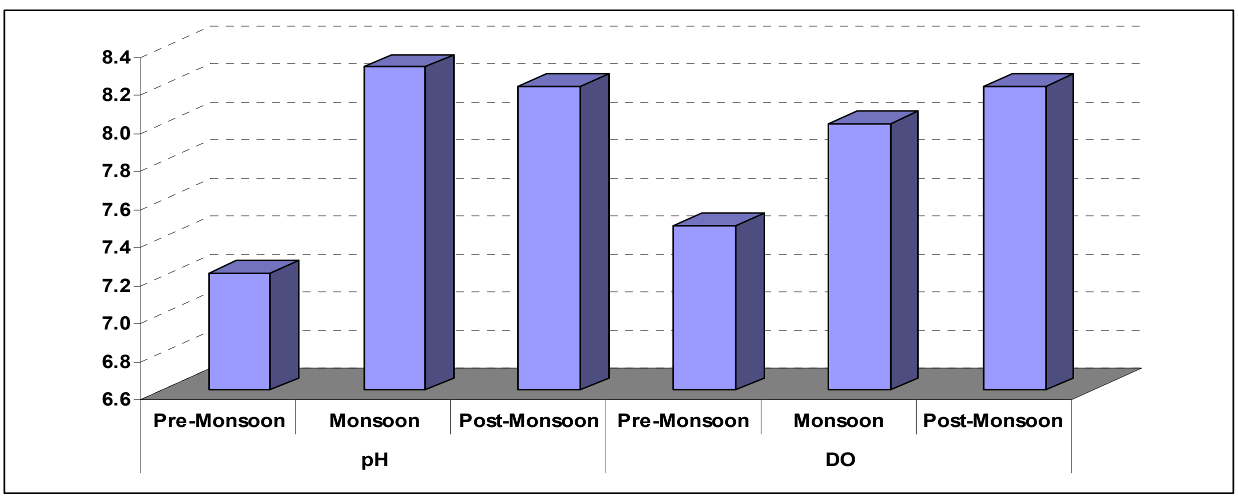


Figure 7.9: pH and Dissolved Oxygen of Kale River

Total Dissolved Solids (TDS) varied between 169.4- 239.9 mg/l during pre-monsoon season to post-monsoon season (**Figure 7.10**). Highest TDS was recorded in post-monsoon season followed by monsoon- and pre-monsoon which may be due to erosion of soil. While Electrical Conductivity (EC) was also observed highest during the post-monsoon season as compare to the monsoon and pre-monsoon season (**Figure 7.10**). EC varied between 161.6- 221.1 μS/cm from pre-monsoon to post monsoon season.

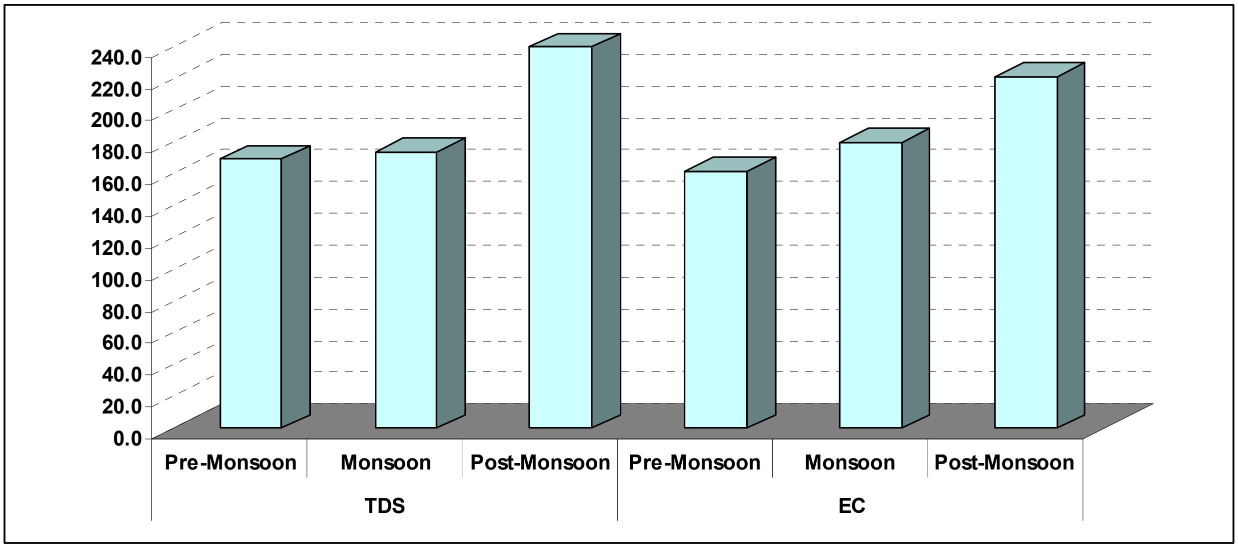


Figure 7.10: Total Dissolved Solids and Electrical Conductivity of Kale River

Both Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were found within permissible limit in all season. The Total Coliform level was almost nil (<2) at Tago-I HEP, indicating the fact that low pollution load in river.

The chlorides were found more in post-monsoon season followed by monsoon and pre-monsoon season which were well below the desirable limit of 200 mg/l, specified for meeting drinking water requirements (**Table 7.4**). The Sulphates were found more in post-monsoon season followed by monsoon and pre-monsoon season. The sulphate was found well below the desirable limit. The concentration of nitrates and phosphates was observed to below <1.0 mg/l during all season which were within the permissible limit.

The concentration of various cations, e.g. sodium, potassium, calcium and magnesium was observed below the desirable limit. The concentration of various heavy metals was found well below the permissible limits. Iron was found well below the permissible limit of 1 mg/l specified for drinking water purposes.

Table 7.4: Physico-chemical characteristics of Kale River

Parameter (mg/l)	Season	Tago-I
		S23
Sodium	Pre-monsoon	7.3
	Monsoon	6.0
	Post-Monsoon	59.5
Potassium	Pre-monsoon	2.3
	Monsoon	2.8

Parameter (mg/l)	Season	Tago-I
		S23
	Post-Monsoon	3.1
Total Hardness	Pre-monsoon	25.1
	Monsoon	30.0
	Post-Monsoon	54.1
Chlorides	Pre-monsoon	13.1
	Monsoon	14.5
	Post-Monsoon	28.3
Calcium	Pre-monsoon	6.5
	Monsoon	10.2
	Post-Monsoon	15.8
Magnesium	Pre-monsoon	2.3
	Monsoon	6.3
	Post-Monsoon	12.9
Sulphates	Pre-monsoon	1.3
	Monsoon	3.7
	Post-Monsoon	5.5
Nitrates	Pre-monsoon	<0.05
	Monsoon	0.1
	Post-Monsoon	0.2
Phosphates	Pre-monsoon	< 0.01
	Monsoon	< 0.01
	Post-Monsoon	< 0.01
Total Alkalinity	Pre-monsoon	33.4
	Monsoon	52.6
	Post-Monsoon	97.7

7.1.2 Conclusion

The pH levels in the Subansiri River and its tributaries ranged from 7.1 to 9.3 in all seasons at various sites covered as a part of the study. Though at number of sites pH was more than 8 indicating marginally higher alkaline nature of water, the pH levels in general are well within the permissible limit specified for drinking water requirements (**Refer Annexure 7.1**). The dissolved oxygen values in general were quite high owing to shallow cold waters and water turbulence in most of the streams.

The BOD values are well within the permissible limit which were due to the absence of organic pollutants load and its sources in the basin in general as the population density is very low and there is complete absence of industries in the basin. The low COD values also indicate the absence of chemical pollutants to be loaded into rivers/streams from the catchment areas. Total Coliform level was nil at all the sampling sites.

The TDS levels ranged from as low as 51.1 to 301.2 mg/l which are well below the permissible limit of 500 mg/l specified for drinking water. The TDS levels were found to be much lower in monsoon months as compared to winter and summer months. Similar trend was also observed for various cations and anions monitored as a part of the study. These lower levels are generally attributed to higher discharges along with monsoon runoff into all the streams.

The hardness level ranged from 25.1 to 139.7 mg/l indicating soft nature of water. The hardness level was well below the permissible limit of 300 mg/l specified for drinking water Class A standards. It is caused by cations like calcium, magnesium, and iron. The low levels of calcium and magnesium are mainly responsible for the soft nature of water. The alkalinity as usual was found to be lower than the total hardness in all the water sampling sites.

Chlorides occur in all natural waters in widely varying concentrations and its levels ranged from 4.8 to 43.9 mg/l, which are well below the permissible limit of 200 mg/l, specified for meeting drinking water requirements. The sulphates levels at various sampling sites were quite low and ranged from 1.3 to 17.8 mg/l.

The concentration of nitrates at various locations ranged 0.01 to 5.5 mg/l while phosphates at various sampling sites were observed to below detectable limit of 0.01 mg/l.

The concentration of various cations, e.g. sodium, potassium, calcium and magnesium was observed to be quite low which is also reflected by the low TDS levels. Iron was found to be well below the permissible limit of 1 mg/l specified for drinking water purposes.

Heavy metals were not detected at any of the sampling sites in the basin during different sampling periods (**see Annexure- 7.1 & 7.2 of Volume-II**). This is because there is no industry in the located in the basin.

Overall as seen from the analysis of all the physico-chemical parameters in the entire basin the water quality of Subansiri River and all its tributaries is well within prescribed limits of CPCB and national drinking water standards.

7.1.3 Water Quality Index

In order to assess the overall water quality of Subansiri, Kurang-I, Page and Kale Rivers along with their tributary streams a Water Quality Index was used which has been developed at Washington State Department of Ecology, Environmental Assessment Programme. The Water Quality Index (WQI) used in the report is a unit less number ranging from 1 to 100. A higher number is indicative of better water quality. For temperature, pH, faecal coliform bacteria and dissolved oxygen, the index expresses results relative to levels required to maintain beneficial uses (based on criteria in Washington's Water Quality Standards, WAC 173-201A). Water quality index is a 100 point scale that summarizes results from a total of eight different parameters listed below.

pH	Total/Faecal Coliform	Nitrates
Dissolved Oxygen	Biochemical Oxygen Demand	Total Suspended Solids
Turbidity	Total Phosphates	

The analysis of above mentioned parameters revealed that most of the parameters are of least importance in hilly and mountainous streams with very scanty population and with very good forested landscape around as seen from the results discussed in previous sections earlier that most of them are within prescribed standards. In addition the concentration of most of the heavy metals is Not Detectable or Below Detectable limits.

Therefore values for all or most of the parameters for each sampling site were used to arrive at a meaningful conclusion and interpretation otherwise the data collected for each and every month for each parameter becomes too voluminous to arrive at any meaningful outcome. The analysis of water quality therefore has been based upon 9 parameters as defined for WQI above.

Water Quality Index Legend	
Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

Analysis of river water quality in the basin based upon WQI is given in the following paragraphs. As discussed earlier in order to assess the physico-chemical water quality of Subansiri River and its tributary streams WQI was calculated and results of the same are shown in **Figure 7.11**. As seen from the chart WQI in general varies from 70 to 81 which indicates that water quality is good.

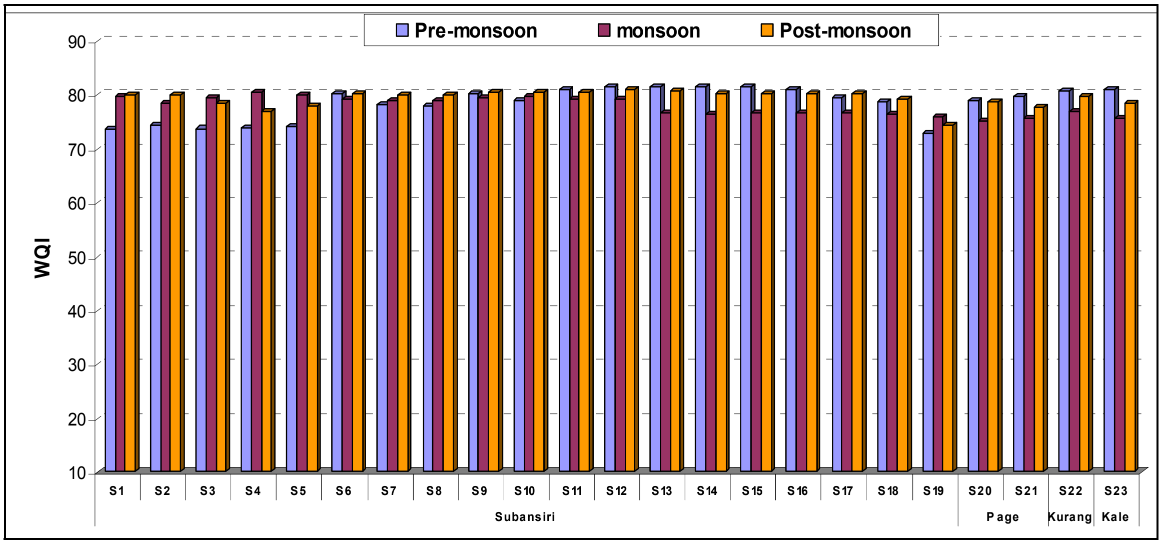


Figure 7.11: Water Quality Index

7.2 Biological Water Quality

Aquatic ecology plays many important environmental functions. An aquatic ecosystem is a system in a body of water where both biotic and abiotic factors interact in a intricate way and constitute the status of ecosystem health. The communities of organisms that are dependent on each other live in the environment without any stress showing normal level of diversity in the habitat .performing all required ecosystem functions. For an example they recycle nutrients, purify water, attenuate floods, recharge ground water and provide habitats for wildlife. The health of an aquatic ecosystem is degraded when the ecosystem's ability to absorb a stress has been exceeded. A stress on an aquatic ecosystem can be resulted from physical, chemical or biological alterations of the environment. The physical and chemical attributes of water bodies are often termed "water quality" and, by implication, a water body with levels outside the normal range of these attributes is considered as having poor water quality. Physical alteration includes change in the water temperature, water flow and availability of light. Chemical alteration includes changes in the loading of biostimulatory nutrients, oxygen consuming materials and toxins. Biological alteration includes the introduction of exotic species and changes in organismal diversity lacking their evenness. Chemical effects on aquatic organisms are often considered in groups including changes to pH and dissolved oxygen, turbidity and electrical conductivity, nutrients and a variety of contaminants such as heavy metals are important indicators of ecosystem health and can provide a measure of change which might happen due to any developmental activity and indiscriminate utilization of river water. Significant changes of these parameters can affect the ecosystem degradation and may also impact the environmental water quality as a whole.

An effort has also been made to describe the aquatic ecology of the study area considering fish resources, fishing practices, fish diversity of wetlands based on secondary and primary data in the project area. Further, inferences based on data have been made at the end of the chapter.

7.3 Wetlands in Arunachal Pradesh and Subansiri basin

Arunachal Pradesh has thirteen districts. District-wise distribution of wetlands showed that three districts can be called as wetland rich. Lohit has highest concentration with around 45719 ha area under wetland. This is mainly due to the large number of rivers/streams area. The other two districts are: Dibang valley and East Siang with around 37,602 ha and 25,512 ha area under wetland. Tirap district has the lowest area under wetland (around 1,262 ha). Wetland category of High Altitude lakes was observed in Dibang Valley (443), Lohit (204) and Tawang (204) districts. Few high altitude lakes are observed in West Kameng, East Kameng, West Siang Lower Subansiri, Upper Subansiri and Upper Siang districts also. No major reservoirs exist in the state. District-wise wetland area estimates is given in **Table 7.5**. **Figure 7.12** shows district-wise graphical distribution of wetlands.

The districts with very high concentration of small wetlands (< 2.25 ha) are Dibang Valley and Lohit with 266 and 240 numbers respectively, while East Kameng district has lowest with 12 such wetlands. Wetland statistics in the Subansiri Basin distribution pattern and density of wetlands in the district is given in **Table 7.5**.

Table 7.5: District-wise wetland highlights

Sr. No.	District	Geographic Area	Wetland Area	% of total wetland area	% of district geographic area
1	Lower Subansiri	10125	3607	2.32	0.36
2	Upper Subansiri	7032	3365	2.16	0.48

Wetland map and corresponding satellite data for district falling in the Subansiri basin is given in **Figure 7.12 and Figure 7.13**.

Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Canal
- Drainage(line)
- Railway
- Roads
- District Boundary
- Towns/Settlements

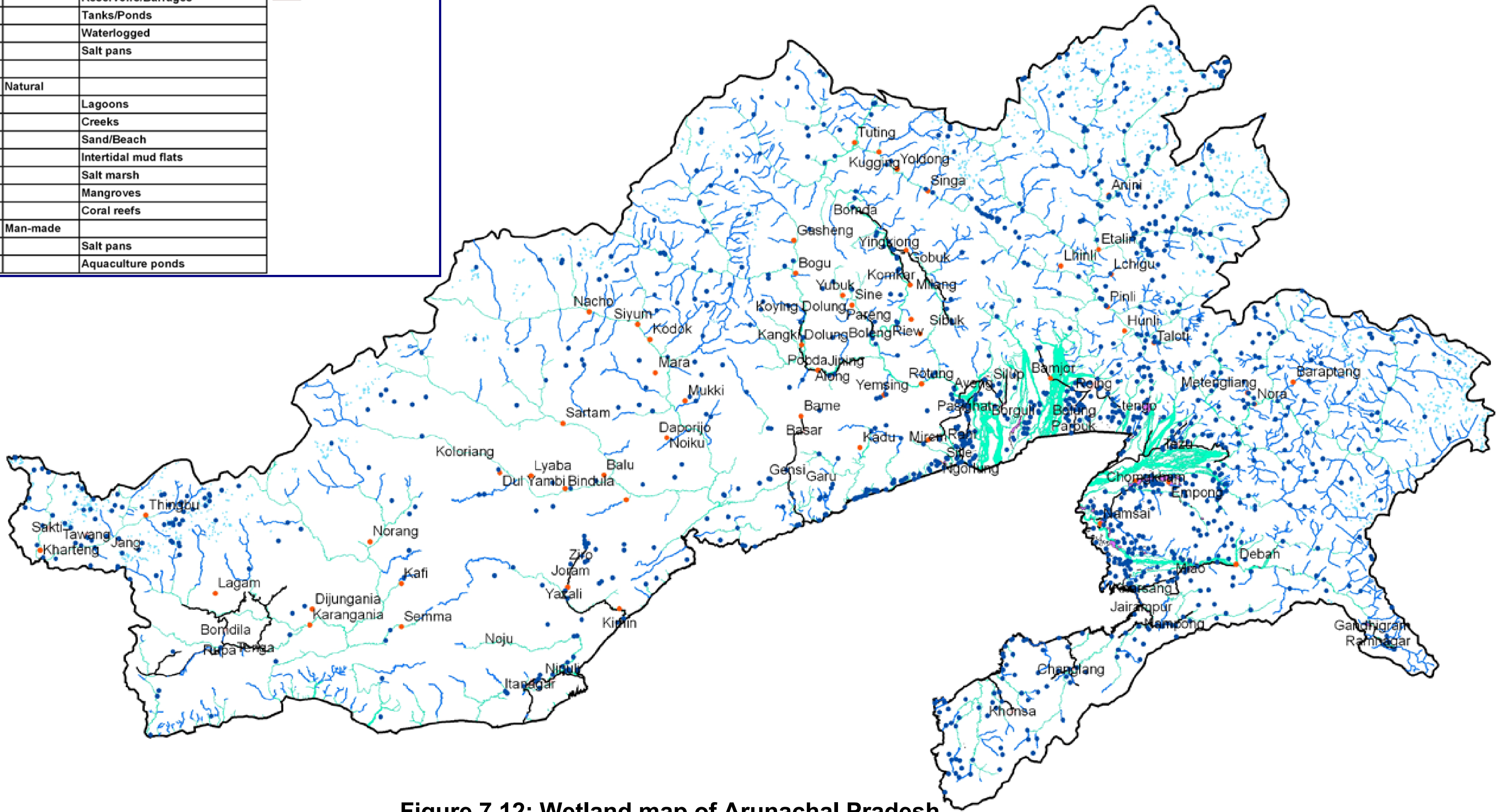
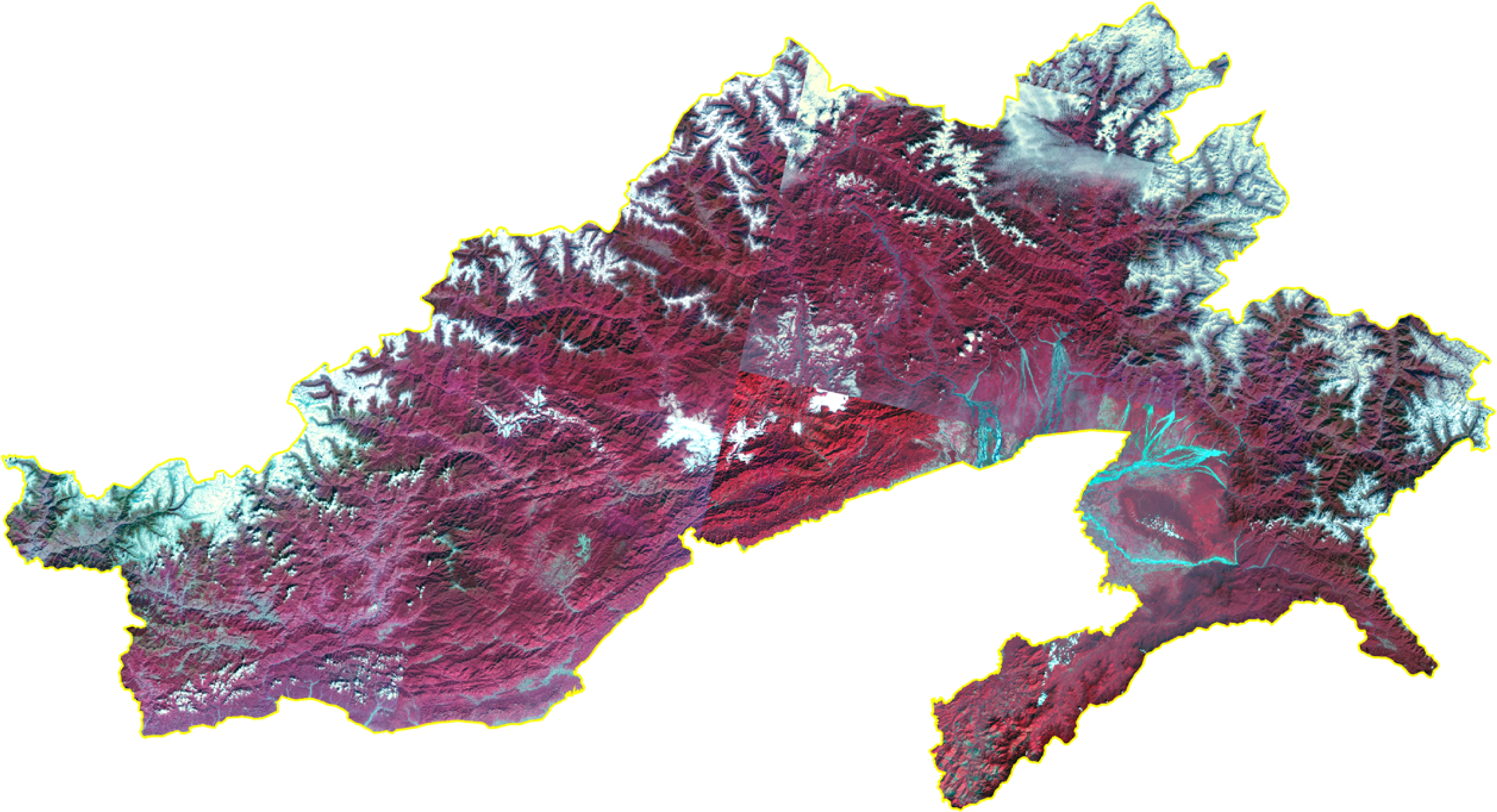


Figure 7.12: Wetland map of Arunachal Pradesh



Source: IRS P6 LISS-III post Monsoon data (2006)

Figure 7.13: Satellite Imagery of Arunachal Pradesh

Wetland Distribution in Upper Subansiri: The district Headquarters are located at Daporijo. The district occupies an area of 7032 km². The wetland area estimated is 3365 ha. Small wetlands, which are less than minimum mapable units (MMU), are 28 in the district. The major wetland types are River/Streams and high altitude lakes. Details are given in **Table 7.6**

Table 7.6: Area estimates of wetlands in Upper Subansiri

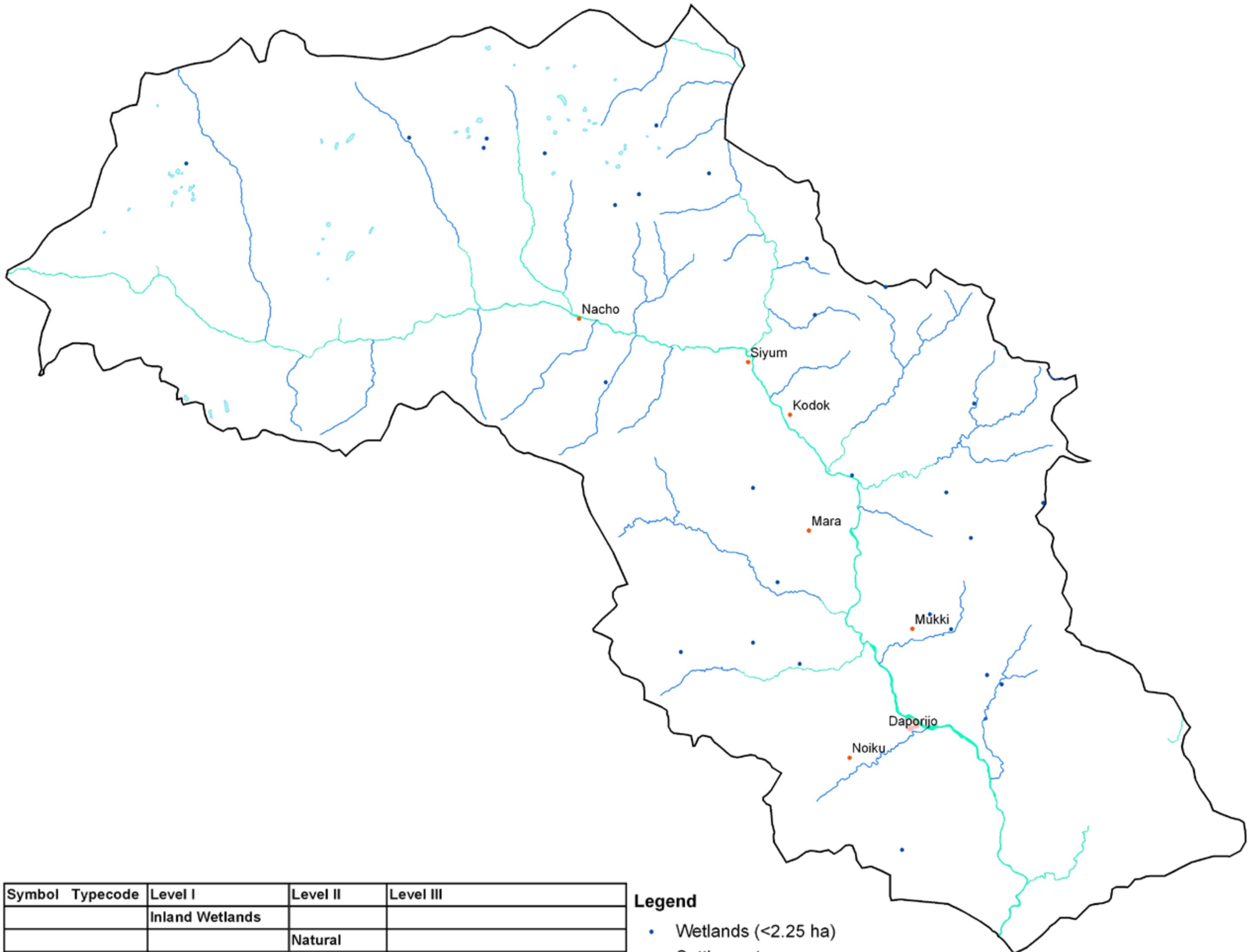
Area in ha

Sr. No.	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
					Post-monsoon Area	Pre-monsoon Area
Inland Wetlands – Natural						
1	Lakes/Ponds	1	11	0.33	-	-
2	High altitude wetlands	53	577	17.15	564	66
3	River/Stream	3	2749	81.69	2360	2381
	Sub-Total	57	3337	99.17	2924	2447
	Wetlands (<2.25 ha), mainly Tanks	28	28	0.83	-	-
	Total	85	3365	100.00	2924	2447

Area under Aquatic vegetation

Area under turbidity levels		
Low	2800	2426
Moderate	109	21
High	15	-

Wetland map and corresponding satellite data of Upper Subansiri district falling in the Subansiri basin is given in **Figure 7.14 and Figure 7.15**.



Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Figure 7.14: Wetlands in Upper Subansiri district falling in the Subansiri basin

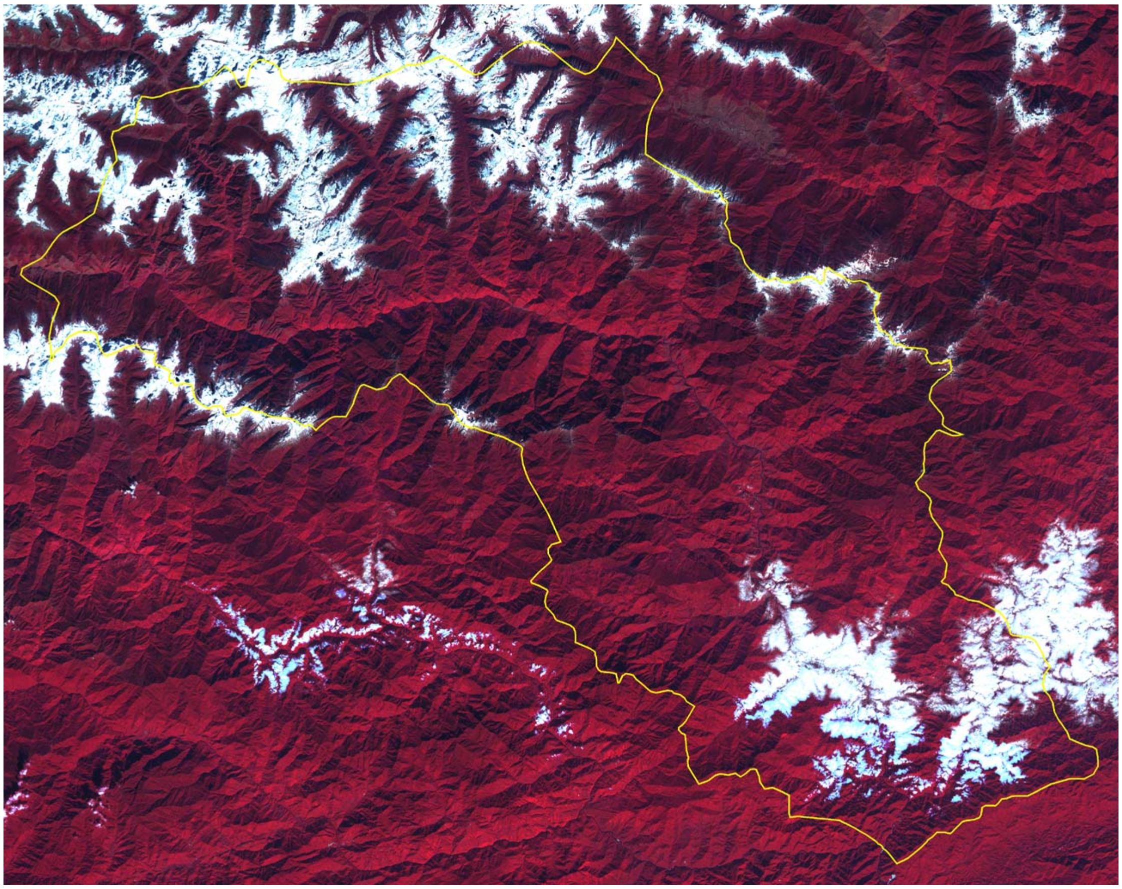


Figure 7.15: Satellite data of Upper Subansiri district falling in the Subansiri basin

Wetland Distribution in Lower Subansiri

The district occupies an area of 10,135 km². It is bounded on the North by Upper Subansiri District of Arunachal, on the South by Papum Pare District of Arunachal Pradesh and Assam, on the East by West Siang and some part of Upper Subansiri on the West by East Kameng District of Arunachal Pradesh.

The wetland area estimated is 3607 ha. Small wetlands, which are less than minimum mapable units (MMU), are 44 in the district. The major wetland types are River/stream and high altitude lakes. The turbidity of the open water is mainly low. Details are given in **Table 7.7**.

Table 7.7: Area estimates of wetlands in Lower Subansiri

Area in ha

Sr. No.	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
					Post-monsoon Area	Pre-monsoon Area
Inland Wetlands – Natural						
1	High altitude wetlands	31	241	6.68	237	-
2	River/Stream	3	3322	92.10	2956	3023
	Sub-Total	34	3563	98.78	3193	3023

Sr. No.	Wetland Category	Number of Wetlands	Total Wetland Area	% of wetland area	Open Water	
					Post-monsoon Area	Pre-monsoon Area
	Wetlands (<2.25 ha), mainly Tanks	44	44	1.22	-	-
	Total	78	3607	100.00	3193	3023

Area under Aquatic Vegetation

Area under turbidity levels		
Low	2665	3023
Moderate	271	-
High	257	-

Wetland map and corresponding satellite data of Lower Subansiri district falling in the Subansiri basin is given in **Figure 7.16** and **Figure 7.17.**

Symbol	Typecode	Level I	Level II	Level III
		Inland Wetlands		
			Natural	
	1101			Lakes/Ponds
	1102			Ox-bow lakes/ Cut-off meanders
	1103			High altitude wetlands
	1104			Reverine wetlands
	1105			Waterlogged
	1106			River/Stream
			Man-made	
	1201			Reservoirs/Barrages
	1202			Tanks/Ponds
	1203			Waterlogged
	1204			Salt pans
		Coastal Wetlands		
			Natural	
	2101			Lagoons
	2102			Creeks
	2103			Sand/Beach
	2104			Intertidal mud flats
	2105			Salt marsh
	2106			Mangroves
	2107			Coral reefs
			Man-made	
	2201			Salt pans
	2202			Aquaculture ponds

Legend

- Wetlands (<2.25 ha)
- Settlements
- Canal
- Drainage(line)
- Railway
- Roads
- District Boundary
- Towns/Settlements

Figure 7.16: Wetland map of Lower Subansiri district falling in the Subansiri basin

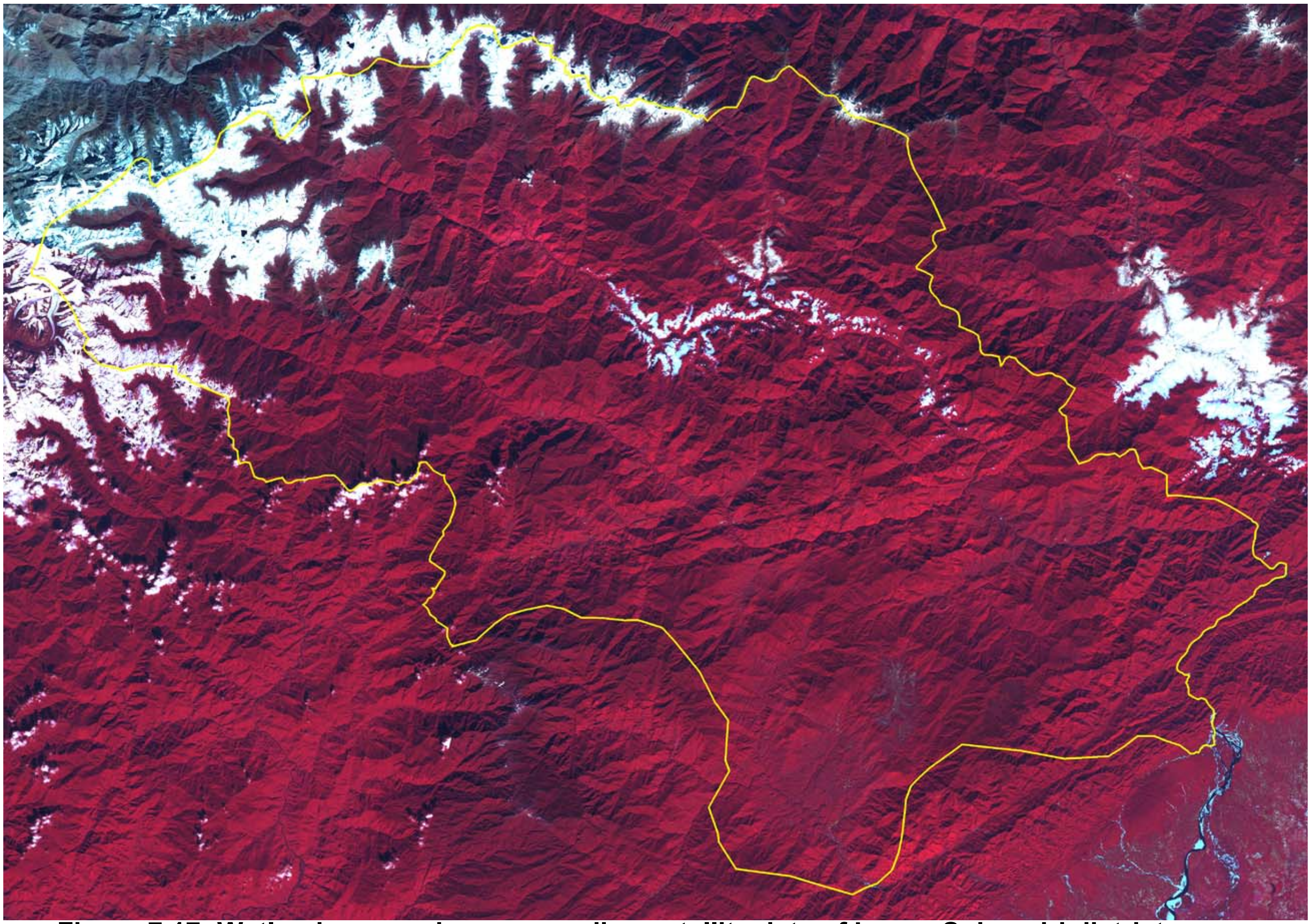


Figure 7.17: Wetland map and corresponding satellite data of Lower Subansiri district falling in the Subansiri basin

The sampling co-ordinates & locations are given in **Table 7.8** & **Figure 7.18.**

Table 7.8: Sampling Co-ordinates & Locations

Coordinates		
Site Name	Dam	
	Latitude (N)	Longitude (E)
Tago-I	27°27´59.75"	93°48´0.36"
Upper Subansiri	28°06´58.70"	94°09' 37.36"
Middle Subansiri	27°46´23.12"	93°59´ 6.53"
Dengser	28°22´50.04"	93°53´ 23.30"
Nalo	28°24´33.72"	93°48´26.74"
Niare	28°21´33.31"	93°31´ 7.09"
Naba	28°22´39.42"	93°38´ 33.68"
Lower Subansiri	27°32´ 57.54"	94°15´ 32.70"
Nyepin	27°44´ 34.47"	93°22´ 52.40"
Hiya	27°45´ 54.75"	93°27´ 59.31"

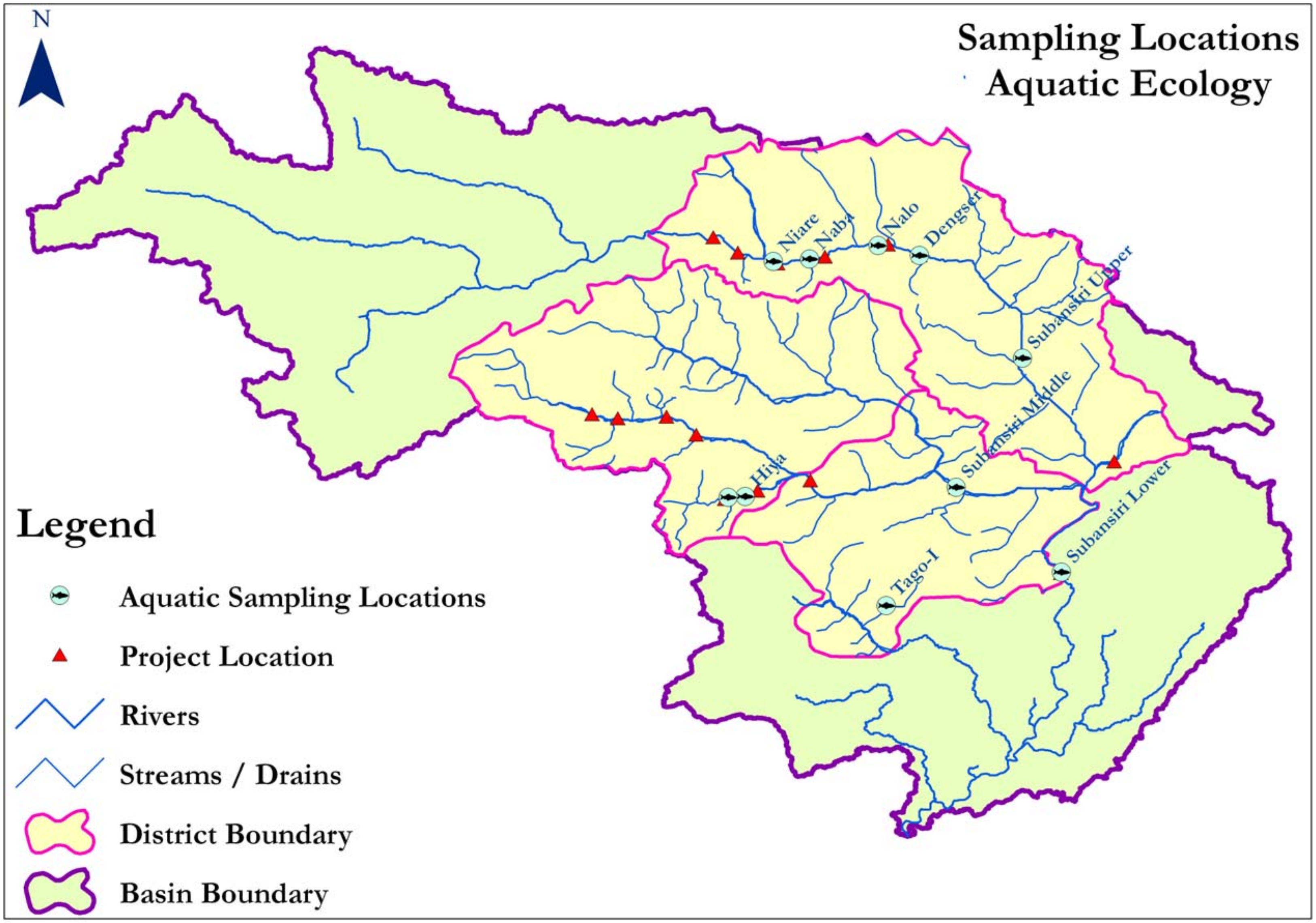


Figure 7.18: Aquatic Ecology Sampling Locations

7.3.1 Plankton

Plankton constitutes an important food item in the aquatic ecosystem. The sampling was done following standard method (APHA[44], 1998). Planktons were collected by truncated cone shaped plankton net made of bolting silk. At each sampling location, fixed quantity of water was filtered gently through the net. The concentrates were preserved at 3% formalin concentrations. Phytoplankton and zooplankton count were made using 'drop count method'. All possible efforts were made to identify the microscopic organism upto the genera level only using microscope ((Nikon Eclipse E200). A single colony in case of colonial forms, a single filament in filamentous forms and a single organism was considered as single individual. The phytoplankton and zooplankton were identified and finally the counts were computed on unit per litre.

a. Quantitative estimation of Plankton

   Plankton (Organism/L) = (n X c)/a

   n = number of animals/plants in 1 ml of concentrate

   c = total volume of concentrate (ml)

   a = total volume of water filtered.

7.3.1.1 Pre monsoon Season

Plankton population in hill stream was greatly influenced by sandy and stony beds, fast current of water and a number of physico- chemical factors. During the present investigation the plankton population was found to be low in the river. The population of phytoplankton was found dominating to that of zooplankton. The plankton density of the investigating site is given in **Table 7.12**. During the present investigation 28 different genera of plankton were recorded sampling site. Among these 11 belong to Chlorophyceae, 8 to Myxophyceae, 2 to Bacillariophyceae (Diatoms) and 8 belongs to Zooplankton.

Naba (121 unit/l) was recorded the site with highest phytoplankton density and Upper Subansiri HEP (50 unit/l) was recorded the lowest. The Zooplankton count was maximum at Upper Subansiri (17) and minimum at Dengser (3) which is shown in **Figure 7.19** and given in **Table 7.13**. Phytoplankton group consisting of Chlorophyceae, Myxophyceae, and Bacillariophyceae as a whole dominated over zooplankton consisting primarily of Copepods, Turbellaria, Cladocera, Rotifera, Ostracoda. The dominant phytoplankton group was Chlorophyceae. This may be due to the fact that water temperature range (16-20) during the pre-monsoon season appears to be optimum for the growth of Chlorophyceae. Buthcher (1946) and Singh (1960) was of the opinion that high atmospheric and water temperature along with bright sunshine are important factors influencing periodicity of Chlorophyceae which has been further supported by Sharma (1983). Myxophyceae were found to be the second group dominating the phytoplankton community after Chlorophyceae. Temperature has been found to play a key role in the periodicity of this group. Only two genera of Bacillariophyceae have been recorded during the study period, although studies done in Subansiri River showed Bacillariophyceae as dominant (Gurumayum *et al*, 2000)[45] with species like *Cymbella,*

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[44] *APHA (2005). Standard method for the examination of water and waste water. 21st ed. Amer. Pub. Health Assoc. Inc. Washington D.C*

[45] *Gurumayum, S. D., P. Daimari, B. S. Goswami, A. Sarkar and M. Choudhary, 2000. Ecology of river Subansiri in Arunachal Pradesh. J. Inland Fish. Soc. India. 33 (2): 50-54*

Navicula, Anomoensis, Synedra, Fragilaria, Gomphonema, Ceratonies, Tabellaria, Pinnularia, Calonies, Ghomphoneis, Nitzschia, Frustulia, Amphora, Daitoma, Rhabdonema, Leimorphora, Eucocconies, Gyrosigma, Surirella, Pinnularia found in pre and post monsoon periods. Copepods, Tubillaria, Cladocera, Rotifer, Ostracoda were the groups representing the Zooplankton community. The water temperature was low during the sampling period which resulted in low count of Zooplankton. Byers (1960) opined that water temperature is the most important controlling factor in the production of Zooplankton.

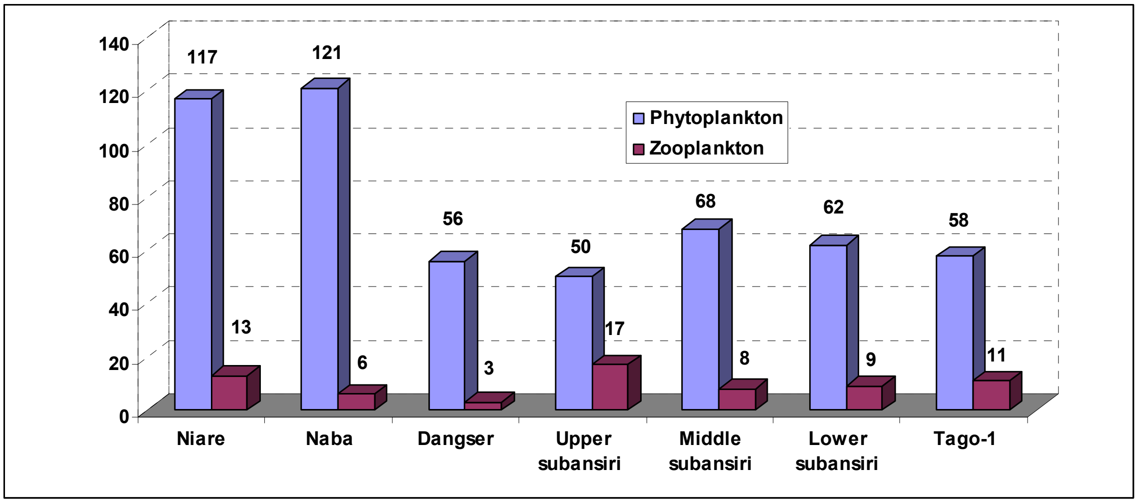

Figure 7.19: Numbers of Plankton recorded in Premonsoon season

The following Plankton were recorded during the pre monsoon sampling

Phytoplankton

Chlorophyceae: *Ulothrix, Enteromorpha, Zygnema, Oedogonium, Cylindrocystis, Stigeoclonium, Tetraspora, Cylindrocystis, Microspora, Schizodictyon, Batrachospermum.*

Myxophyceae: *Notochopsis, Phormidium, Oscillatoria, Glocotrichia, Nostoc, Notochopsis, Anabena, Lynbya*

Bacillariophyceae: *Gyrosigma, Pinnularia*

Zooplankton

Copepod: *Diaptomus, Epischura*
Tubillaria: *Microstomum, Bothrioplana*
Cladocera: *Daphnia*
Rotifera: *Asplancha*
Ostracoda: *Limnocythere*

Macro-Invertebrates: Macro- invertebrates play a significant role within the food chain, as they are the source of food for large fish. Macro-invertebrates are sensitive to different chemicals and physical conditions, any changes in the water quality, perhaps because of a pollutant entering the water, or a change in the flow downstream of a dam, the macro-invertebrate community also changes. So, macro-invertebrate richness act as indicator for determining biological conditions and monitoring of pollution of water.

During the study, macro-invertebrates fauna consisted of 19 genera falling under 6 order belonging to 16 families viz. Peltoperlidae, Pteronarcidae, Psychomyiidae, Hellicopsoichidae, Leptoceridae, Hydroptilidae, Glossosmatidae, Simulidae, Heleidae, Chironomidae, Psychodidae, Sisyridae, Ephemereludae, Bactidae, Elmidae, Limnichidae. Order Trichoptera dominated the group with 5 Genera followed by Diptera (4 genera), Pleocoptera (4 genera), Neuroptera (2 genera), Epemeroptera (2 genera), Coleoptera (2 genera).The detail of macro-invertebrate found during the survey are given in **Table 7.9.**

Macro- invertebrates' population was found to be highest in Middle Subansiri HEP (Kamala HEP), followed by Upper Subansiri HEP and minimum at Naba. Middle Subansiri HEP site was dominated by the genera *Lype*, *Malanna*, *Simulium*, *Maruina*, *Ephemerella*, *Ampumixis*, *Lutrochus which was maximum in population.* Psychomyiidae family having maximum genera was found almost in the entire sampling site. In fast flowing water (lotic) such as the upland streams, the bed consists of large rocks and stones and the stream is heavily shaded. The influence of vegetation is very high. This provides food supply for largely collectors and shredders. Aquatic plants, particularly rushes and sedges, provide a surface on which macro-invertebrates can live, but during our survey most of the sampling site was devoid of macrophytes and aquatic vegetation which might have resulted in the poor distribution of Macro invertebrates.

Table 7.9: Macro-invertebrate found during the survey

S. .No	Order	Family	Genera
1.	Pleocoptera	Peltoperlidae	*Allocapnia*
			Isocapnia
			Megaleuctra
		Pteronarcidae	*Archynopteryx*
2.	Trichoptera	Psychomyiidae	*Lype*
		Hellicopsoichidae	*Malanna*
		Leptoceridae	*Leptocerus*
		Hydroptilidae	*ochrotichia*
		Glossosmatidae	*Agapetus*
3.	Diptera	Simulidae	*Simulium*
		Heleidae	*Culicoides*
		Chironomidae	*Ablabermyia*
		Psychodidae	*Maruina*
4.	Neuroptera	Sisyridae	*Sisyravicaria*
			Climacia
5.	Ephemeroptera	Ephemerellidae	*Ephemerella*
		Bactidae	*Baetis*
6	Coleopteran	Elmidae	*Ampumixis*
		Limnichidae	*Lutrochus*

7.3.1.2 Monsoon Season

Data had been generated by analysis under binocular microscope (Nikon Eclipse E 200). It was observed that macro- invertebrate such as fresh water insect and insects larva were dominant. They are belonging in different order such as Trichoptera, Diptera, Coleoptera, Ephemeroptera, Hemiptera and Plecoptera. Trichoptera consists of 5 families (Hydroptillidae, Limnephilidae, Molonnaida, Leptoceridae and Glossosmatidae) 6 genus (*Leucotrichia, Ochrotrichia, Psycnopsyche, Molanna, Leptocerus and Agapetus*) and Diptera with 6 families (Culicidae, Ephydridae, Simulidae, Chironomidae, Psycodidae and Tipulidae) and 6 genus (chaoborus, simulium, chironomus, limnophora, antocha and maruina) dominated the group followed by Coleoptra consisting of 4 families (Psephenidae, Dryopidae, Limnichidae and Elmidae) and 5 genus (*Zaitzevia, Lutrochus, Heterlimnius, Ampuimixis* and *Psephenus*). Ephemeroptera consisted of 4 families (Ephemeredae, Ephemerellidae, Hydroptillidae, Baetidae and Heptageniidae) and 5 genus (*Callibaetis, Ephemerella, Stenonema , Baetis* and *Heptagenia*). Plecoptera consists of 3 families (Pteronarcidae, Peltoperlidae and Perlodidae) and 4 genus (*Isocapnia, Archynopteryx, Megaleuctra* and *Isoperla*). Species of *Cladocera*, Oligochaetes and Nematode were also presents in water sample. The numbers of plankton and macro-invertebrates found in monsoon season survey are shown in **Figure 7.20, 7.21 and 7.22** and also given in **Table 7.13**.

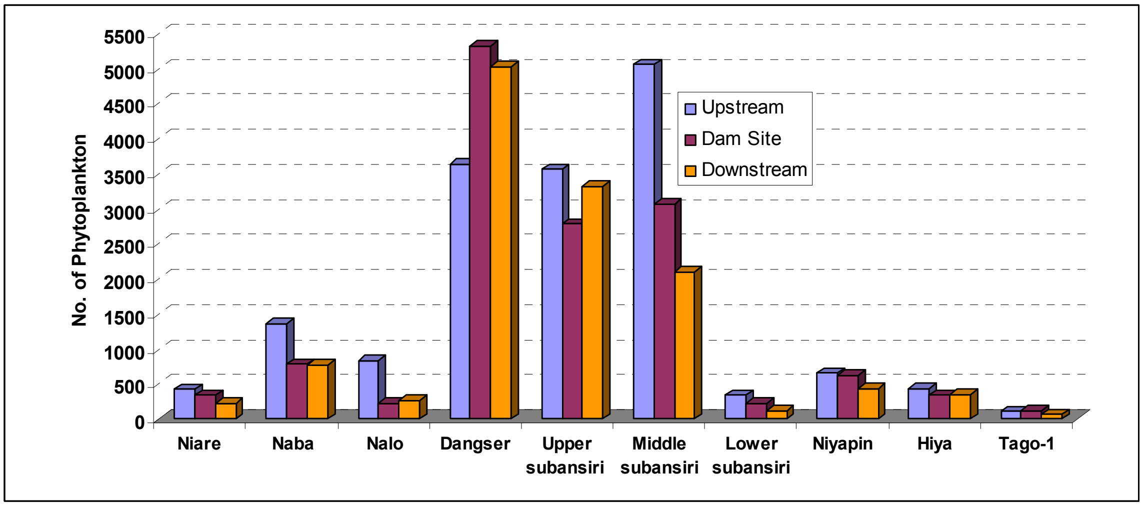

Figure 7.20: Numbers of Phytoplankton recorded in Monsoon Season

From the Figure 7.20, 7.21 and 7.22, Phytoplankton density in Tago-1 site was highest at Dam site (116) and lowest at downstream (63). Zooplankton density was highest at upstream (108) and lowest at downstream (87). Macro-invertebrates were also highest at Dam site (830) and lowest at upstream (522).

In Lower Subansiri site, Phytoplankton, Zooplankton and Macro-invertebrates density were highest at upstream (i.e., 342, 322 and 674) and lowest at downstream (112, 172 and 376).

In Middle Subansiri site, Phytoplankton density was highest at upstream (5056) and lower at dam site (2062) while Zooplankton density was highest at downstream (648) and lowest at dam site (436) whereas macro-invertebrates density was highest at upstream (544) and lowest at downstream (364).

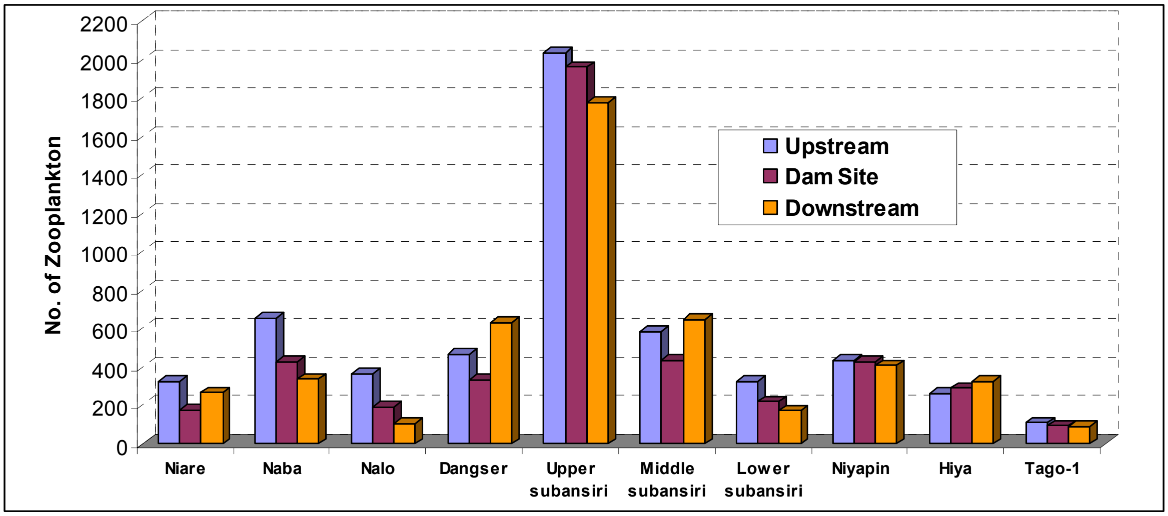

Figure 7.21: Numbers of Zooplankton recorded in Monsoon Season

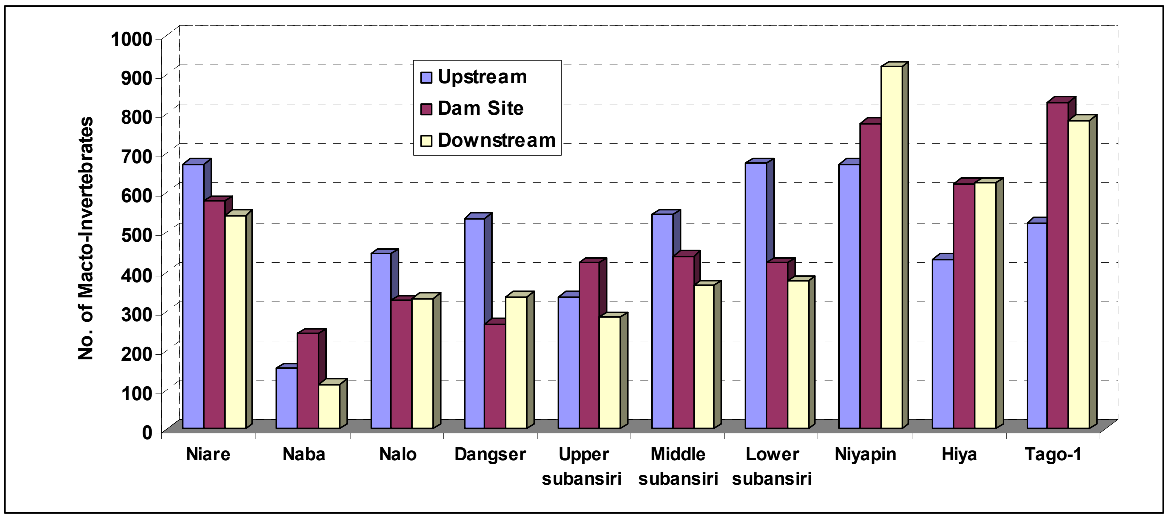

Figure 7.22: Numbers of Macro-Invertebrates recorded in Monsoon Season

In Upper Subansiri HEP site, phytoplankton density was highest at upstream (3558) and lowest at dam site (2782). Similarly, Zooplankton density was also highest at upstream (2032) and lowest at downstream (1776). However, Macro-invertebrates were highest at dam site (422) and lowest at downstream (284).

In Dengser site, phytoplankton density was highest at dam site (5326) and lowest at upstream (3634). Zooplankton density was highest at downstream (630) and lowest at dam site (734). Macro-invertebrates density was highest at upstream (534) and lowest at dam site (266) which was opposite to phytoplankton density.

In Naba site, phytoplankton (1362) and Zooplankton (656) density were highest at upstream and lowest at downstream (774 and 336). However, macro-invertebrates density was highest at dam site and lowest at downstream.

In Niare site, Phytoplankton was highest at upstream (420) and lowest at downstream (216). Zooplankton density was highest at upstream (324) and lowest at dam site (178). Macro-invertebrates were highest at upstream (672) and lowest at downstream (542).

In Nalo site, phytoplankton (832) and Zooplankton (364) were highest at upstream. However, phytoplankton (224) density was lowest at dam site and zooplankton density (104) was lowest at downstream. But Macro-invertebrates were highest at upstream (444) and lowest at downstream (332).

In Nyepin site, phytoplankton and zooplankton density was also highest at upstream and lowest at downstream. However, Macro-invertebrates were highest at downstream and lowest at upstream. While in Hiya site, phytoplankton density was highest at upstream (428) and lowest at downstream (344). Zooplankton density was highest at downstream (326) and lowest at upstream (262). Macro-invertebrates density was also highest at downstream (624) and lowest at upstream (432).

7.3.1.3 Post monsoon Season

Phytoplankton

The post monsoon study showed a similar trend with Algae dominating the group with class Bacillariophyceae and Chlorophyceae. Class Bacillariophyceae were represented by order Bacillariales and 2 family Naviculoideae and Gomphonemaceae with 6 genus (*Navicula, Pinnularia, Poloneis, Peidium, Gomphoneis and Gomphonema*).

Chlorophyceae were found dominant among Phytoplankton. They consisted of 3 order (Zygnematales, Chaetophoraceae and Volvocales) and 3 families (Mesotaeniaceae, Ulotrichales and Chlamydomonadeceae) with 7 genus (*Penium, Gonotozygon, Tetmemorus, Cylindrocystis, Dermatophyton, Geoclonium and Chlamydomonas*). The numbers of Phytoplankton recorded at various locations are given in **Table 7.10** and shown in **Figure 7.23**.

Table 7.10: Name of phytoplankton recorded.

S. No.	ORDER	FAMILY	GENUS
1	Bacillariales	Naviculoideae	*Navicula*
			Pinnularia
			Peidium
		Gomphonemaceae	*Gomphoneis*
			Gomphonema
		Achnanthaceae	*Cocconeis*
2	Zygnematales	Mesotaeniaceae	*Penium*
			Gonotozygon
			Cylindrocystis
			Dermatophyton
3	Chaetophoraceae	Ulotrichales	*Stigeoclonium*
			Chlamydomonas
4	Volvocales	Chlamydomonadeceae	

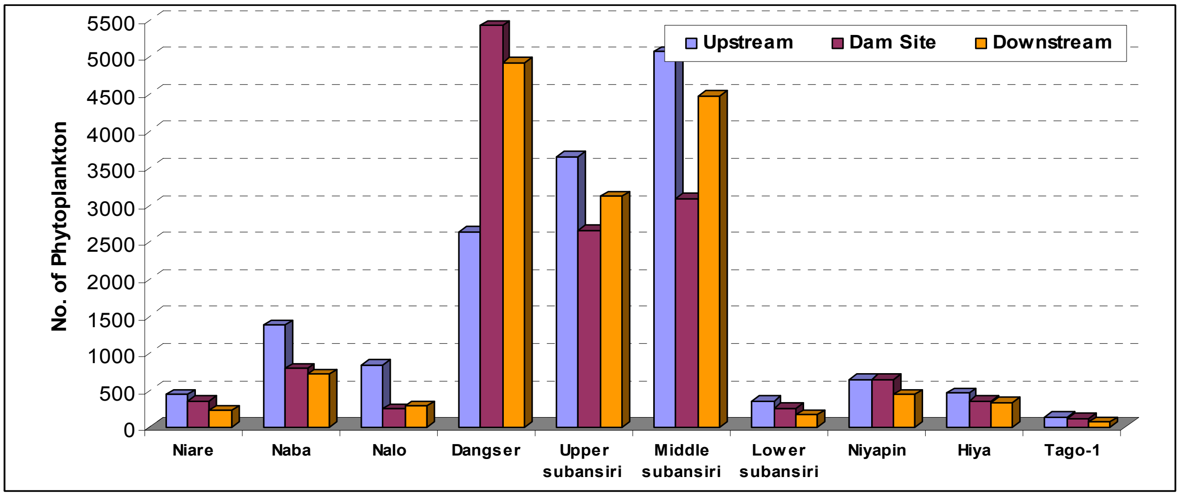

Figure: 7.23: Numbers of Phytoplankton recorded

Zooplanktons

Zooplanktons were represented by Rotifera, Protozoa and Crustacean. They were dominated by Rotifer having 3 order (Ploima, Blelloida and Flosculariaceae), 3 families (Brachionidae, Habrotrochidae and Floscularioceae) and 5 genus (*Trichotria, Brachionus, Keratella, Ceratotrocha and Filinia*) followed by crustacean having 2 order (Anostraca and Cladocera), 2 families (Branchinectidae and Daphnidae) and 3 genus (*Steptocephalus, Branchinecta and Daphnia*). Protozoans were clearly observed having 2 families (Euglenidae, Anisonemidae) and 2 genera (*Euglena and Paranema*). Order Gastropoda having 1 family (Melaniidae) and 1 genus (*Tiara*) was also recorded. The numbers of Zooplankton recorded at various locations are given in **Table 7.11** and shown in **Figure 7.24**.

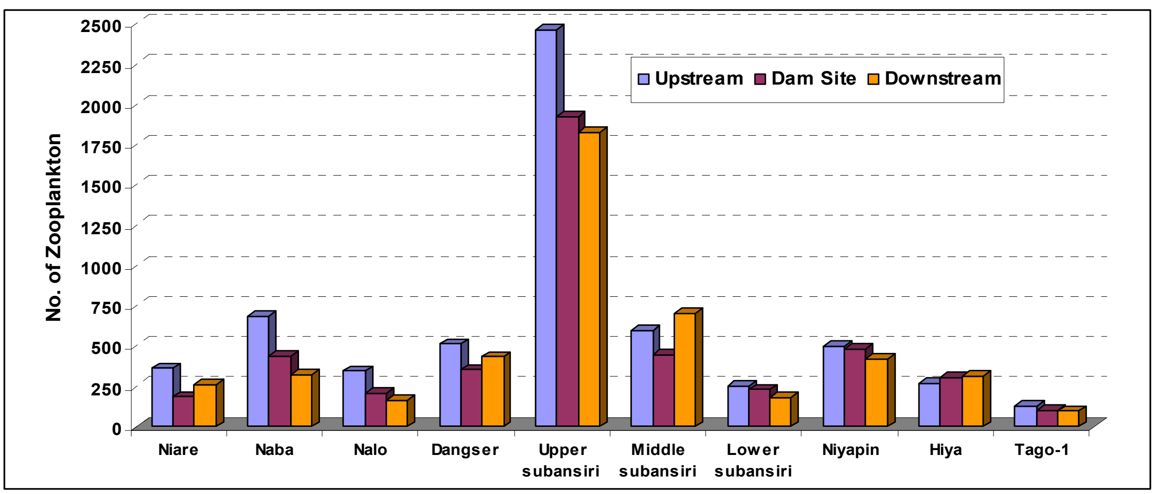

Figure 7.24: Numbers of Zooplankton recorded (organism/1)

Table 7.11: Name of zooplankton recorded

S. No.	ORDER	FAMILY	GENUS
1	Ploima	Brachionidae	*Trichotria*
			Brachonus
			Keratella
2	Blelloida	Habrotrochidae	*Ceratotrocha*
3	Flosculariaceae	Flosculariaceae	*Filinia*

S. No.	ORDER	FAMILY	GENUS
4.	Mastigophora	Anisonemidae	*Paranema*
		Euglenidae	*Euglena*
5	Anostraca	Branchinectidae	*streptocephalus*
			Branchinecta
6	Cladocera	Daphnidae	*Daphnia*
7	Gastropoda	Amullariidae	*Tiara*

Macro-invertebrates

Macro – Invertebrates (Benthic Organism)

Macro- invertebrate plays a significant role within the food chain, as they are the source of food for large fishes. Macro-invertebrates were collected by lifting of stones and sieving of substratum from the wade able portion of the river. The material was sieved through 125µ sieve and preserved in 70% ethyl alcohol. Standard keys were used for identification of macro-invertebrates samples (Pennek 1953; Edmondson 1959; Macan[46] 1979; Edington[47] and Hildrew 1995).

Crude density= Total No. of individual in each quadrat/total quadrats

The post monsoon survey recorded 9 orders, 25 families and 29 genera of macro-invertebrates as compared to 10 orders, 28 families and 33 genera during pre-monsoon and monsoon. Order trichoptera consisting of 5 families (Hydroptillidae, Limnephilidae, Molonnaida, Leptoceridae and Glossosmatidae) 6 genus (*Leucotrichia, Ochrotrichia, Psycnopsyche, Molanna, Leptocerus and Agapetus*) dominated the group like the previous two season followed by Diptera with 5 families (culicidae, ephydridae, simulidae, chironomidae, and Tipulidae) and 5 genus (*chaoborus, simulium, chironomus, limnophora and antocha*). Coleopteran with 4 families (Psephenidae, Dryopidae, Limnichidae and Elmidae), 5 genus (*Zaitzevia, Lutrochus, Heterlimnius, Ampuimixis* and *psephenus)* and Ephemeroptera with 4 families (Ephemeredae, Ephemerellidae, Hydroptillidae, Baetidae and Heptageniidae), 5 genera (*Callibaetis, Ephemerella, Stenonema, Baetis*and *Heptagenia*) were other notable group in the population. Plecoptera consists of 2 families (Pteronarcidae and Peltoperlidae), 3 genera (*Isocapnia, Megaleuctra and Isoperla*) and Species of cladocera, Nematod were also recorded during the study. The numbers of Macro-invertebrates recorded at various locations are given in **Table 7.12** and shown in **Figure 7.25.**

[46] *Macan, T. T. (1979). A key to the nymphs of the British species of Ephemeroptera with notes on their ecology. Scient. Pubis Freshwat. biol. Ass. No. 20, 3rd Edn. 80 pp*

[47] *Edington, J. M. & Hildrew, A. G. (1995): Caseless caddis larvae of the British Isles.- Freshwater Bio-logical Association Scientific Publication 53, 134pp., Ambleside, Cumbria*

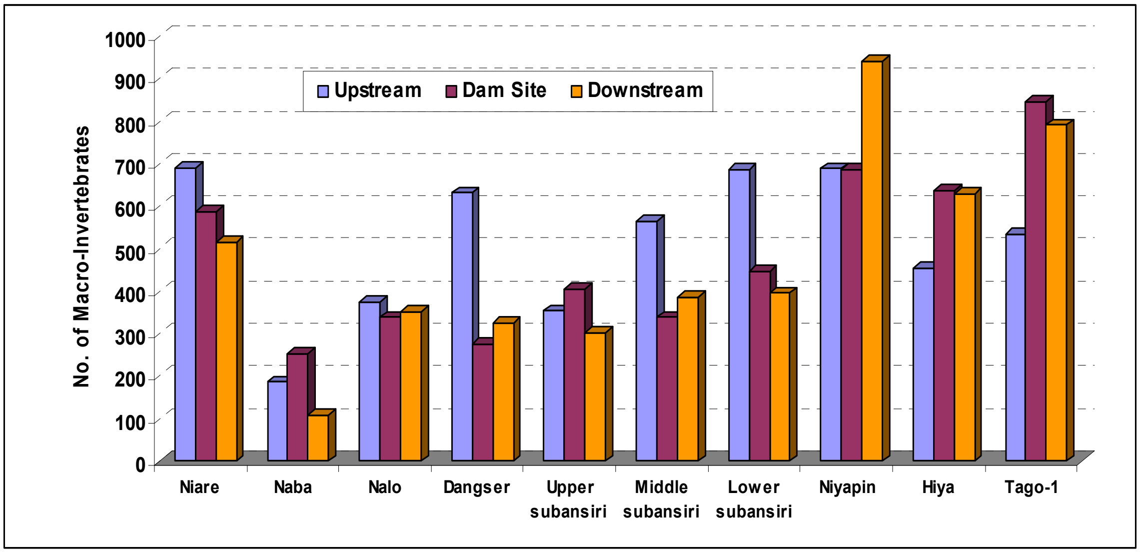

Figure: 7.25: Numbers of Micro-Invertebrates recorded (organism/m2)

Table 7.12: Name of macro-invertebrates (benthic organisms) recorded.

S. No.	ORDER	FAMILY	GENUS
1	Cladocera	Macrothricidae	*Moina*
2	Nematoda	Plectidae	*Anonchus*
		Mononchidae	*Ethmolaimus*
3	Pelecypoda	Sohaeriidae	*Glossostylus*
4	Ephemeroptera	Ephemeredae	*Callibaetis*
		Ephemerellidae	*Ephemerella*
		Baetidae	*Baetis*
		Heptageniidae	*Stenonema*
			Heptagenia
5	Trichoptera	Hydroptillidae	*Leucotrichia*
			Ochrotichia
		Limnephilidae	*Psycnopsyche*
		Molonnaidae	*Molonna*
		Leptoceridae	*Leptocerus*
		Glossosmatidae	*Agapetus*
6	Diptera	Culicidae	*Chaoborus*
		Ephydridae	*Limnophora*
		Simulidae	*Simulium*
		Chironomidae	*chironomus*
		Tipulidae	*Antocha*
7	Coleoptera	Psephenidae	*Psephenus*
		Elmidae	*Ampumixis*
			Heterlimnius
		Limnichidae	*Lutrochus*
		Dryopidae	*Zaitzevia*
8	Hemiptera	Hydrometidae	*Hesperocorixa*
9	Plecoptera	Perlodidae	*Isoperla*
		Peltoperlidae	*Isocapnia*
			Megaleuctra

From the figures 7.19, 7.20 and 7.21, Phytoplankton density in Tago-1 site was highest at upstream (130) and lowest at downstream (68). Zooplankton density was highest at upstream (125) and lowest at downstream (95). Macro-invertebrates were also highest at Dam site (846) and lowest at upstream (535). The numbers of Phytoplanktons, Zooplanktons and Macro-invertebrates in all season are summarized in **Table 7.13**.

In Lower Subansiri site, Phytoplankton, Zooplankton and Macro-invertebrates density were highest at upstream (i.e., 352, 2523 and 686) and lowest at downstream (162, 183 and 396).

In Middle Subansiri site, Phytoplankton density was highest at upstream (5062) and lowest at dam site (3083) while Zooplankton density was highest at downstream (702) and lowest at dam site (445) whereas macro-invertebrates density was highest at upstream (564) and lowest at dam site (338).

In Upper Subansiri HEP, phytoplankton density was highest at upstream (3651) and lowest at dam site (2654). Similarly, Zooplankton density was also highest at upstream (2462) and lowest at downstream (1824). However, Macro-invertebrates were highest at dam site (406) and lowest at downstream (302).

In Dengser site, phytoplankton density was highest at dam site (5412) and lowest at upstream (2634) .Zooplankton density was highest at upstream (512) and lowest at dam site (352). Macro-invertebrates density was highest at upstream (631) and lowest at dam site (276) which was opposite to phytoplankton density.

In Naba site, phytoplankton and Zooplankton density were highest at upstream (1371 & 682) and lowest at downstream (712 & 321). However, macro-invertebrates density was highest at dam site (253) and lowest at downstream (109).

In Niare site, Phytoplankton, zooplankton and macro invertebrates population was found highest at upstream (i.e. 440,362 & 691) and lowest at downstream for phytoplankton and macro invertebrates, whereas for zooplankton the lowest was at dam site (184).

In Nalo site, Phytoplankton, zooplankton and macro invertebrates population was found highest at upstream (i.e. 841,344 & 374) and lowest at downstream for phytoplankton and zooplankton. Macro invertebrates population was lowest at dam site (338).

In Nyepin site, phytoplankton and zooplankton density was also highest at upstream (644 & 498) and lowest at downstream (438 & 422). However, Macro-invertebrates were highest at downstream (942) and lowest at dam site (686).

In Hiya site, phytoplankton density was highest at upstream (454) and lowest at dam site (352). Zooplankton density was highest at downstream (315) and lowest at upstream (269). Macro-invertebrates density was also highest at dam site (636) and lowest at upstream (454).

The overall study reveal that Phytoplankton, zooplankton and macro-invertebrates population raises a bit higher level during post-monsoon as compared pre-monsoon and monsoon, similar findings were also recorded by Daimary et al.,(2005) & Sarma[48] et al.. (2012). The reason might optimum weather condition and presence of excess of food in the form of bacteria and suspended detritus. Also the fact that turbidity and water current which are detrimental factor limiting the growth of plankton community is more effective during the monsoon season. Increased density during post monsoon is due to high

[48] *Sarma, D. Das, D.N. Dutta, R. Baruah, D. Kumar, P. Tyagi, B.C and Mahanta, P.C (2012) Coldwater lakes and rivers in Arunachal Pradesh, India. Bull. No. 19, Directorate of coldwater fisheries research, Uttarakhand, India*

transparency, high dissolved oxygen, shallow water, low current etc. Dilution factors and its effects leads to less photosynthetic activity by primary producers (singh et al., 2002) also contribute to minimal population during monsoon.

Table 7.13: Plankton (organism/l) and Macro-Invertebrates Density (organism/m²) at Various Project Site in Subansiri River

Species	Season	Location	Niare	Naba	Nalo	Dengser	Upper Subansiri	Middle Subansiri	Lower Subansiri	Niacin	Hiya	Tago-1
Phytoplankton	I	Average of All Location	117	121	NA	56	50	68	62	NA	NA	58
	II	Upstream	420	1362	832	3634	3558	5056	342	652	428	103
		Dam Site	338	782	224	5326	2782	3062	224	624	338	116
		Downstream	216	774	266	5022	3324	2102	112	436	344	63
	III	Upstream	420	1362	832	3634	3558	5056	342	652	428	103
		Dam Site	338	782	224	5326	2782	3062	224	624	338	116
		Downstream	216	774	266	5022	3324	2102	112	436	344	63
Zooplankton	I	Average of All Location	13	6	NA	3	17	8	9	NA	NA	11
	II	Upstream	324	656	364	468	2032	582	322	436	262	108
		Dam Site	178	428	192	334	1958	436	218	428	288	93
		Downstream	266	336	104	630	1776	648	172	406	326	87
	III	Upstream	324	656	364	468	2032	582	322	436	262	108
		Dam Site	178	428	192	334	1958	436	218	428	288	93
		Downstream	266	336	104	630	1776	648	172	406	326	87
Macro-Invertebrates	I	Average of All Location	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	II	Upstream	672	154	444	534	336	544	674	673	432	522
		Dam Site	578	242	326	266	422	438	422	776	622	830
		Downstream	542	114	332	336	284	364	376	920	624	784
	III	Upstream	672	154	444	534	336	544	674	673	432	522
		Dam Site	578	242	326	266	422	438	422	776	622	830
		Downstream	542	114	332	336	284	364	376	920	624	784

7.3.2 Primary Productivity

Gross primary productivity (GPP) and Net primary productivity (NPP)

Surveys were conducted in different seasons of the year to collect data related to biological parameters including the net primary productivity and the Gross primary productivity. In addition, surveys and studies were also conducted for understanding aquatic ecology of different sites of Subansiri basin and its tributaries.

Table 7.14: Sampling of water parameters conducted in the proposed sites at different seasons.

Particulars	Seasons		
	Pre Monsoon	Monsoon	Post Monsoon
Water quality on aquatic biology	February-March 2013	April- May 2013	Nov-Dec 2013

The comparative analyses of biological water quality at the proposed sites during the three seasons are given in the **Table 7.15.**

The gross primary productivity (GPP) of the investigated sites ranged from 0.65 -2.01 (mgC/m³/day), Net primary productivity (NPP) ranged from 0.51-1.81 (mgC/m³/day) during winter. GPP and NPP showed an increase in summer sampling compared to the former. During this period the GPP ranged from 0.73 – 2.25 ($mgC/m^3/day$) and NPP from 0.39 – 2.13 ($mgC/m^3/day$). In the final survey during Nov to Dec the GPP ranged from 0.04 to 1.5 ($mgC/m^3/day$), Net primary productivity ranged from 0.01 to 1.2. The rivers were found to be oligotrophic in nature as the primary productivity recorded were found to be quite low. The GPP was found to be maximum at Middle Subansiri (2.01 $mgC/m^3/day$) sampling site, whereas the minimum was recorded at Niare (0.65 $mgC/m^3/day$), The NPP was also found to be maximum at Middle Subansiri (1.81 $mgC/m^3/day$) and minimum at Niare (0.51 $mgC/m^3/day$) during February – March 2013. The survey period during April – May 2013 showed a increasing trend in the primary productivity with Middle Subansiri recording the highest in GPP (**2.25** $mgC/m^3/day$) and NPP (**2.13** $mgC/m^3/day$) on the other hand Niare recorded the lowest in both GPP (**0.73** $mgC/m^3/day$) and NPP(**0.39** $mgC/m^3/day$). In the last survey we recorded the maximum GPP at again the Middle Subansiri (1.5 $mgC/m^3/day$) and the minimum at Hiya and Tago-I (0.04 $mgC/m^3/day$), the NPP was found maximum in the middle Subansiri (1.2 $mgC/m^3/day$) and minimum in the Hiya (0.01 $mgC/m^3/day$). Low values of primary production were noted when the transparency of water was more and vice versa. The transparency is affected mainly due to phytoplankton population as the phytoplankton count was low in almost all the sampling site it resulted in low Primary production. Temperature of the ecosystem also seems to have great influence in regulating the primary production in freshwater ecosystem. During the survey, the Primary production was seen increasing and decreasing with the increase and decrease of surface water temperatures. Northcote[49] & Larkin (1956) have reported a significant relationship between summer surface temperature and plankton. Sreenivasan (1964a) has also reported low values during winter months.

Table 7.15: Seasonal variation in GPP and NPP during different sampling season

Productivity(mgC/)m³/day)	Pre-Monsoon		Monsoon		Post-Monsoon	
	GPP	NPP	GPP	NPP	GPP	NPP
Middle Subansiri	2.01	1.81	2.25	2.13	1.5	1.2
Upper Subansiri	1.01	0.61	1.2	1.06	1.27	0.5
Dengser	1.64	1.09	1.69	1.27	0.63	0.27
Niare	0.65	0.51	0.73	0.39	0.58	0.36
Naba	1.03	0.7	1.1	0.98	0.97	0.86
Tago-I	1.3	0.78	1.83	1.78	0.04	0.08
Lower Subansiri	1.52	1.27	1.62	1.35	0.56	0.38
Nalo	1.55	1	1.6	1.25	0.78	0.52
Hiya	2	0.75	2.15	1.7	0.04	0.01
Nyepin	1	0.95	1.35	1.25	0.17	0.08

NPP- Net Primary Productivity, GPP- Gross Primary Productivity

7.4 Fish and Fisheries

Fishes are important food resource and good indicators of the ecological health of the waters they inhabit. They are invariable living components of water bodies. Running water of Himalaya comprise many torrential rivers and streams providing a wide variety of ecological niche. The distribution of fishes in Arunachal Pradesh can be mainly attributed to altitude and topology. The higher elevations generally support cold water fishes and the foot hills region and mid elevations comprises of fishes which are economically important, but most of the fish resources in the lotic systems of this region

[49] *Northcote, T. G., and P. A. Larking (1956). Indices of productivity in British Columbia Lakes, J. Fish. Res. BD. Can., 13: 515-540.*

had not been completely explored because most of the rivers are located in unapproachable mountainous steep terrain with dense forest cover. According to the IUCN 2011 of 94 species sampled 6 have been categorized as endangered species and while 8 under vulnerable category as per the criterion IUCN (2011). 15 species have been categorized under lower risk near threatened, 40 as lower risks least concern and 25 species not evaluated till date. The studies by Das et al (2013) also reveals the presence of 87 (Eighty Seven) species of fishes belonging to 9 (Nine) orders, 22 (Twenty) families and 55 (Fifty five) genera in River Subansiri. Cypriniformes dominates the whole river and found in higher numbers and Beloniformes and Tetradontiformes are found in less number. The diversity of fishes from the upstream to downstream of the Subansiri River was earlier described by Sharma et al. (2008), where, they found 137 fish species belonging to 7 types of order. Das et al. in 2011 reported 48 species of fishes in Subansiri River belonging to 15 families under 7 different orders. There has been studies conducted by various authors in Arunachal Rivers (Bagra et al, 2009), which showed varying presence of fish species in Subansiri River.

7.4.1 Fish Composition and Distribution

Fish resources

Fish are invariable living components of water bodies. These organisms are important food resource and good indicators of the ecological health of the waters they inhabit. However, the rich biodiversity of the freshwater fish of the Indian region has been rapidly dwindling because of increasing degradation of inland water. Out of a total of 2,500 species of fish in India, 930 are in fresh waters and belong to 326 genera, 99 families and 20 orders (Stalwart and Dhingra 1991). Arunachal Pradesh (AP) state is the largest in geographical as well as in river drainage area in North-Eastern India and harbors innumerable rivers and rivulets which are home to diverse fish species, of which many are endemic to this region. AP is regarded as the type locality for more than 11 freshwater fish species in the world.

Nath and Dey (2000) published their pioneering works on systematic account of fish resources of AP revealing 131 species from (AP Nath, P. and S. C. Dey. 2000. *Fish and fisheries of North Eastern India* (Arunachal Pradesh). Narendra Publishing House, New Delhi. 217 p. In 2006, Zoological Survey of India reported 143 species from Arunachal Pradesh (Fauna of Arunachal Pradesh, Zoological Survey of India (ZSI), 2006 (No. 13 Part-I).

Moreover, two new species have been described namely: *Pseudechenies sirenica* Vishwanath and Darshan 2007, *Psilorhynchus arunachalensis* (Nebeshwar, Bagra and Das 2007) and *Garra kalpangii* sp. nov. This indicates that water bodies of AP are of taxonomic importance. Subsequently, in 2009, 213 fish species were reported to occur in Arunachal Pradesh (Kenjam Bagra, *et al.* 2009: *Ichthyological survey and review of the checklist of fish fauna of Arunachal Pradesh, India Check List* **5**(2): 330–350, 2009, ISSN: 1809-127 X).

Recent study by Das et. al (2013) showed Ichthyofauna of Subansiri River in Assam and Arunachal Pradesh showed presence of 87 species. The studies by Das et al (2013) also reveals the presence of 87 (Eighty Seven) species of fishes belonging to 9 (Nine) orders, 22 (Twenty) families and 55 (Fifty five) genera in River Subansiri. Cypriniformes dominates the whole river and found in higher numbers and Beloniformes and Tetradontiformes are found in less number (**Table 7.16**).

Table 7.16: List of Fish species of Subansiri River in Assam and Arunachal Pradesh

S. No	Name of the Fish	Order	Family
1	*Notopterus notopterus* (Pallas)	Osteoglossiformes	Notopteridae
2	*Chitala chitala* (Hamilton-Buchanan)	Osteoglossiformes	Notopteridae
3	*Amblypharyngodon mola* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
4	*Aspidopario jaya* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
5	*Aspidapario morar* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
6	*Barilius barila* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
7	*Barilius barana* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
8	*Bengala elenga* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
9	*Brachydanio aceticephala* (Hora)	Cypriniformes	Cyprinidae
10	*Cirrhinus mrigala* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
11	*Cirrhinus reba* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
12	*Danio acquipinnatus* (McClelland)	Cypriniformes	Cyprinidae
13	*Danio dangila* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
14	*Devario devario* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
15	*Labeo bata* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
16	*Labeo calbasu* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
17	*Labeo gonius* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
18	*Labeo pangusia* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
19	*Labeo rohita* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
20	*Osteobroma cotio cotio* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
21	*Puntius chola* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
22	*Puntius sophore* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
23	*Puntius ticto ticto* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
24	*Puntius conchonius* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
25	*Puntius sarana sarana* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
26	*Puntius gelius* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
27	*Puntius rasbora* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
28	*Raimas bola* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
29	*Salmostoma bacila* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
30	*Semipolotus semipolotus* (McClelland)	Cypriniformes	Cyprinidae
31	*Tor progenies* (McClelland)	Cypriniformes	Cyprinidae
32	*Tor putitora* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
33	*Tor tor* (Hamilton-Buchanan)	Cypriniformes	Cyprinidae
34	*Acanthocobitis botia* (Hamilton-Buchanan)	Cypriniformes	Balitoridae
35	*Acanthocobitis kempi* (Chadhuri)	Cypriniformes	Balitoridae
36	*Balitora brucei*	Cypriniformes	Balitoridae
37	*Botia berdmorei* Gray	Cypriniformes	Cobitidae
38	*Botia Dario* (Hamilton-Buchanan)	Cypriniformes	Cobitidae
39	*Botia rostrata* (Gunther)	Cypriniformes	Cobitidae
40	*Lepidocehlichthys berdmorrei* (Blyth)	Cypriniformes	Cobitidae
41	*Lepidocephalus guntea* (Hamilton-Buchanan)	Cypriniformes	Cobitidae
42	*Hemibagrus monoda* (Hamilton-Buchanan)	Siluriformes	Bagridae
43	*Mystus bleekari* (Day)	Siluriformes	Bagridae
44	*Mystus tengara* (Hamilton-Buchanan)	Siluriformes	Bagridae
45	*Mystus cavasius* (Hamilton-Buchanan)	Siluriformes	Bagridae
46	*Mystus vittatus* (Hamilton-Buchanan)	Siluriformes	Bagridae
47	*Rita rita* (Hamilton-Buchanan)	Siluriformes	Bagridae
48	*Sperata aor* (Hamilton-Buchanan)	Siluriformes	Bagridae
49	*Batasio batasio* (Hamilton-Buchanan)	Siluriformes	Bagridae
50	*Batasio tengana*(Hamilton-Buchanan)	Siluriformes	Bagridae
51	*Ompok bimaculatus* (Bloch)	Siluriformes	Siluridae
52	*Ompok pabda* (Hamilton-Buchanan)	Siluriformes	Siluridae
53	*Wallogo attu* Scheidner	Siluriformes	Siluridae
54	*Ailia coila* (Hamilton-Buchanan)	Siluriformes	Schilbeidae

S. No	Name of the Fish	Order	Family
55	*Clupisoma garua* (Hamilton-Buchanan)	Siluriformes	Schilbeidae
56	*Eutropiichthys vacha* (Hamilton-Buchanan)	Siluriformes	Schilbeidae
57	*Pseudeutropius atherinodes* (Bloch)	Siluriformes	Schilbeidae
58	*Silonia silondia* (Hamilton-Buchanan)	Siluriformes	Schilbeidae
59	*Amblyceps apangi* (Nath and Day)	Siluriformes	Schilbeidae
60	*Amblyceps mangois* (Hamilton-Buchanan)	Siluriformes	Amblycipitidae
61	*Bagarius bagarius* (Hamilton-Buchanan)	Siluriformes	Sisoridae
62	*Erethistes pussilis* (Mullar and Troscell)	Siluriformes	Sisoridae
63	*Gangata cenia* (Hamilton-Buchanan)	Siluriformes	Sisoridae
64	*Gagata gagata* (Hamilton-Buchanan)	Siluriformes	Sisoridae
65	*Heteropneustes fossilis* (Bloch)	Siluriformes	Heteroneustidae
66	*Chaca chaca* (Hamilton-Buchanan)	Siluriformes	Chacidae
67	*Monopterus cuchia* (Hamilton-Buchanan)	Siluriformes	Synbrachidae
68	*Chanda nama* (Hamilton-Buchanan)	Perciformes	Channidae
69	*Channa gachua* (Bloch and Schneider)	Perciformes	Channidae
70	*Channa punctate* (Bloch)	Perciformes	Channidae
71	*Channa stewartii* (Playfair)	Perciformes	Channidae
72	*Channa striata* (Bloch)	Perciformes	Channidae
73	*Polyacanthus labiosus* (Day)	Perciformes	Belonidae
74	*Polyacanthus fasciatus* (Schneider)	Perciformes	Belonidae
75	*Polyacanthus lalia* (Hamilton-Buchanan)	Perciformes	Belonidae
76	*Polyacanthus sota* (Hamilton-Buchanan)	Perciformes	Belonidae
77	*Rhinomugil corsula* (Hamilton-Buchanan)	Perciformes	Mugilidae
78	*Nandus nandus* (Hamilton-Buchanan)	Perciformes	Nandidae
79	*Badis assamensis* Ahl	Perciformes	Nanidae
80	*Badis badis* (Hamilton-Buchanan)	Perciformes	Nanidae
81	*Glossogobius giuris* (Hamilton-Buchanan)	Perciformes	Gobidae
82	*Anabus testudineus* (Bloch)	Perciformes	Anabantidae
83	*Tetradon cutcutia* (Hamilton-Buchanan)	Perciformes	Tetradontidae
84	*Xenentodon cancilla* (Hamilton-Buchanan)	Beloniformes	Belonidae
85	*Mastacembelus pancalus* (Hamilton-Buchanan)	Synbranchiformes	Mastacembelidae
86	*Mastacembelus armatus* (Lacpede)	Synbranchiformes	Mastacembelidae
87	*Macrognatus aral* (Bloch and Schneider)	Synbranchiformes	Mastacembelidae

(Source: Das et al, 2013; *International Journal of Current Research, Vol. 5, Issue, 11, pp.3314-3317, November, 2013)*

7.4.2 Important Fish Habitat

During the survey period Order Cypriniformes dominated the whole river in all seasons and was found in higher numbers compared to that of Beloniformes and Salmoniformes which were very less in numbers. Species richness was very less in Nyepin sampling site and was comparatively high in Lower Subansiri HEP region during the whole survey period. The fishes recorded are in the categories of true hill stream, semi torrential as well as migratory forms. True hill stream fishes recorded were *Garra spp, Psilorhynchous spp, Glypthothorax species.* Semi torrential were *Schistura species, Botia species, Aconthocobitis botia, Lepidocephalichthyes species, Amblyceps species, Aborichthys species, Olyra longicaudata.* Among the migratory species recorded were *Tor species, Barilius species, Labeo dero, Channa species, Badis species, Danio species, Neolissocheilus hexagonalipis. Xenentodon cancila, Macrognathus aral, Aspidoparia species, puntius species* etc. were recorded from the lower reaches of the Subansiri River.

7.4.3 Fishes of Subansiri Basin

Fish found in the River Subansiri basin and its tributary where proposed HEPs are located in Subansiri basin are given below:

Project Name[50]	Fish Species
Oju – I	*Garra gotyla gotyla, Naemachellus botia botia, Channa punctatus, Schizothorax richardsoni, Barilius bendelisis, Labeo dero, Mastacembelus armatus, etc.*
Oju – II	*Garra gotyla gotyla, Naemachellus Botia botia, Channa punctatus, Schizothorax richardsoni, Barilius bendelisis, Labeo dero, Mastacembelus armatus, etc.*
Niare	*Tor putitora, Tor tor, Schizothorax richardsonii, Barilius Barna, B. bendelisis, Labeo dero, Gara gotyla gotyla, Psilorhynchus balitora, Naemacheilus botia botia, Xenentodon cancila, Channa punctatus, Mastacembelus armatus, Badis badis.*
Naba	*Tor putitora, Tor tor, Schizothorax richardsonii, Barilius barna, B. bendelisis, Labeo dero, Gara gotyla gotyla, Psilorhynchus balitora, Naemacheilus botia botia, Xenentodon cancila, Channa punctatus, Mastacembelus armatus, Badis badis.*
Kurung I and II	*Labeo dero, Labeo dyocheilus, Tor tor, Tor putitora, Tor khudri, Schizothorax plagiostomus*.
Lower Subansiri	*Sperata aor* and *Sperata seenghala*
Middle Subansiri (Kamla)	*Tor tor, Tor putitora*, *Tor khudree*, *Schizothorax, Labeo dero,* etc. The fish species such as *Tor tor* and *Schizothorax* sp. are the important migratory species observed in river Kamala *Amblyceps apangi*, *Balitora brucei*, *Batasio fasciolatus*, *Botia rostrata*, *Crossocheilus latius*, *Garra annandalei*, *Pseudecheneis sulcata*, *Pseudecheneis sulcata, Schizothorax richardsonii, Schistura rupecula* McClelland, etc has been recorded in Panye nallah which outfalls in Kamala River in Tamen
Upper Subansiri	*Schizothorax richardsonii, Brachydanio rerio, Barilius barna, B. bola, B. tileo, Labeo dero, L. pangusia, Acrossocheilus hexagonolepis, Tor putitora, T. tor, Bagarius bagarius, Schizopyge esocinus, S. progastus,* etc. *Amblyceps arunachalensis, Amblyceps apangi* and *Amblyceps* sp. have been reported to occur in Subansiri at Daporijo.
Nalo	*Tor putitora, Tor tor*, *Schizothorax richardsonii*, *Barilius barna*, *Barilius vagram B. bendelisis*, *Labeo dero*, *Gara gotyla gotyla*, *Psilorhynchus balitora*, *Naemacheilus botia botia*, *Xenentodon cancila, Channa punctatus, Channa striatus, Mastacembelus armatus, Mastacembelus pancalus, Badis badis, Puntius chola, Puntius sophore, Mystus montanus, Colisa fasciatus, Glosso gobius, Chela gochine, Amblypharyngodon* sp
Dengser	*Barilius vagra, Puntius chola, Puntius sophore, Tor putitora, Mystus montanus, Psilorhynchus balitora, Channa striatus, Colisa fasciatus, Mastacembelus pancalus*

(Source: PFR Reports)

Photographs of fish found in sampling locations in Upper Subansiri are given in **Figure 7.26.**

[50]PFR of (i) Kurung HE Project, Naba HE project, Nalo HE project, Niare HE project, Oju-I HE project, Oju-II HE project, Dengser HE project; FR is of middle Subansiri project; and DPR is of Subansiri Upper HE project.

Figure 7.26: Fish found during Sampling

7.4.4 Fishery Activities and Fishing Techniques / Devices Used in Basin

Fishing practices

The indigenously used fishing devices, their construction and the methods of application are described below:

***i) Takom gaanam*:** technique of placing a *Takom* in the river or stream. *Takom* is a conical shaped fish trap made of bamboo with a mouth diameter ranging from 0.1 to 0.3 meter. It is fixed against the water current. Once the fish enter inside, they remain entangled in the base with the pressure of water current.

ii) *Tasum kunam*: fishing method in which a conical shaped basket made of cane is used to collect fishes from streams or rivers. With this fishing gear small sized fishes, especially bottom dwellers, are easily collected.

iii) *Lipum paanam*: fishing method in which the flat stones are piled one on other in the pool or slow flowing river of approximately 1 meter depth. The stone are piled in such a way that forms a round shape of aggregated stone block called *lipum*. The diameter of *lipum* ranges from 1.2 to 2.0 meters and height ranges from 0.4 to 0.5 meter. *Lipum paanam* is practiced during winter season and is allowed to remain undisturbed for 2 to 3 months where fish take shelter. The aggregated fishes are then collected by un-piling stones just after cordoning the *lipum* with a circular screen made of bamboo. These indigenous devices are used where common fishing gears are not appropriated. There are no regular fish landing centers. Fishes are caught with the help of long line, cast nets and traps from different streams and nallahs in the area.

7.4.5 Fishes Found During Study

The highest number of fish species was recorded in Lower Subansiri followed by Middle Subansiri (Kamala HEP), Upper Subansiri, Tago-I, Nalo, Hiya, Nyepin, Naba, Dengser and Niare which is shown in **Figure 7.27** and name of fish species is given in **Table 7.17**.

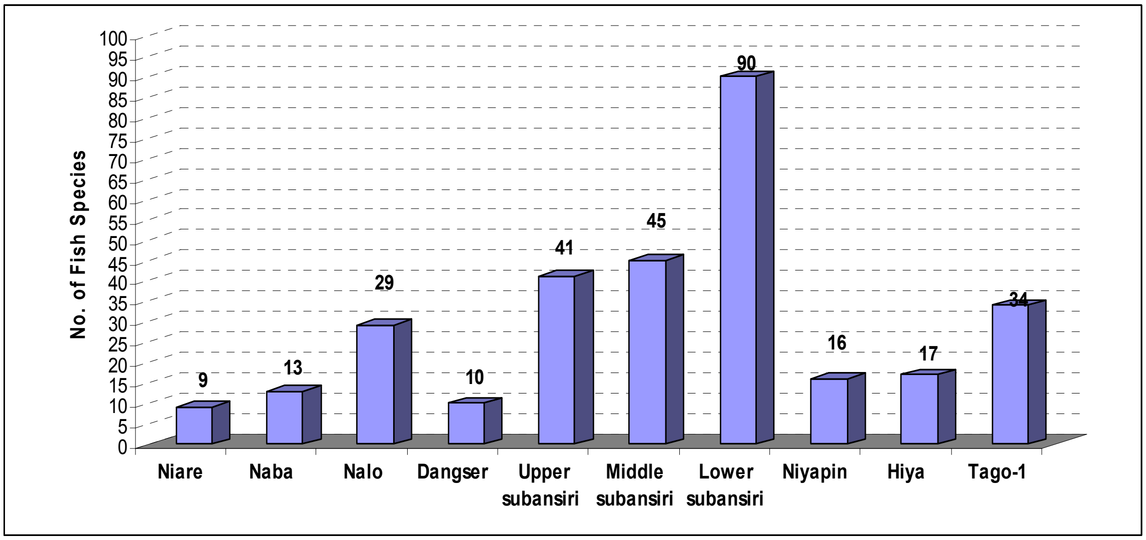

Figure 7.27: Number of Fishes Species in Project Area

Table 7.17: Occurrence of fish species at various sampling sites.

Sr. no	Species	Middle Subansiri	Upper Subansiri	Dengser	Niare	Naba	Tago-1	Lower Subansiri	Nalo	Nyepin	Hiya
1	*Barilius bendelisis*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
2	*B. barna*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
3	*B. vagra*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
4	*B.barila*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
5	*Danio aequipinnatus*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
6	*Danio (Danio) dangila*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
7	*Danio (Brachydanio) rerio*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
8	*D. devario*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
9	*Garra gotyla gotyla*	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes
10	*G. kempi*	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
11	*G. nasuta*	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes
12	*G. annandalei*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
13	*G. mcClellandi*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
14	*Tor tor**	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
15	*T. putitora**	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
16	*T.progenies**	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Sr. no	Species	Middle Subansiri	Upper Subansiri	Dengser	Niare	Naba	Tago-1	Lower Subansiri	Nalo	Nyepin	Hiya
17	*Neolissocheilus hexagonalepis**	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
18	*Schizothorax richardsonii**	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes
19	*Schizothorax esonicus**	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes
20	*Amblypharyngodon mola*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
21	*Aspidoparia jaya*	No	No	No	No	No	No	Yes	No	No	No
22	*A. morar*	No	No	No	No	No	No	Yes	No	No	No
23	*Labeo dero*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
24	*L.bata*	No	No	No	No	No	No	Yes	No	No	No
25	*L.calbasu*	No	No	No	No	No	No	Yes	No	No	No
26	*L.gonius*	No	No	No	No	No	No	Yes	No	No	No
27	*L.pangusia*	No	No	No	No	No	No	Yes	No	No	No
28	*L.rohita*	No	No	No	No	No	No	Yes	No	No	No
29	*Osteobama cotio cotio*	No	No	No	No	No	No	Yes	No	No	No
30	*Puntius chola*	No	No	No	No	No	No	Yes	No	No	No
31	*P. sophore*	No	No	No	No	No	No	Yes	No	No	No
32	*P. ticto*	No	No	No	No	No	No	Yes	No	No	No
33	*P.conchonius*	No	No	No	No	No	No	Yes	No	No	No
34	*P. sarana sarana*	No	No	No	No	No	No	Yes	No	No	No
35	*P. gelius*	No	No	No	No	No	No	Yes	No	No	No
36	*P.rasbora*	No	No	No	No	No	No	Yes	No	No	No
37	*Raimas bola*	No	No	No	No	No	No	Yes	No	No	No
38	*Salmostoma bacila*	No	No	No	No	No	No	Yes	No	No	No
39	*Semiplotus semiplotus*	Yes	Yes	No	No	No	Yes	Yes	No	No	No
40	*Psilorhynchous balitora*	Yes	Yes	No	No	No	No	Yes	No	No	No
41	*Aborichythys elongatus*	Yes	Yes	No	No	No	No	Yes	No	No	No
42	*A.kempi*	Yes	Yes	No	No	No	No	Yes	No	No	No
43	*Acanthocobitis botia*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
44	*Botia dario*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
45	*B. rostrata*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
46	*B.bredmorei*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
47	*Schistura rupecola rupecola*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
48	*Nemacheilus devdevi*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
49	*Lepidocehlichthys berdmorrei*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
50	*Lepidocephalus annandalei*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
51	*L.guntea*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
52	*Balitora brucei*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
53	*Cirrhinus mrigala*	Yes	No	No	No	No	Yes	Yes	No	No	No
54	*Glypthothorax ater*	Yes	No	No	No	No	Yes	Yes	No	No	No
55	*G.horai*	Yes	No	No	No	No	Yes	Yes	No	No	No
56	*Bagarius bagarius*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
57	*Erethistes pussilis*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
58	*Gagata cenia*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
59	*G.gagata*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
60	*Pseudecheneis sulcata*	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes
61	*Ompok pabo*	No	No	No	No	No	No	Yes	No	No	No
62	*O.bimaculatus*	No	No	No	No	No	No	Yes	No	No	No

Sr. no	Species	Middle Subansiri	Upper Subansiri	Dengser	Niare	Naba	Tago-1	Lower Subansiri	Nalo	Nyepin	Hiya
63	*Wallogo attu*	No	No	No	No	No	No	Yes	No	No	No
64	*Heteropneustes fossilis*	No	No	No	No	No	No	Yes	No	No	No
65	*Clarias batrachus*	No	No	No	No	No	No	Yes	No	No	No
66	*Amblyceps apangi*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
67	*A.mangois*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
68	*A.arunachalensis*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
69	*Olyra longicaudata*	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No
70	*Mystus bleekari*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
71	*M.tengara*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
72	*M.cavasius*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
73	*M.vittatus*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
74	*Sperata aor*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
75	*Batasio batasio*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
76	*B.tangana*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
77	*Ailia coila*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
78	*Clupisoma garua*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
79	*Eutropiichthys atherinodes*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
80	*Silonia silondia*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
81	*Channa orientalis*	Yes	Yes	No	No	No	No	Yes	No	No	No
82	*C. punctata*	Yes	Yes	No	No	No	No	Yes	No	No	No
83	*C.gachua*	Yes	Yes	No	No	No	No	Yes	No	No	No
84	*C.stewarti*	Yes	Yes	No	No	No	No	Yes	No	No	No
85	*C.striata*	Yes	Yes	No	No	No	No	Yes	No	No	No
86	*Badis* spp.	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*Yes*
87	*Chanda nama*	Yes	Yes	No	No	No	No	Yes	No	No	No
88	*Chanda baculis*	Yes	Yes	No	No	No	No	Yes	No	No	No
89	*C.ranga*	Yes	Yes	No	No	No	No	Yes	No	No	No
90	*Xenentodon cancila*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
91	*Macrognathus aral*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
92	*M.pancalus*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
93	*Macrognatus aral*	*No*	*No*	*No*	*No*	*No*	*No*	*Yes*	*No*	*No*	*No*
94	*Oncorhynchus mykiss*	*No*	*No*	*No*	*No*	*No*	*No*	No	No	yes	No

*Recorded migratory species

During the survey a total of 94 species (comprising of 6 orders, 19 families and 51 genera) were recorded as highest in the post-monsoon season compared to 51 species (6 order, 17 families and 30 genera) during monsoon and 29 species (6 Orders, 12 families and 20 genera) in pre monsoon. Sampling in rivers was conducted using available fishing method used for catching fishes mainly from mountainous river and also from secondary sources (Local fisherman, villagers, fishery officers etc).

As per the estimate, the average fish production per day was estimated to be 12.0 kg from Subansiri River. Based on this data average fish catch was estimated during the post monsoon one month study period was calculated to be 360 kg. Average catch of fish by an individual per day was estimated to be 6 kg. As per the tribal people involved in fish catches usually done for their local family level consumption , the catch percentage during post-monsoon is high compared to other season, they were also of the view that the fish catch of fish is decreasing continuously. This indicates that the species richness, composition and abundance vary greatly among seasons. Generally most of the tribals, who undertake fishing are usually very poor and uneducated. The involvement of children in fishing is rarely noted in the entire area.

Fish species collected from the sampling site at Daporijo, Upper Subansiri, Arunachal Pradesh, India.		
Sr. No.	Species name	
1.	*Barilius bendelisis* (Hamilton)	
2.	*Barilius vagra* (Hamilton)	
3.	*Botia rostrata* (Gunther)	
4.	*Raiamas bola* (Hamilton)	
5.	*Garra gotyla* (Gray)	
6.	*Schizothorax richardsonii* (Gray)	

Fish species collected from the sampling site at Daporijo, Upper Subansiri, Arunachal Pradesh, India.		
Sr. No.	Species name	
7.	*Tor putitora* (Hamilton)	

7.4.6 Habitat Characteristics of Threatened Fish Species Reported from Subansiri River

Threatened fish species namely endangered, vulnerable, low risk, least concern, near threatened and not evaluated are summarized in **Table 7.18**.

Table 7.18: list of fish species recorded

S. No.	order	Family	Sr. no	Species	Conservation Status
1.	Cypriniformes	Cyprinidae	1	*Barilius bendelisis*	LR-nt
			2	*B. barna*	LR-nt
			3	*B. vagra*	VU
			4	*B.barila*	LR-lc
			5	*Danio aequipinnatus*	LR-nt
			6	*Danio (Danio) dangila*	NE
			7	*Danio (Brachydanio) rerio*	LR-lc
			8	*Devario devario*	LR-nt
			9	*Garra gotyla gotyla*	VU
			10	*G. kempi*	VU
			11	*G. nasuta*	LR-lc
			12	*G. annandalei*	LR-lc
			13	*G. mcClellandi*	LR-lc
			14	*Tor tor*	EN
			15	*T. putitora*	EN
			16	*T.progenies*	NE
			17	*Neolissocheilus hexagonelepis*	LR-nt
			18	*Schizothorax richardsonii*	VU
			19	*Schizothorax esonicus*	NE
			20	*Amblypharyngodon mola*	LR-lc
			21	*Aspidoparia jaya*	LR-lc
			22	*A. morar*	LR-lc
			23	*Labeo dero*	LR-lc
			24	*L.bata*	LR-lc
			25	*L.calbasu*	LR-lc
			26	*L.gonius*	LR-lc
			27	*L.pangusia*	LR-lc
			28	*L.rohita*	LR-lc
			29	*Osteobama cotio cotio*	NE
			30	*Puntius chola*	LR-lc
			31	*P. sophore*	LR-lc
			32	*P. ticto*	LR-lc
			33	*P.conchonius*	LR-lc
			34	*P. sarana sarana*	LR-lc
			35	*P. gelius*	LR-lc
			36	*P.rasbora*	NE
			37	*Raimas bola*	NE

S. No.	order	Family	Sr. no	Species	Conservation Status
			38	*Salmostoma bacila*	NE
			39	*Semiplotus semiplotus*	NE
		Psilorhynchidae	40	*Psilorhynchous balitora*	LR-lc
		Balitoridae	41	*Aborichythys elongatus*	NE
			42	*A.kempi*	NE
			43	*Acanthocobitis botia*	LR-lc
		Cobitidae	44	*Botia dario*	LR-lc
			45	*B. rostrata*	VU
			46	*B.bredmorei*	NE
			47	*Schistura rupecola rupecola*	LR-nt
			48	*Nemacheilus devdevi*	LR-nt
			49	*Lepidocehlichthys berdmorrei*	NE
			50	*Lepidocephalus annandalei*	LR-lc
			51	*L.guntea*	LR-lc
			52	*Balitora brucei*	LR-nt
		Labeoninae	53	*Cirrhinus mrigala*	LR-nt
2.	Siluriformes	Sisoridae	54	*Glypthothorax ater*	EN
			55	*G.horai*	NE
			56	*Bagarius bagarius*	LR-nt
			57	*Erethistes pussilis*	NE
			58	*Gagata cenia*	LR-lc
			59	*G.gagata*	LR-lc
			60	*Pseudecheneis sulcata*	VU
		Siluridae	61	*Ompok pabo*	LR-nt
			62	*O.bimaculatus*	NE
			63	*Wallogo attu*	NE
		Heteroneustidae	64	*Heteropneustes fossilis*	LR-lc
		Clariidae	65	*Clarias batrachus*	VU
		Amblycipitidae	66	*Amblyceps apangi*	EN
			67	*A.mangois*	EN
			68	*A.arunachalensis*	EN
		Bagridae	69	*Olyra longicaudata*	LR-lc
			70	*Mystus bleekari*	NE
			71	*M.tengara*	LR-lc
			72	*M.cavasius*	NE
			73	*M.vittatus*	LR-lc
			74	*Sperata aor*	LR-lc
			75	*Batasio batasio*	LR-lc
			76	*B.tangana*	NE
		Schilbeidae	77	*Ailia coila*	LR-nt
			78	*Clupisoma garua*	LR-lc
			79	*Eutropiichthys atherinodes*	NE
			80	*Silonia silondia*	LR-lc
3.	Perciformes	Channidae	81	*Channa orientalis*	VU
			82	*C. punctata*	LR-nt
			83	*C.gachua*	LR-lc
			84	*C.stewarti*	NE
			85	*C.striata*	NE
		Badidae	86	*Badis* spp.	LR-lc
		Ambassidae	87	*Chanda nama*	LR-lc
		Chandidae	88	*Chanda baculis*	LR-lc
			89	*C.ranga*	LR-lc

S. No.	order	Family	Sr. no	Species	Conservation Status
4.	Beloniformes	Belonidae	90	*Xenentodon cancila*	LR-nt
5.	Synbranchiformes	Mastecembelidae	91	*Macrognathus aral*	LR-nt
			92	*M.pancalus*	NE
			93	*Macrognatus aral*	NE
6.	Salmoniformes	Salmonidae	94	*Oncorhynchus mykiss*	NE

LRnt = lower risk- near threatened. LR-lc = Lower risk- least concern. VU = Vulnerable.
EN = Endangered. NE = Not evaluated

7.4.7 Fish Migration and Breeding / Spawning Grounds in Subansiri Basin

The fish life of River Subansiri can be classified under the categories temperate warm sub-tropical species and warm tropical species. Depending on water temperature and DO levels, these species undertake short and long journeys to survive and propagate in most optimal conditions. Altitude wise distribution of fish species in River Subansiri[51] is given in **Table 7.19.**

Table 7.19: Altitude wise distribution of fish species in River Subansiri

Sr. no	Predominant Species below 800 MSL (Lower reaches)	Predominant Species between 800-1200 MSL (Middle reaches)	Predominant Species above 1200-MSL (Upper reaches)
1.	*Danio (Danio) aequipinnatus* (Mc Clelland)	1. *Barilius barna* (Hamilton)	1.*Schizopyge esocinus* (Heckel)
2.	*Danio (Danio) dengila* (Hamilton)	2. *Barilius barilla* (Hamilton)	2.*Schizopyge progastus* (Mc Clelland)
3.	*Danio (Brachydanio) devario* (Hamilton)	3. *Barlius bola* (Hamilton)	3.**Schizothorax richardsoni*
4.	*Aspidoparia morar* (Hamilton)	4.*Puntius ticto* (Hamilton)	4.*Schizopygopsis stoliczkae* (Steind)
5.	*Aspidoparia jaya* (Hamilton)	5.*Labeo dero* (Heckel)	
6.	*Barilius tileo* (Hamilton)	6. **Acrossocheilus hexagonolepis* (Mc Clelland)	
7.	*Semiplotus semiplotus* (Mc Clelland)	7.*Chagunius chagunio* (Hamilton)	
8.	*Puntius chola* (Hamilton)	8.**Tor putitora* (Hamilton)	
9.	*Puntius sophore* (Hamilton)	9.**Tor tor*	
10.	*Labeo pangusia* (Hamilton)	10. *Crossocheilus latius latius* (Hamilton)	
11.	*Lepidocephalus guntea*	11.*Garra annandalei* (Hora)	
12.	*Lepidocephalus annandalei* Chaudhuri	12.*Garra gotyla gotyla* (Gray)	
13.	*Bagarius bagarius* (Hamilton)	13.*Garra lamta* (Hamilton)	
14.	*Silurus afghana* Gunther	14.*Garra mcclellandi* (Jerdon)	
15.	*Olyra longicaudata* (Mcclelland)	15.*Psilorhynchus balitora* (Hamilton)	
16.	*Xenentodon cancila* (Hamilton)	16.*Aborichthys elongatus* (Hora)	
17.	*Channa marulius* (Hamilton)	17.*Aborichthys kempi* (Chaudhury)	
18.	*Channa orientalis*	18.*Noemacheilus devdevi* (Hora)	

51 Nath and Dey, 1990

Sr. no	Predominant Species below 800 MSL (Lower reaches)	Predominant Species between 800-1200 MSL (Middle reaches)	Predominant Species above 1200-MSL (Upper reaches)
	(Schneider)		
19.	*Channa punctatus* (Bloch)	19.*Noemacheilus manipurensis* (Chaudhuri)	
20.	*Channa striatus* (Bloch)	20.*Acanthocobitis botia* (Hamilton)	
21.	*Chanda baculis* (Hamilton)	21.*Botia dana* (Hamilton)	
22.	*Chanda nama* (Hamilton)	22.*Botia rostrata* (Gunther)	
23.	*Chanda ranga* (Hamilton)	23.*Ambeyceps mangois* (Hamilton)	
24.	*Badis badis* (Hamilton)	24.*Glyptothorax horai* (Shaw & Shebeare)	
25.	*Colisa fasciata* (Schneider)		
26.	*Mastacembelus armatus* (Lacepede)		
27.	*Mastacembelus passcalus* (Hamilton)		

*Migratory species

Generally fish are periodic in migration, in which, time, direction and purpose are most important factors[52]. Fishes migrate to find suitable site for spawning and breeding purpose to sustain their future progeny. Migration can be from few meters to few kilometers or more in search of food and feeding sites. Among the fish species of River Subansiri, *Tor putitora, T. Tor* and *Acrossocheilus hexagonolepis* traverse a long distance to perform upstream migration but mainly for search of food and breeding sites. Usually, it is observed that they ascend in the months of April and May for the purpose of spawning. These species use mainstream as migratory route and access a particular stream. After spawning, they descend in the months of September and October.

Schizothorax richardsonii ascend comparatively for short distance. The Mahseer is a fresh water stream fish, having their territorial regime confined up to foothills, migrate up and down for spawning. The snow melt water from the springs induces spawning. The snow melts in the months of April to May and during this period these fishes migrate upstream for spawning. After spawning, the fish migrates downstream during September. The fish migrates considerable distances upstream in search of suitable spawning grounds[53]. Adults and juveniles of species such as *Schizothorax* spp. and *Tor* spp. move upstream and downstream respectively in river including streams. Majority of the tributaries serve as the routes through which the fish can have easy access to the spring-fed placid streams that provide congenial environment for fish to breed. The presence of gravel, pebbles, sand and bankside vegetation is prerequisite for Mahaseer to build their spawning nests. Mahaseer needs clean, stable, well oxygenated, gravel habitats to spawn. The eggs laid in the gravels require well-oxygenated water[54].

Four migratory fish species are recorded in Subansiri Basin namely *Acrossocheilus hexagonolepis, Tor putitora* (golden mahseer)*, Tor tor* and *Schizothorax richardsoni (snow trout).* Habitat and Ecology of migratory species is described below:

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[52] *Beaven, 1877*
[53] *Badola and Singh, 1984; Nautiyal and Lal, 1984; Singh, 1988.*
[54] *Sharma, 1984*

Acrossocheilus hexagonolepis **(Copper mahaseer/Chocolate mahaseer)**
It Inhabits streams with fast flowing water mostly in high gradient and low gradient riffles and pools. It prefers rocky and boulder areas with high flow. It lives mainly in the middle of streams. The species is known to breed from April to October with a peak in August to September. The male of this species mature at an early size of 9 cm. It breeds in pools with running water. It's an omnivorous species and feeds mainly on filamentous green algae, lesser on chironomid larvae, crustaceans and water beetles. Migrate upstream during the breeding season where spawning takes place on stones and gravel. It's a Near Threatened species.

Tor putitora **(Golden mahseer)**
It inhabits the montane and submontane regions, in streams and rivers. It inhabits rapid streams with rocky bottom, riverine pools and lakes. It's a benthopelagic and potamodromous species found in the depth range of usually 0 - 1 m. The fish is a column feeder in freshwater found in pH ranges 7.4 – 8.0 and in subtropical condition 13°C-30°C. It is omnivorous in nature during their adult stage and feed on periphytic algae and diatoms in juvenile stage. The feeding and breeding habitats are lost almost throughout their distributional range. It's an omnivorous, feeding on fish, zooplankton, dipteran larvae and plant matter Juveniles subsist on plankton while fingerlings feed mainly on algae Ascend streams to breed over gravel and stones and returns to perennial ponds after breeding. It's an endangered species.

Tor tor **(mahseer)**
It grows better in rivers with a rocky bottom. It breeds during August-September and continues up to December. After spawning, downstream migration occurs in large shoals. It's a benthopelagic and potamodromous species found in depth range of 15 metres. The species travel toward headwaters at the start of the rainy season and downstream at the end of the rainy season. It's an omnivorous fish, which feeds on filamentous algae, chironomid larvae, water beetles and crustaceans. It spawns from March to September, over stones and gravel. It is reported to reach 150 cm TL and gain a maximum weight of 68 kg and is considered a long-living species. It's a near threatened species.

Schizothorax richardsonii **(Snow trout)**
It's a demersal and potamodromous species, inhabits mountain streams and rivers, and prefers to live among rocks. It's primarily a bottom feeder, preferably near big submerged stones. It is herbivorous feeding mainly on algae, aquatic plants and detritus and insects encrusted on the rocks. It breeds during April-May, before the monsoon flood the rivers and streams; the fry grows to such a size as to bear the rigours of the flood waters. The species is vulnerable.

Biological and habitat characteristics of migratory fish species reported in Subansiri basin is given in **Table 7.20.**

Table 7.20: Biological and habitat characteristics of migratory fish species reported in Subansiri basin

Sr. No.	Species name	Distribution and habitat	Anatomy	Depth Range	Weight	ph range	Maturity
1	*Acrossocheilus hexagonolepis*	Benthopelagic potamodromous	Max length: 120 cm TL male/unsexed	2-2.3 m	max. published weight: 11.0 kg	7.4 – 8.0	23 cm
2	*Tor tor*	Benthopelagic	Max length :	usually	max.	7.4 - 7.9	Maturity:

Sr. No.	Species name	Distribution and habitat	Anatomy	Depth Range	Weight	ph range	Maturity
		potamodromous	200 cm TL male/unsexed Common length : 17.5 cm TL male/	3-6* metres	published weight: 9.0 kg		L_m 36.0 Max. reported age: 10 years
3	*Tor putitora*	Benthopelagic potamodromous	275 cm TL male/unsexed	usually 0 - 1 m		7.4 - 8.0	33 cm
4	*Schizothorax richardsonii*	demersal; potamodromous	Max length : 60.0 cm TL male/unsexed Common length : 183 cm	usually 1 m	max. published weight: 54.0 kg	7.4-8.0	60 cm

*based on various papers[55] and the simulation data for discharge /flow done for Subansiri river.

The data on depth range indicate that *Tor* spp. (Mahaseer) is found in the depth range of 0-1 metre[56].

According to Karamchandani (1972), the best places for mahseer fishing are:
(1) the junctions of rivers especially those with a difference in water temperature, where one of the two rivers is discoloured by melting snow;
(2) rapids of many forms, sizes and depth, at places where the backwaters and rapid waters meet forming swirls and eddies along the edges;
(3) the water above a rapid and at the tail of a pool having a depth of about 0.9 to 1.2 m and a smooth flow over large boulders, gaining in velocity as it approaches the rapid.

According to FAO Report, 2003, the depth range of *Tor tor* in rivers and reservoirs observed for fishing nets operated in both deep and shallow waters was generally 3 to 4 meters. In Rana Pratap Reservoir, Chaudhary 1978 captured Mahseer from 11 to 12 m depth (FAO, 2003). Another study by Islam and Tanaka (2006) and Md Shahidul Islam (2005) for *Tor* spp showed a maximum depth range of 15m.Whereas, simulated studies on discharge for keeping a minimum flow of 240 cumec release shows water depth of river Subansiri in the range of 2.79 – 6.18m. Also, it was observed during aquatic data

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[55] *FAO, 2003. Synopsis of Biological Data on the Tor Mahseer Tor tor (Hamilton, 822). FAO Fisheries Synopsis M.158, prepared by V. R. Desai, CICFRI, Barrackpore, West Bengal.*

Islam, M. S, and Tanaka, M., 2006. Threatened fishes of the World: Tor putitora Hamilton 1822 (Cypriniformes: Cyprinidae). Environmental Biology of Fishes (2007). 78:219-220. Springer 2006

Md. Shahidul Islam, 2005. Threatened fishes of the world: Tor tor Hamilton 1822 (Cyprinidae). Environmental Biology of Fishes (2005) 74: 66 Springer 2005

Pathani, S.S. 1983. Recent advances in the biology and ecology of Mahseers. In: Recent Advances in Fish Ecology and Limnology and Eco-conservation (ed. Surinder Nath):115-121.

Jingran, V.G., 1982. Fish and Fisheries of India. Hindustan Publishing Corporation, New Delhi, India

[56] *Talwar, P.K.and A.G. Jhingran, 1991. Inland fishes of India and adjacent countries. vol 1. A.A. Balkema, Rotterdam. 541 p; Fishbase and IUCN's database*

collection that Subansiri river showed presence of *Tor* spp in existing water depth, which can be taken as same as observed from simulation studies.
Therefore, for present study it can be safely deduced that depth range of *Tor* spp can be between 2.79 to 6.18m, without impacting the species survival.

Pathani (1983) located spawning grounds of Mahseer on sandy bottom, pebbles and aquatic weeds at a depth of 2.0 to 2.3 m in Lake Bhimtal. Jhingran (1982) reported egg laying by *Schizothorax* spp in clean water with gravelly bottom at 30-60 cm depth.

7.4.8 Factors that Need Attention for Maintenance of Aquatic Ecosystem

Since Subansiri Basin is rich in fish resources and other aquatic animals like river Dolphin *(Platanista gangetica)*, Otter etc, there is need to continuously maintain aquatic flow downstream of all proposed dams, so that there is no shortage of water ultimately at Lower Subansiri where important downstream fauna like Dolphin, though away from the project site thrives on continuous source of water flow in the Subansiri River.

As per the project planning (NHPC), it has been assured that at least 240 Cumec water will always be available for aquatic flora and fauna downstream of proposed Lower Subansiri HEP, which would safeguard aquatic habitat from drying and bringing drastic changes in the local biodiversity. Although, regulated flow of water can never replace a natural flow of river, but can provide adequate supply of water to sustain minimum requirement needed for aquatic biodiversity.

7.4.9 Impacts on Dolphins

There has been a few studies on the Gangetic Dolphin *(Platanista gangetica gangetica)* in Brahmaputra and Subansiri Rivers (Wakid, 2009[57]; Baruah *et al*., 2012[58];) which reported presence of Dolphins in Subansiri River mainly confined to 100-110 km upstream of the confluence (Baruah *et al*, 2012). They attributed absence of dolphins in the first 20 km stretch below proposed Subansiri HEP **due to rocky nature of the riverbed and harsh riverine conditions** because of transported debris from the site. It makes the river water murky and degrades the habitat (Baruah *et al.* 2012), whereas, they also added that dolphins prefer deeper pools of the Subansiri River as natural habitats. The major issue is to maintain the constant source of water flow for sustainability of dolphin and other aquatic biodiversity downstream, which can be addressed by maintaining minimum average flow discharge to the tune of 240 cumec atleast on constant perennial basis. There has been no confirmed reports which suggest presence of Dolphins in upstream of Lower Subansiri HEP, whereas they are an important species needing attention for conservation in Subansiri River below Lower Subansiri downstream till confluence with Brahmaputra River in Assam.

[57] Wakid, A. (2009): Status and distribution of the endangered Gangetic dolphin (Platanista gangetica gangetica) in Brahmaputra River within India in 2005. Current Science, Vol. 97, No. 8. Pp 1143-1151.

[58] Baruah et al. (2012) A grave danger for the Ganges dolphin (Platanista gangetica Roxburgh) in the Subansiri River due to a large hydroelectric project, Environmentalist (2012) 32:85–90

Ecological Requirement of Gangetic River Dolphin for sustenance in River Subansiri

The Gangetic dolphin (*Platanista gangetica*), is one of the important flagship species of Gangetic riverine ecosystem in northern India and is one of the four freshwater dolphins in the world, facing extinction, and included as Schedule-I animal in the Wildlife (Protection) Act-1972. It has been recognized as Endangered by IUCN Red List of threatened species and listed in Appendix I of CITES. The Ganges River dolphin has been notified as the national aquatic animal by government of India and also state aquatic animal in Assam since 2008, when their population was estimated to be around 2000 individuals in Ganges and Brahmaputra River systems in India. Locally called a souns or susu in Hindi, it is distributed along Ganges, Brahmaputra, Karnali-Sangu and Meghna River systems and their tributaries in foothills of Himalayas. Their existing population is fragmented as earlier these were found in large numbers and now their estimated population is approximately 2000 individuals found in India, where as in Brahmaputra alone it is estimated to be nearly 250-400 individuals.

Various studies showed best estimate of 250 dolphins in Brahmaputra River system with 197 in Brahmaputra mainstream, 27 dolphins in Kulsi River and 26 in Subansiri River. Out of the 197 dolphins in Brahmaputra mainstream, 21 dolphins were recorded in Assam-Arunachal Border to Balijan, 16 dolphins from Balijan to Dikhowmukh, 28 dolphins in between Dikhowmukh to Dhansirimukh, 40 dolphins in between Dhansirimukh to Gabhorumukh, 16 dolphins from Gabhorumukh to Guwahati, 29 dolphins from Guwahati to Pancharatna and 47 dolphins were recorded in between Pancharatna to India-Bangladesh border (Wakid, 2009). Other studies recorded estimate of 264 dolphins in the same stretches of Brahmaputra River system with 212 dolphins in the Brahmaputra mainstream, 29 in Kulsi River and 23 in Subansiri River Wakid and Braulik (2009)[59]. Out of recorded 212 dolphins in Brahmaputra mainstream, a best estimate of 25 dolphins were recorded in the Brahmaputra River stretch from Tengapanimukh-Oiramghat (Assam - Arunachal Pradesh border) to Balijan, 22 dolphins from Balijan to Dikhowmukh, 28 dolphins from Dikhowmukh to Dhansirimukh, 42 dolphins from Dhansirimukh to Tezpur, 24 dolphins from Tezpur to Guwahati, 36 dolphins from Guwahati to Jugighopa and 35 dolphins from Jugighopa to Dhubri.

The ecological requirement of Gangetic River Dolphin for sustenance in River Subansiri is adequate water availability throughout the year to sustain its habitat. As per various studies, currently Dolphins are mainly confined to 100-110 km upstream of the confluence of Brahmaputra in Subansiri River, which is 20 km below the proposed Subansiri HEP. The dolphins prefer deeper pools of the River Subansiri as natural habitats, which are available downstream. The species need constant source of water flow for sustainability of its habitat and other aquatic biodiversity downstream, which required maintaining minimum average flow discharge to the tune of 240 cumec on constant basis throughout the year. There have been no confirmed reports which suggest presence of Dolphins in upstream of Lower Subansiri HEP as checked through various publications and discussions with fishermen. Certainly Dolphin needs special attention for conservation in Subansiri River below Lower Subansiri downstream till confluence with Brahmaputra River in Assam, which is possible be maintaining the continuous water flow discharge and maintaining the sufficient aquatic flow discharge on

[59] Wakid, A. and Braulik, G. (2009): Protection of endangered Ganges river dolphin in Brahmaputra River. Final Technical Report submitted to IUCN-Sir Peter Scott Fund, 44 pp.

downstream of all proposed HEPs on upper Subansiri River that there is no shortage of water ultimately at Lower Subansiri.

Following are the major ecological requirements of Gangetic Dolphin in context to Subansiri:

1. A constant source of aquatic flow discharge to maintain the critical water flow to the tune of 240 Cumec at all the time on continuous basis to provide protection to its habitat and conservation of aquatic biodiversity. This is crucial as all proposed dams upstream needs to maintain proper aquatic flow discharge to ensure availability of this much of water downstream of Lower Subansiri at all times to accord protection to aquatic ecosystem.
2. Availability of water depth/cover of at least minimum of 3 meter (Biswas et al, 1997) during lean season for Gangetic Dolphin habitat especially 10 km downstream of lower Subansiri proposed HEP for maintaining its ecological activities and sustenance of aquatic ecosystem. A few studies showed maximum sightings of Gangetic Dolphins in Brahmaputra in the depth range of 4.1-6.0m (Wakid A., 2009)
3. Availability of sufficient water and totally avoid water removal in the river which can bring dramatic changes in flow regime causing harm to its ecosystem.
4. Availability of fishes and other biodiversity components in its habitat, on which Gangetic Dolphins forage.
5. Ensure protection to the species and its habitat from illegal fishing, human disturbances, population fragmentation etc.

7.4.10 Findings of the Aquatic Study

The distribution of fishes in Arunachal Pradesh can be mainly attributed to altitude and topology. The higher elevations generally support cold water fishes and the foot hills region and mid elevations comprises of fishes which are economically important, Arunachal Pradesh is rich in high altitude fish species like *Tor putitora, Tor tor, Schizothorax richardsonii, Barilius barna, B. bendelisis, Labeo dero, Garra gotyla gotyla, Psilorhynchus balitora, Nemacheilus botia botia, Xenentodon cancila, Channa punctatus, Mastacembelus armatus, Badis badis,* etc. Though there are no regular fish landing centres, fishes are caught with the help of long line, cast nets and traps from different streams and nullahs (drains) in the area. Construction of dams may affect habitat of fish fauna and their natural breeding grounds. The movement of some migratory fish species may be obstructed and cause depletion of important sport fish like Mahaseer.

With the completion of proposed dams, the flow in the downstream stretch of the river would be reduced considerably more so during the lean period. The most important changes that can be expected are:

- Reduced flow rate
- Increase in water temperature
- Reduction in availability of stenothermal aquatic animals i.e. animals which can adapt to only small temperature range.
- Increase in population of eurythermal species. i.e. species which can adapt to a large temperature range.
- Unless the desired flow is maintained downstream of the dam, river stretches at places are subjected to near desiccation.

Certainly, the flow in the downstream stretch of the river will be reduced causing reduction in flow rates as compared to natural flow before dam construction. Also, the reduced flow and quantity of water will have increase in water temperature in river, which may cause outward movement of few stenothermal aquatic animals as they would not be able to adapt to changed temperature regime. The raise in water temperature will encourage inward movement of eurythermal species as they get favourable habitat. Most important thing is maintenance of desired flow at the downstream of all proposed dams in the river stretch all along for sustainability and conservation of aquatic habitat.

The proposed dams may obstruct the migration route of the Mahaseer species, which can be termed as one of the major impacts. The Mahaseer species undertake upstream migration in River Subansiri during summer and monsoon months for feeding and breeding. As the winter sets in the upper reaches, the species takes a downstream journey as far as up to its confluence with River Brahmaputra. In addition certain species of *Schizothorax* (Snow trout) also undertake migration from upper reaches during winter months. This fish species breeds in the lower reaches.

Amongst the aquatic animals, it is the fish life that would be most affected. The migratory fish species, e.g. Mahseers and snow trouts are likely to be adversely affected due to obstruction created by the proposed dams. The Mahseers (*Tor tor, T. putitora* and *Acrossocheillus hexagonolepis)* migrate from warm water to the upstream sometime in April-May for breeding and feeding purposes. The fish remains upstream much beyond Gerukamukh, Lower Subansiri, till optimal conditions are met for breeding during the months of August-September. The wide stretches of River Subansiri in the project area have deeper pools. A shallower area with gravel substratum is one of the essential requirements for spawning of Mahaseers. This situation is likely to change, once the dam is constructed. As a result of obstruction in the migratory route due to the construction of the dam, the Mahseers are likely to congregate below the wall of the dam. For mature fish, upstream migration would not be feasible. This is certainly going to be the major adverse impact of the project.

The snow trouts, *Schizothorax richardsonii, Schizopyge progastus* and *S.esocinus,* which are autochthonous of cold water, are observed in River Subansiri. They undertake migration downstream as low as near its confluence with the Brahmaputra during prolonged winter months. These species remain in the lower reaches till the onset of summer. Like Mahseers, snow trouts too undertake migration in search of suitable breeding and feeding grounds.

Fisheries are not well developed in the project area, and there are no fish landing centers in the project area. It is observed that no large-scale fishing activities are being practiced in the area.

The creation of reservoir is generally beneficial to non-migratory fish species. Local fish population adapt better to the pronounced changes in the abiotic habitat than the biotic. In the latter situation, management measures have to be designed to adjust fish stocks to the changed condition[60].

Further, aquatic ecosystem is greatly regulated by its physical surroundings; therefore, any changes in the physico-chemical profile of the water affect the biota exist therein. Low values of primary production have been noted when the transparency of water was more and vice versa. The transparency is affected mainly due to phytoplankton

[60] *Environment Impact Assessment and Environment Management Plan for Subansiri Lower Project, Arunachal Pradesh and Assam (2000 MW), NHPC/WAPCOS, Gurgaon*

population as the phytoplankton count was low in almost all the sampling sites, it resulted in low Primary production. Temperature of the ecosystem also seems to have great influence in regulating the primary production in freshwater ecosystem. During the survey, the Primary production was seen increasing and decreasing with the increase and decrease of surface water temperatures.

During the present investigation the plankton population was found to be low in the river. The population of phytoplankton was found dominating to that of zooplankton. Phytoplankton group consisting of Chlorophyceae, Myxophyceae and Bacillariophyceae as a whole dominated over zooplankton consisting of Copepod, *Turbellaria Cladocera*, Rotifera and Ostracoda. The dominant phytoplankton group was Chlorophyceae. This may be due to the fact that water temperature range (16-20º) during the pre-monsoon season appears to be optimum for the growth of Chlorophyceae. High atmospheric and water temperature along with bright sunshine are important factors influencing periodicity of Chlorophyceae. Myxophyceae were found to be the second group dominating the phytoplankton community after Chlorophyceae. Only two genera of Bacillariophyceae have been recorded during the study period. Copepods, Turbellaria, Cladocera, Rotifer, Ostracoda were the groups representing the Zooplankton community. The water temperature was low during the sampling period which resulted in low count of Zooplankton. It may be noted that water temperature is the most important controlling factor in the production of Zooplankton.

In fast flowing water (lotic) such as the upland streams, the bed consists of large rocks and stones and the stream is heavily shaded. The influence of vegetation is very high. This provides food supply for largely collectors and shredders. Aquatic plants, particularly rushes and sedges, provide a surface, on which macro-invertebrates can live.

Low values of primary production have been noted in the primary survey. Macro-invertebrates plays a significant role within the food chain, as they are the source of food for large fish. Macro-invertebrates are sensitive to different chemicals and physical conditions, any changes in the water quality, perhaps because of a pollutant entering the water, or a change in the flow downstream of a dam, the macro-invertebrate community also changes. During the survey most of the sampling site was devoid of macrophytes and aquatic vegetation which might have resulted in the poor distribution of macro invertebrates. These factors may have impacts on fisheries resources which could be intensified owing to change in the free flowing regime of water in view of the cascade development of HEPs, more so for migratory species.

Biological and habitat characteristics of migratory fish species reported in Subansiri basin and the data on depth range indicate that *Tor* spp. (Mahaseer) is found in the depth range of 0-1 metre. Further, as snow trout is local migratory species, successful migration depends upon adequate water depth and flow velocity. Large fish like mahaseer during upstream migration need a water depth of at least 0.51 m and can tolerate a flow velocity of up to 1.4 m/s, whereas snow trout need a water depth of 0.3 – 0.4 m and a maximum water velocity of 1.2 m/s. Spawning habitat is increased when the stream flow is high enough to cover suitable gravels but is decreased when velocity becomes too high for successful spawning activities.

Photographs

Commonly used fishing net in Subansiri River

Throwing of Cast Net for fish catch in Subansiri River

Fish caught in a gill-net

Assorted fish catch through Gill Net

Aquatic parameter collection, analysis and documentation

Plankton collection by the aquatic team

Small fishes caught by fishermen for their local consumption

Snow trout *Schizothorax richardsonii* caught in Subansiri River

Chapter 8: Assessment of Environmental Flows

8.0 Introduction

Assessment of environmental flow is one of the important aspects in the cascade development of hydro power projects in a river basin. This flow should be ensured immediately downstream of the diversion structure in all seasons to sustain the ecology and environment of the river. Since, Ecological systems supported by rivers are diverse & complicated, they require comprehensive environmental flow regimes to be defined. Literature cites that "Environmental flow regime" means a schedule of flow quantities that reflects seasonal fluctuations and should be adequate to support a sound ecological environment to maintain productivity, extent, and persistence of key aquatic habitats in, along & around the affected water bodies. In a cascade development of hydro power projects, the most critical stretch for assessing release of environmental flow is immediately downstream of diversion structure till first significant tributary meets river. The following sections describe current norms being followed in India, assessment methodologies adopted globally, methodology adopted in the current study & its findings.

8.1 Current Norms Being Followed for Environmental Flow

Currently, there are no norms for minimum environmental flow releases to be maintained in rivers in all seasons in India. Expert Appraisal Committee (EAC) for River Valley and Hydroelectric Projects of Ministry of Environment & Forests (MOEF) recommends minimum environmental flow during lean season as 20% of the average discharge in four leanest months in 90% dependable year of the water availability series used to design the project. EAC is also recommending releases for monsoon months to be maintained as 30% of flows in monsoon months of 90% dependable year and 20-30% for non-lean and non-monsoon months.

8.2 Description of Various Methodologies & Methodology adopted for Environmental Flow Assessment

Literature review cites that there are four types of environmental flow assessment methodology: (1) hydrological, (2) hydraulic rating, (3) habitat simulation and (4) holistic methodologies; among other techniques generally applied during Environment Flow Assessment. A brief description of these methodologies & their application is given in Chapter 5.

In this study, a combination of hydraulic rating methodologies and elements of habitat simulations have been used. The primary reason for applying this method is its objectivity, availability of data including surveyed river cross-sections and limited timeframe available for the study.

Hydrological Methods have not been used though these provide a relatively rapid, non-resource intensive, but give low resolution estimate of environmental flows. They have been found to be usefully applicable at the planning level for preliminary estimates.

Among holistic methods Building Block Method (BBM) has not been used because:

(i) It is essentially a prescriptive approach, designed to construct a flow regime for maintaining a river in a predetermined condition. It requires detailed data from different sectors including provision of consultation among the experts and stakeholders.

(ii) It addresses the health (structure and functioning) of all components of the riverine ecosystem, rather than focusing on selected group or species.

In context of Subansiri basin study, the major stakeholder is only riverine ecology and fish. Hence adopting such rigorous exercise carrying both the above aspects is not practical within a limited time frame and resources.

Environmental flow regime has been worked out keeping annual occurrence of following main seasons in this region. These are:

(a) Season I: This season is considered as low or lean or dry flow season which covers the months from December to March
(b) Season II: It is considered as high flow season influenced by monsoon. It covers the months from June to September.
(c) Season III: This season is considered as average flow period, covers the months of April, May and October, November

8.3 Hydro-Power Development Scenario

In all 19 hydro-power projects are planned, of which one project currently exists and one is under construction. Table 4.1 also shows the list of these projects. The cascade configuration of the hydropower projects in Subansiri basin and Kurung sub basin are respectively shown in **Figure 8.1 to 8.4**.

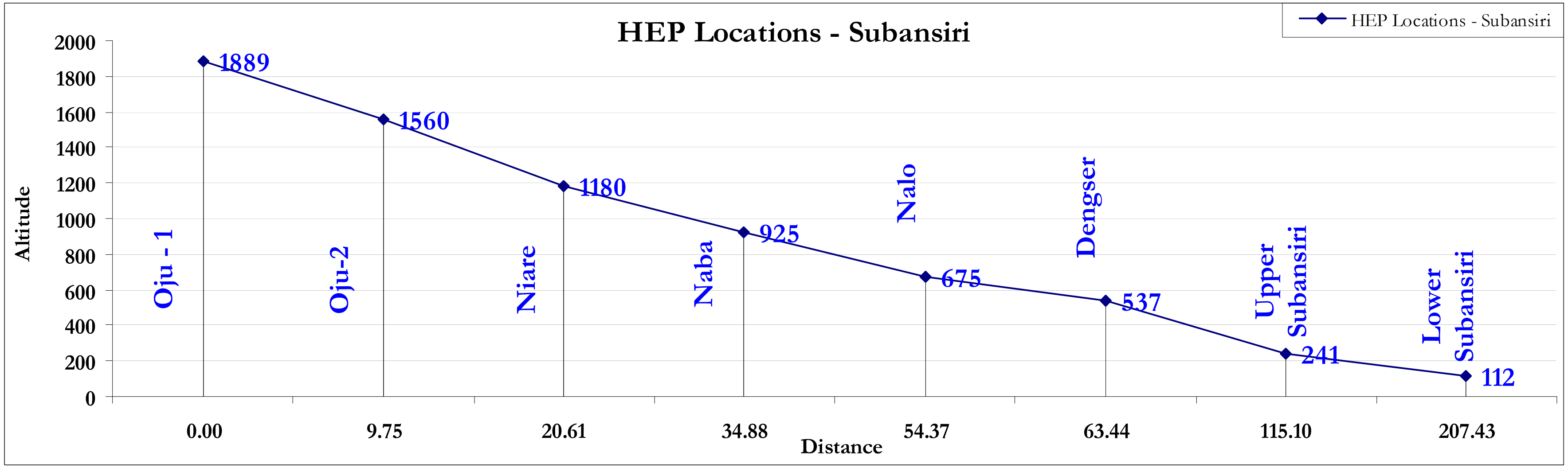

Figure 8.1: Proposed Cascade Development of HEP on Main Stem of Subansiri

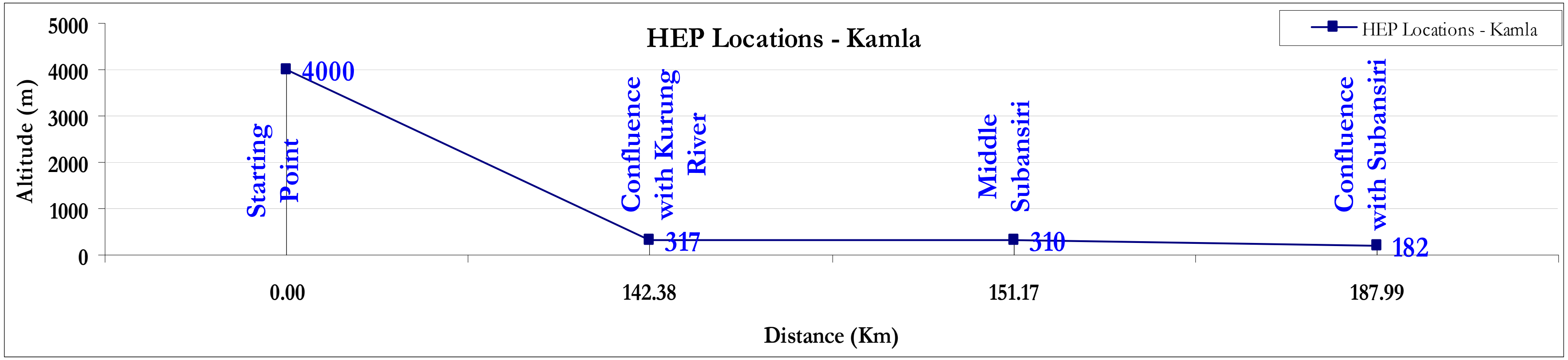

Figure 8.2: Proposed Cascade Development of HEP on Kamla River

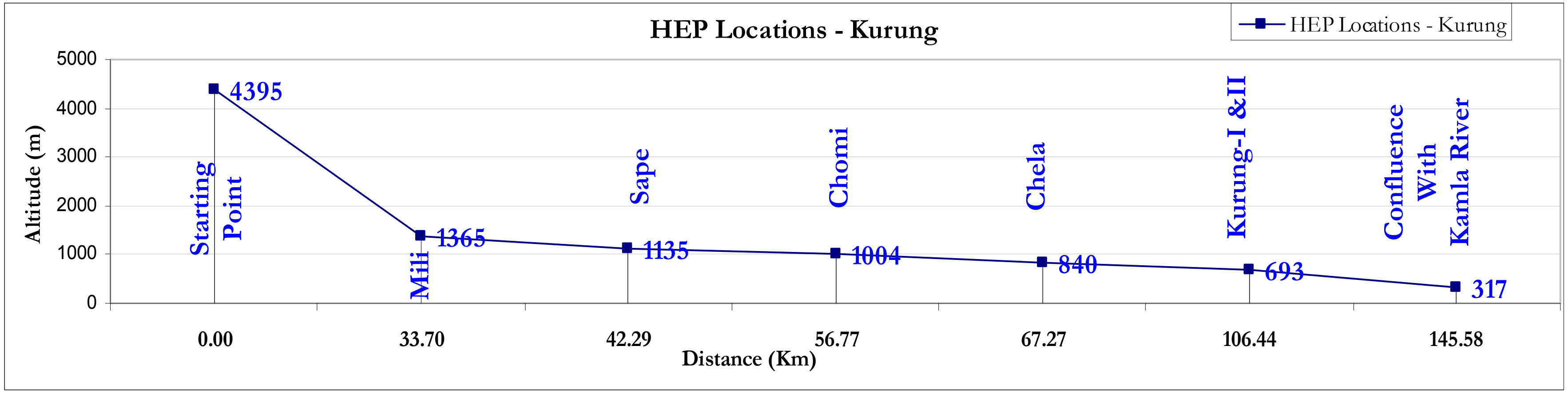

Figure 8.3: Proposed Cascade Development of HEP on Kurung River

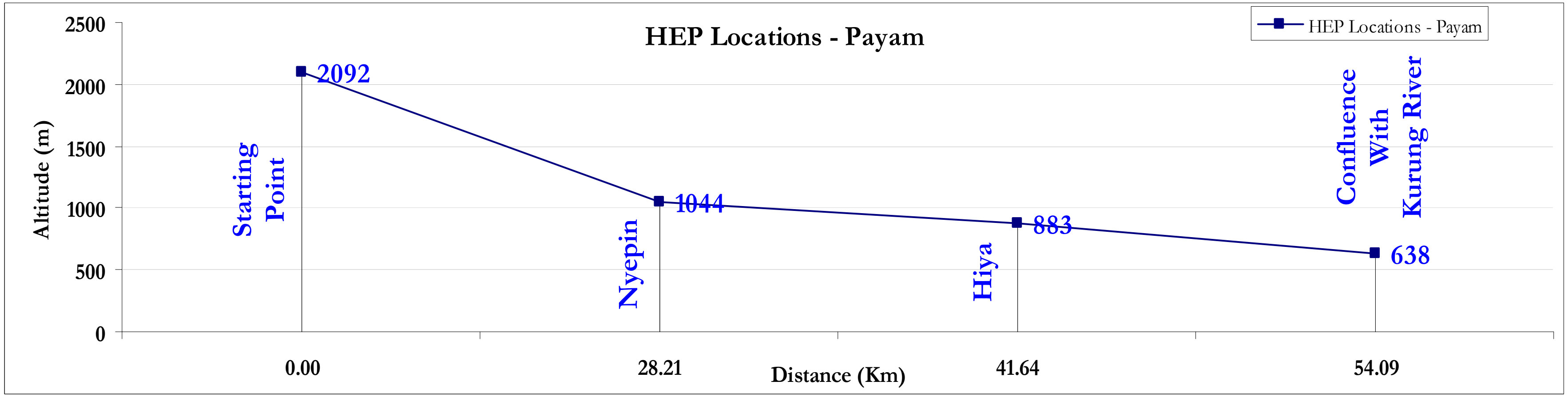

Figure 8.4: Proposed Cascade Development of HEP on Payam River

8.4 Dependability Analysis

The dependability analysis has been carried out on the basis of water availability series of the projects by arranging the annual flow series in descending order and using Weibull formula. The environmental flow estimate 90% dependable flow at different project sites has been used.

8.5 Modelling Studies for Assessment of Environmental Flows

As per the terms of reference of the present assignment the flow depth, velocity of flow and top flow width are to be estimated for assessing the requirement of environmental flow releases from different projects being planned in Subansiri basin. To assess environmental flow requirements, a flow simulation study has been carried out using one dimensional mathematical model **HEC-RAS version 4.1.0** developed by Hydrologic Engineering Center of U.S. Army Corps of Engineers.

HEC-RAS Model

HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking environment. The system is comprised of a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities. The present version of HEC-RAS system contains three one-dimensional hydraulic components for: **i**) Steady flow surface profile computations; **ii**) quasi-unsteady flow simulation and **iii**) unsteady flow simulation. The steady/unsteady flow components are capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles. The system can handle a full network of channels, a dendric system, or a single river reach. The basic computational procedure is based on the solution of one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/ expansion (coefficient multiplied by the velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied.

The graphics include X-Y plots of the river system schematic, cross-sections, profiles, rating curves, hydrographs, and many other hydraulic variables. Users can select from pre-defined tables or develop their own customized tables. All graphical and tabular output can be displayed on the screen, sent directly to a printer, or passed through the Windows clipboard to other software, such as word processor or spread sheet. Reports can be customized as to the amount and type of information desired.

Input data for developing a Hydraulic Model

The input data required for developing a hydraulic model with HEC-RAS are geometric data, flow data and boundary conditions data. Geometric data is the river cross section, Manning's and length of the study reach. Flow data comprises of discharge values for which profile computations are to be performed. Boundary condition data consist of upstream and downstream boundaries of model set up. The upstream boundary is generally the time series of discharge. The downstream boundary may be stage-discharge relationship (Rating curve), known water surface, normal depth etc. For the present study following input data has been used.

Geometric data (River cross sections)

The critical reach of river for any hydro electric project is the river reach between dam site and TRT outfall of the project due to diversion of flow from the intake of the project. In this reach of the river, there may be number of small Nalla joining the main river. Hence, the most critical river reach for estimating the environmental flow release is the reach of river from the dam site of the project till the confluence of first major Nalla/stream. In this reach of a river the available discharge will be only the environmental flow release from the respective hydroelectric project. This reach of the river for each project has been represented in hydraulic model set up with HEC-RAS through a close grid of river cross sections.

Flow considered

As per the terms of reference of the present assignment the flow depth, velocity of flow and top flow width are estimated for assessing the requirement of environmental flow releases from different projects being planned in Subansiri basin. It is proposed to model the following flow scenarios for environmental flow considerations:

The flow scenario of 90% dependable year series of the each hydro electric project was used and the average discharge of leanest four months, monsoon four months and non lean non monsoon four months have been computed. The flow parameters i.e. water depth, velocity of flow and top flow width has been assessed through hydro dynamic simulation for 10%, 15%, 20%, 30%, 40%, 50% and 100% release of respective average of the three season’s flows of each hydroelectric project to estimate the environmental flow release during the lean, monsoon and non lean non monsoon periods. The portion of river reach between dam site and TRT outfall up to its confluence with first stream has been represented in the model set up by a number of cross sections as this reach will be most critical reach from Environmental flow point of view.

8.6 River Cross Sections

Environmental flow assessment is carried out for the stretch of river, which starts downstream of diversion structure and up to the tailrace channel outfall point; generally termed as intermediate stretch between dam and powerhouse. For each project this stretch is calculated. Out of this stretch initial 1-2 Km or the length up to which first major tributary meets the river is considered critical as for the rest of the stretch, tributary will add to the environment flow released from the diversion structure. Therefore, modelling exercise to work out the environment flow to meet the habitat requirement for the initial critical stretch hold good for the rest of the river has been done. Keeping this in view, 8-10 cross sections were taken immediate downstream of the diversion structure for each project and used in the modelling exercise. These sections have been represented in HEC-RAS model set up. Typical model set up showing locations of river cross sections and actual surveyed river cross sections have been shown in **Figure 8.5.**

Table 8.1: Flow series of 90% dependable year of Projects

Unit: Cumec

90% dependable Year		1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	2006-07	Synthetic Series	1981-82	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07
Months		Oju-I (CA-9827 sq.km)	Oju-II (CA-9979 sq. km)	Niare (CA-11181 sq.km)	Naba (CA-11272 sq.km)	Nalo (CA-12150 sq.km)	Dengser CA-12581 sq.km)	Subansiri Upper (CA-14665 sq.km)	Tammu (CA-952 sq.km)	Subansiri Lower	Subansiri Middle (CA-7213 sq.km)	Kurang-I & II (CA-2680 sq.km)	Mili (CA-723 sq.km)	Sape (CA-990 sq.km)	Chomi (CA-1335 sq.km)	Chela (CA-1446 sq.km)	Nyepin (CA-318 sq.km)	Hiya (CA-607 sq.km)
June	I	290.13	296.15	338.20	341.88	377.04	394.41	478.36	163.33	1484.56	1237.47	459.78	124.04	169.85	204.84	248.08	54.56	104.14
	II	291.94	298.01	340.32	344.02	379.40	396.88	481.36	205.80	1505.55	1559.3	579.36	156.30	214.02	258.12	312.60	68.74	131.22
	III	487.09	497.21	567.81	573.99	633.02	662.17	803.12	154.87	2692.18	1173.38	435.97	117.61	161.05	194.23	235.23	51.73	98.74
July	I	725.67	740.75	845.92	855.13	943.07	986.50	1196.49	146.21	2315.28	1107.79	411.6	111.04	152.05	183.38	222.08	48.84	93.22
	II	863.46	881.4	1006.54	1017.50	1122.14	1173.82	1423.68	155.55	3082.95	1178.58	437.9	118.14	161.76	195.10	236.27	51.96	99.18
	III	606.68	619.29	707.22	714.92	788.44	824.75	1000.31	111.02	2447.4	841.18	312.54	84.32	115.45	139.24	168.63	37.09	70.79
August	I	412.89	421.47	481.31	486.55	536.59	561.30	680.78	73.03	3405.57	553.29	205.58	55.46	75.94	91.59	110.92	24.39	46.56
	II	359.71	367.18	419.31	423.88	467.47	489.00	593.09	56.08	4408.61	424.92	157.88	42.59	58.32	70.34	85.18	18.73	35.76
	III	474.82	484.68	553.50	559.53	617.07	645.49	782.89	144.51	3059.18	1094.91	406.82	109.75	150.28	181.25	219.50	48.27	92.14
Sept	I	423.55	432.35	493.73	499.11	550.44	575.79	698.35	111.09	1726.11	841.68	312.73	84.37	115.52	139.33	168.73	37.11	70.83
	II	359.71	367.18	419.31	423.88	467.47	489.00	593.09	185.47	1635.85	1405.25	522.12	140.86	192.87	232.62	281.71	61.95	118.26
	III	304.48	310.8	354.93	358.79	395.69	413.92	502.02	92.49	1370.38	700.78	260.38	70.24	96.18	116.00	140.49	30.9	58.97
Oct	I	349.24	356.49	407.11	411.54	453.86	474.77	575.82	99.28	2250.03	752.2	279.48	75.40	103.24	124.52	150.79	33.16	63.30
	II	205.79	210.07	239.90	242.51	267.45	279.76	339.31	88.85	1106.97	673.17	250.12	67.48	92.39	111.43	134.95	29.68	56.65
	III	141.18	144.11	164.57	166.36	183.47	191.92	232.77	55.04	988.83	417.03	154.95	41.80	57.24	69.03	83.60	18.39	35.09
Nov	I	100.27	102.35	116.88	118.16	130.31	136.31	165.32	43.67	777.53	330.91	122.95	33.17	45.42	54.78	66.34	14.59	27.85
	II	78.9	80.54	91.97	92.98	102.54	107.26	130.09	38.80	739.28	293.99	109.23	29.47	40.35	48.67	58.94	12.96	24.74
	III	65.38	66.74	76.22	77.05	84.97	88.89	107.8	40.31	538.4	305.44	113.49	30.62	41.92	50.56	61.23	13.47	25.70
Dec	I	51.61	52.69	60.17	60.82	67.08	70.17	85.1	35.76	400.15	270.92	100.66	27.16	37.18	44.85	54.31	11.94	22.80
	II	44.34	45.26	51.68	52.25	57.62	60.27	73.1	33.38	410.23	252.92	93.97	25.35	34.71	41.87	50.70	11.15	21.28
	III	47.36	48.34	55.20	55.80	61.54	64.38	78.08	26.44	393.49	200.32	74.43	20.08	27.49	33.16	40.16	8.83	16.86
Jan	I	38.85	39.66	45.29	45.79	50.49	52.82	64.06	25.16	315.89	190.62	70.83	19.11	26.16	31.55	38.21	8.4	16.04

																	Unit:	Cumec
90% dependable Year		1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	2006-07	Synthetic Series	1981-82	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07
Months		Oju-I (CA-9827 sq.km)	Oju-II (CA-9979 sq. km)	Niare (CA-11181 sq.km)	Naba (CA-11272 sq.km)	Nalo (CA-12150 sq.km)	Dengser CA-12581 sq.km)	Subansiri Upper (CA-14665 sq.km)	Tammu (CA-952 sq.km)	Subansiri Lower	Subansiri Middle (CA-7213 sq.km)	Kurang-I & II (CA-2680 sq.km)	Mili (CA-723 sq.km)	Sape (CA-990 sq.km)	Chomi (CA-1335 sq.km)	Chela (CA-1446 sq.km)	Nyepin (CA-318 sq.km)	Hiya (CA-607 sq.km)
	II	38.42	39.22	44.79	45.27	49.93	52.23	63.35	24.76	260.82	187.62	69.71	18.81	25.75	31.06	37.61	8.27	15.79
	III	40.99	41.84	47.78	48.30	53.27	55.72	67.58	23.70	241.33	179.53	66.7	18.00	24.64	29.72	35.99	7.91	15.11
Feb	I	38.78	39.58	45.20	45.69	50.39	52.71	63.93	27.65	328.8	209.52	77.85	21.00	28.76	34.68	42.00	9.24	17.63
	II	46.26	47.23	53.93	54.52	60.13	62.89	76.28	28.25	272.99	214.07	79.54	21.46	29.38	35.44	42.91	9.44	18.01
	III	41.61	42.48	48.51	49.03	54.08	56.57	68.61	29.43	340.35	222.96	82.84	22.35	30.60	36.91	44.70	9.83	18.76
March	I	53.68	54.79	62.57	63.25	69.76	72.97	88.5	40.65	502.41	308	114.44	30.87	42.27	50.98	61.75	13.58	25.92
	II	92.24	94.16	107.53	108.70	119.88	125.40	152.09	43.89	733.12	332.54	123.56	33.33	45.64	55.05	66.66	14.66	27.98
	III	147.86	150.93	172.36	174.23	192.15	201.00	243.78	45.52	604.08	344.92	128.16	34.57	47.34	57.10	69.15	15.21	29.03
April	I	110.2	112.49	128.46	129.86	143.22	149.81	181.7	68.40	734.85	518.27	192.56	51.95	71.13	85.79	103.90	22.85	43.61
	II	128.63	131.3	149.94	151.57	167.16	174.86	212.08	67.00	967.02	507.65	188.62	50.88	69.68	84.03	101.77	22.38	42.72
	III	159.72	163.04	186.19	188.22	207.57	217.13	263.35	115.10	922.79	872.04	324.01	87.41	119.69	144.35	174.82	38.45	73.39
May	I	192.85	196.85	224.80	227.25	250.62	262.16	317.97	60.86	1070.87	461.09	171.32	46.22	63.29	76.33	92.44	20.33	38.80
	II	463.77	473.41	540.62	546.51	602.71	630.47	764.67	75.88	1119.67	574.9	213.6	57.63	78.91	95.17	115.25	25.35	48.38
	III	205.47	209.74	239.52	242.12	267.03	279.32	338.78	117.05	1273.96	886.87	329.52	88.90	121.72	146.81	177.79	39.1	74.63

																Unit: Cumec
90% dependable Year	1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	1981-82	2006-07	1981-82	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07	2006-07
Months	Oju-I (CA-9827 sq.km)	Oju-II (CA-9979 sq. km)	Niare (CA-11181 sq.km)	Naba (CA-11272 sq.km)	Nalo (CA-12150 sq.km)	Dengser CA-12581 sq.km)	Subansiri Upper (CA-14665 sq.km)	Tammu (CA-952 sq.km)	Subansiri Middle (CA-7213 sq.km)	Kurang-I & II (CA-2680 sq.km)	Mili (CA-723 sq.km)	Sape (CA-990 sq.km)	Chomi (CA-1335 sq.km)	Chela (CA-1446 sq.km)	Nyepin (CA-318 sq.km)	Hiya (CA-607 sq.km)
Monsoon Discharge																
Mon-Avg-Jun to Sep-cumec	466.68	476.37	544.01	549.93	606.49	634.42	769.46	133.29	1009.88	410.92	101.23	138.61	167.17	202.45	44.52	84.98
10 % of avg -cumec	46.67	47.64	54.40	54.99	60.65	63.44	76.95	13.33	100.99	41.09	10.12	13.86	16.72	20.25	4.45	8.50
15 % of avg -cumec	70	71.46	81.60	82.49	90.97	95.16	115.42	19.99	151.48	61.64	15.18	20.79	25.08	30.37	6.68	12.75
20 % of avg -cumec	93.34	95.27	108.80	109.99	121.30	126.88	153.89	26.66	201.98	82.18	20.25	27.72	33.43	40.49	8.90	17.00
30 % of avg -cumec	140	142.91	163.20	164.98	181.95	190.33	230.84	39.99	302.96	123.28	30.37	41.58	50.15	60.74	13.36	25.50
40 % of avg -cumec	186.67	190.55	217.60	219.97	242.60	253.77	307.78	53.32	403.95	164.37	40.49	55.44	66.87	80.98	17.81	33.99
50 % of avg -cumec	233.34	238.19	272.00	274.97	303.24	317.21	384.73	66.64	504.94	205.46	50.61	69.30	83.58	101.23	22.26	42.49
100 % of avg -cumec	466.68	476.37	544.01	549.93	606.49	634.42	769.46	133.29	1,009.88	410.92	101.23	138.61	167.17	202.45	44.52	84.98
Lean Months Discharge																
Lean-Avg-Nov to Feb-cumec	52.73	53.83	61.47	62.14	68.53	71.68	86.94	31.44	238.24	96.94	23.88	32.70	39.44	47.76	10.50	20.05
10 % of avg -cumec	5.27	5.38	6.15	6.21	6.85	7.17	8.69	3.14	23.82	9.69	2.39	3.27	3.94	4.78	1.05	2.00
15 % of avg -cumec	7.91	8.07	9.22	9.32	10.28	10.75	13.04	4.72	35.74	14.54	3.58	4.90	5.92	7.16	1.58	3.01
20 % of avg -cumec	10.55	10.77	12.29	12.43	13.71	14.34	17.39	6.29	47.65	19.39	4.78	6.54	7.89	9.55	2.10	4.01
30 % of avg -cumec	15.82	16.15	12.29	18.64	20.56	21.51	26.08	9.43	71.47	29.08	7.16	9.81	11.83	14.33	3.15	6.01
40 % of avg -cumec	21.09	21.53	24.59	24.86	27.41	28.67	34.78	12.58	95.29	38.78	9.55	13.08	15.77	19.10	4.20	8.02
50 % of avg -cumec	26.37	26.91	30.73	31.07	34.26	35.84	43.47	15.72	119.12	48.47	11.94	16.35	19.72	23.88	5.25	10.02
100 % of avg -cumec	52.73	53.83	61.47	62.14	68.53	71.68	86.94	31.44	238.24	96.94	23.88	32.70	39.44	47.76	10.50	20.05
Other 4 Months Discharge																
Avg-Oct-March-Apr-May-cumec	187.55	191.45	218.63	221.01	243.74	254.97	309.24	73.13	554.06	225.45	55.54	76.05	91.72	111.07	24.43	46.63
10 % of avg -cumec	18.76	19.14	21.86	22.10	24.37	25.50	30.92	7.31	55.41	22.54	5.55	7.60	9.17	11.11	2.44	4.66
15 % of avg -cumec	28.13	28.72	32.79	33.15	36.56	38.24	46.39	10.97	83.11	33.82	8.33	11.41	13.76	16.66	3.66	6.99
20 % of avg -cumec	37.51	38.29	43.73	44.20	48.75	50.99	61.85	14.63	110.81	45.09	11.11	15.21	18.34	22.21	4.89	9.33
30 % of avg -cumec	56.27	57.43	65.59	66.30	73.12	76.49	92.77	21.94	166.22	67.63	16.66	22.81	27.51	33.32	7.33	13.99
40 % of avg -cumec	75.02	76.58	87.45	88.40	97.50	101.99	123.69	29.25	221.62	90.18	22.21	30.42	36.69	44.43	9.77	18.65
50 % of avg -cumec	93.78	95.72	109.32	110.51	121.87	127.48	154.62	36.56	277.03	112.72	27.77	38.02	45.86	55.54	12.21	23.31
100 % of avg -cumec	187.55	191.45	218.63	221.01	243.74	254.97	309.24	73.13	554.06	225.45	55.54	76.05	91.72	111.07	24.43	46.63

Manning's roughness coefficient

Selection of an appropriate value for Manning's n is very significant to the accuracy of the computed water surface profiles. The value of Manning's n is highly variable and depends on a number of factors including: surface roughness; vegetation; channel irregularities; channel alignment; scour and deposition; obstructions; size and shape of the channel; stage and discharge; seasonal changes; temperature; and suspended material and bedload. HEC-RAS manual suggests the Manning's roughness coefficient for different type of channels as given in **Table 8.2**.

Table 8.2: Value of Manning's roughness coefficient as per HEC-RAS manual

Type of Channel and Description	Minimum	Normal	Maximum
A. Natural Streams			
1. Main Channels			
a. Clean, Straight, full, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. Same as "d" but more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stands of timber and brush	0.070	0.100	0.150
2. Flood Plains			
a. Pasture no brush			
1. Short grass	0.025	0.030	0.035
2.High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
2. Same as above, but heavy sprouts	0.050	0.060	0.080
3. Heavy stand of timber, few down trees, little undergrowth, flow below branches	0.080	0.100	0.120
4. Same as above, but with flow into branches	0.100	0.120	0.160
5. Dense willows, summer, straight	0.110	0.150	0.200
3. Mountain streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged			
a. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. Bottom: cobbles with large boulders	0.040	0.050	0.070

The river reaches in the present study are the mountain streams with steep bank and bed consisting of cobbles and large boulders, where the normal value of Manning's n can be adopted from 0.040 to 0.050. As the depth of water for a constant discharge will be more for a higher value of Manning's n, hence, to get a conservative estimate of water depth the Manning's n will be taken as 0.040.

Flow data used for upstream boundary of hydraulic model

The flow scenario of 90% dependable year series of the each hydro electric project was used and the average discharge of leanest four months, monsoon four months and non lean non monsoon four months were computed. The flow parameters i.e. water depth, velocity of flow and top flow width has been assessed through hydro dynamic simulation for 10%, 15%, 20%, 30%, 40%, 50% and 100% release of respective average of the three season's flows of each hydroelectric project to estimate the environmental flow release during the lean, monsoon and non lean non monsoon periods. The portion of river reach between dam site and TRT outfall up to its confluence with first stream has been represented in the model set up by a number of cross sections as this reach will be most critical reach from Environmental flow point of view.

Hydraulic Model Set up with HEC-RAS

In general the hydraulic model set up for steady flow water surface profile computation with HEC-RAS consist of a river reach and upstream/ downstream boundary. Based on the approach, methodology and input data discussed above, the HEC-RAS model used for steady flow water surface profile computations of Subansiri Upper HE project is shown in **Figure 8.5**. Here, in this case the first stream joins the Subansiri River 1.8 km downstream of the proposed Subansiri upper dam site. The study reach of the river has been taken as 2.1 km so that the downstream boundary can be applied 300 m downstream of the study reach. The 10%, 15%, 20%, 30%, 40%, 50% and 100% release of the average lean, monsoon and other four months discharge in 90% dependable flow series of the project has been used as upstream boundary and applied at the uppermost cross section of the model set up. The downstream boundary has been adopted as normal depth applied at downstream most river cross section of model set up.

Model set up for all other projects have also been carried out in the same way as stated for Subansiri upper HE Project.

Model Results

The release computations and flow parameters i.e. flow depth, flow velocity, flow top width corresponding to different release conditions for the projects in Subansiri basin as computed by hydraulic model set up with HEC-RAS is given at **Table 8.3 to Table 8.17**. The plot of water level corresponding to different releases is shown in **Figure 8.6 to Figure 8.8** at one of the river cross section located about 200 m downstream of Subansiri middle (Kamla) HE project. *This may be noted that notations WS 20%, WS 100% denote water level for 20% and 100% of corresponding average discharge release.*

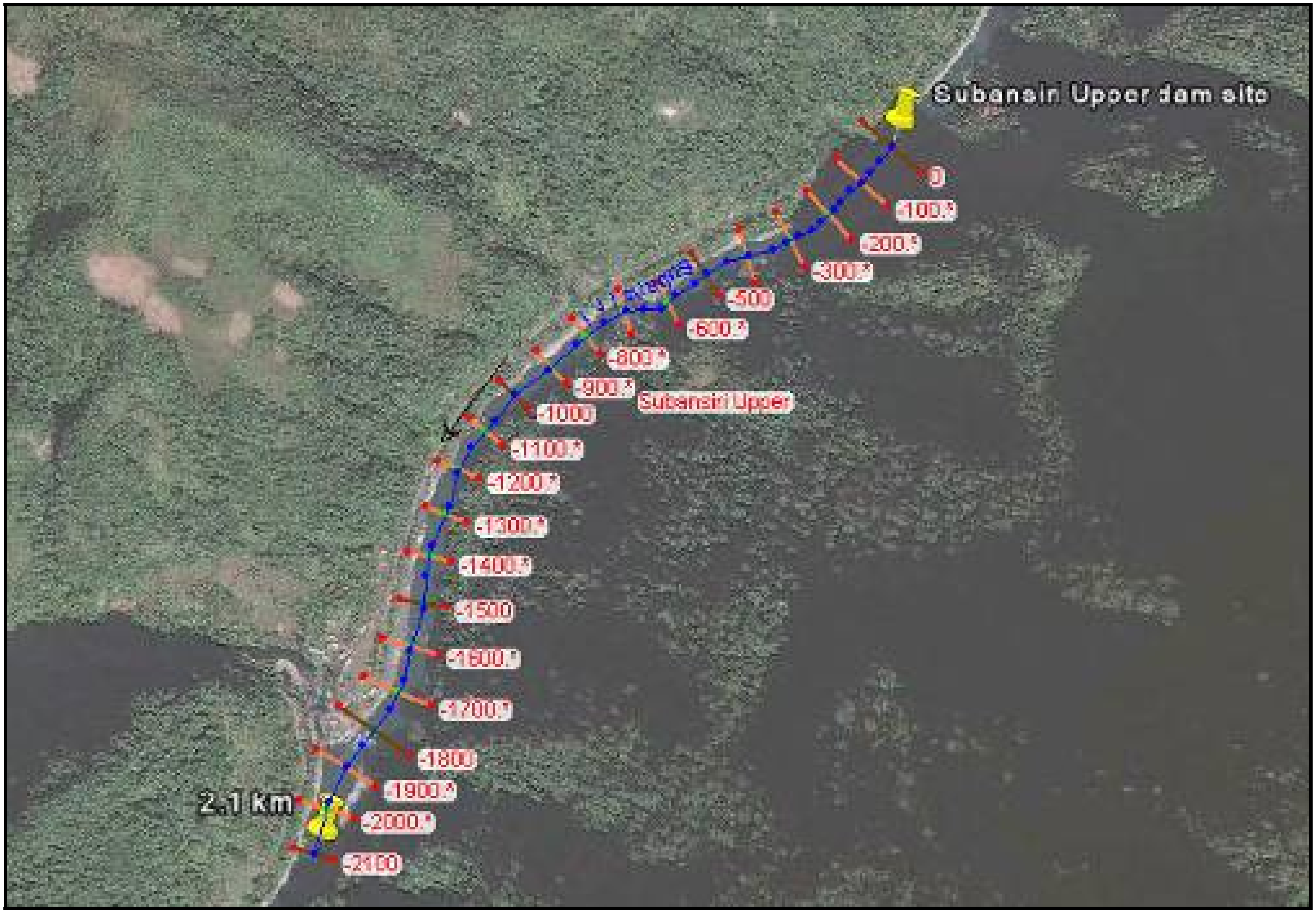

Figure 8.5: HEC-RAS Model set up for flow profile study of Subansiri Upper HE Project (Note: -100, -200 etc shows locations 100 m, 200 m d/s of dam site)

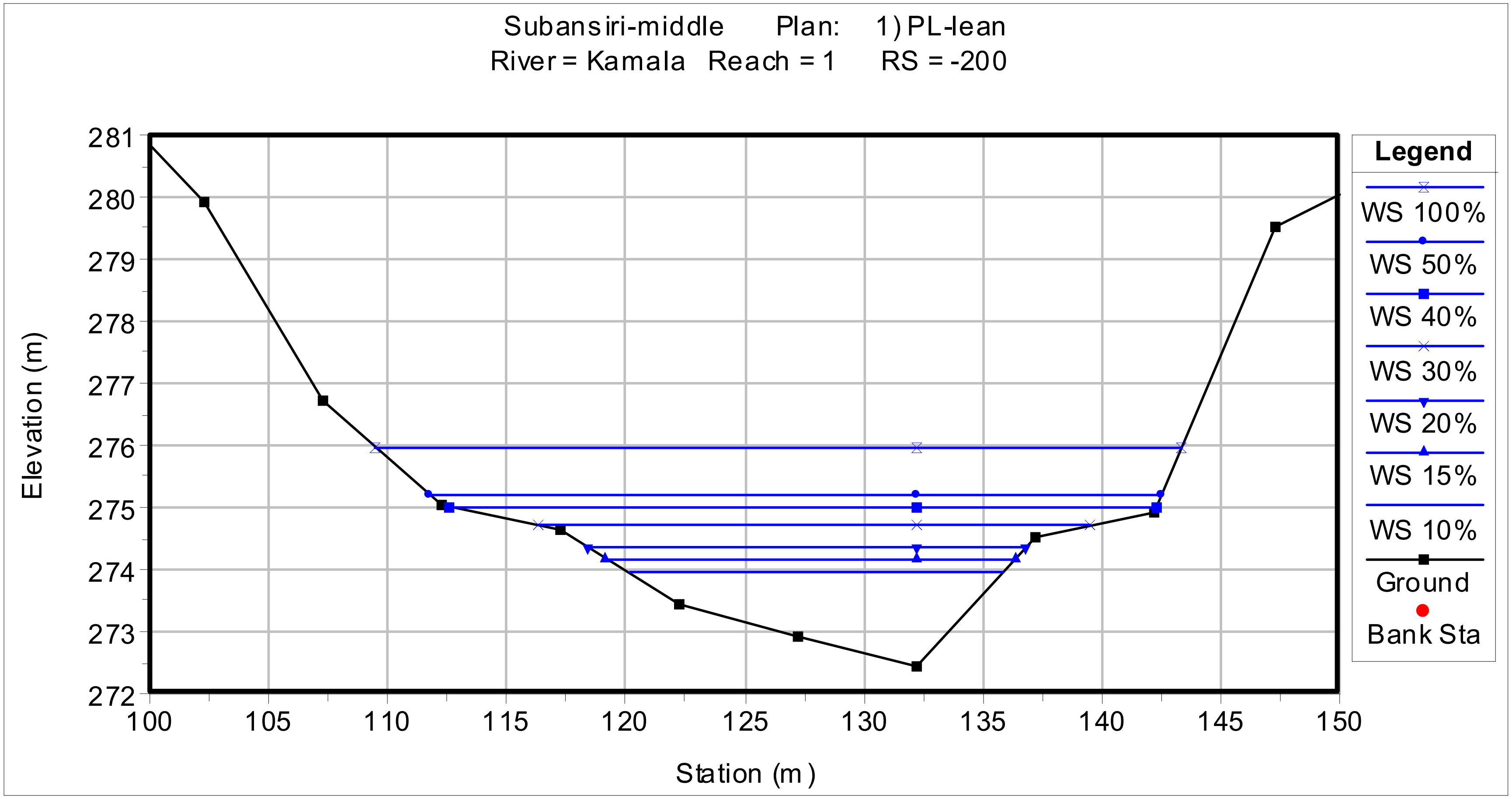

Figure 8.6: River bed profile and water surface profiles in Lean Season

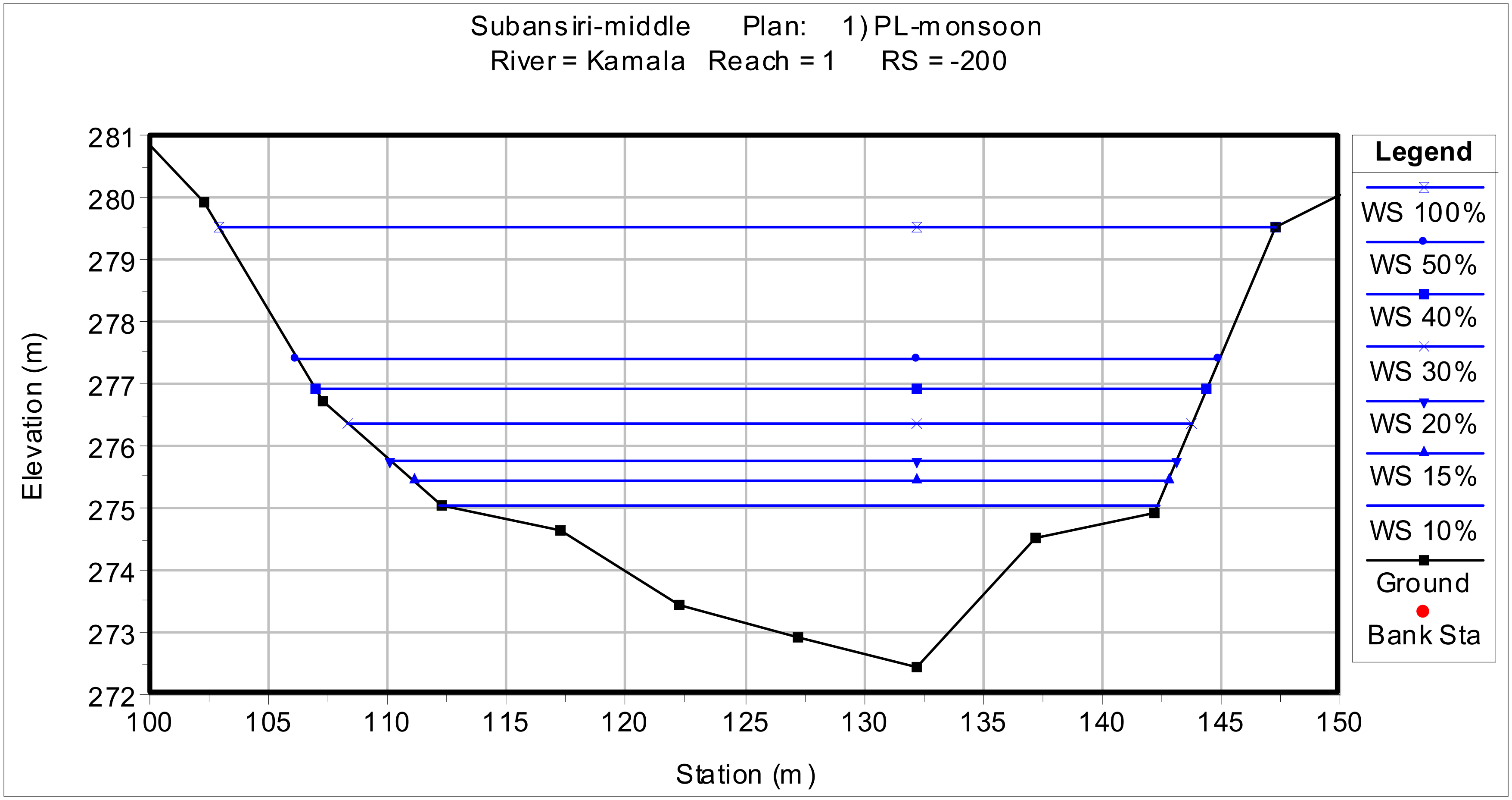

Figure 8.7: River bed profile and water surface profiles in Monsoon Season

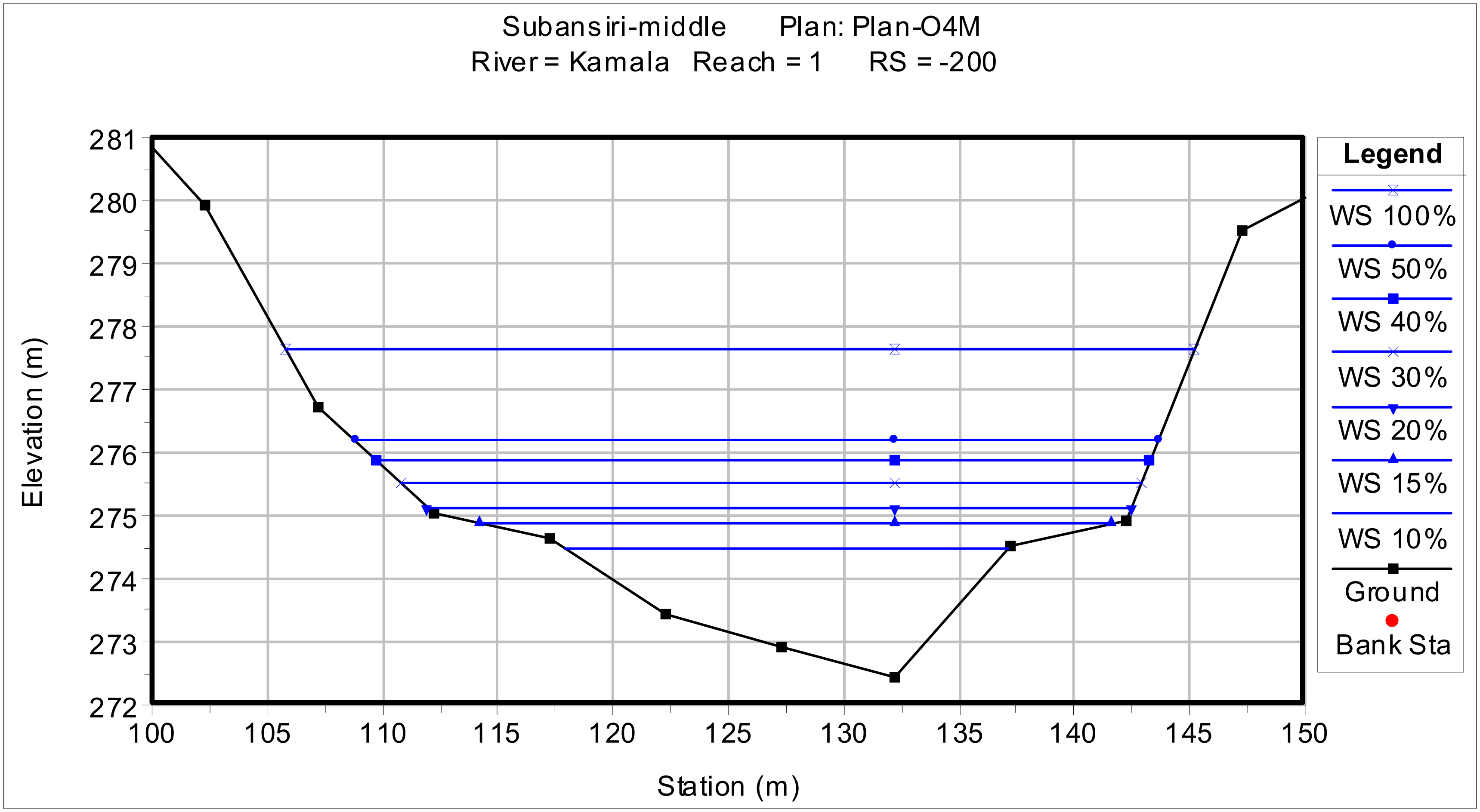

Figure 8.8: River bed profile and water surface profiles in other months

Table8.3: Model Output for Different Release Scenarios for Oju – I HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	1851.08	1852.04	95.89	2.04	5.55
	15% release	1851.08	1852.21	112.67	2.20	6.64
	20% release	1851.08	1852.34	126.11	2.34	7.50
	30% release	1851.08	1852.56	147.33	2.54	8.88
	40% release	1851.08	1852.74	165.33	2.68	10.13
	50% release	1851.08	1852.88	180.11	2.80	11.41
	100% release	1851.08	1853.45	236.89	3.15	15.35
Monsoon (June-Sept)	10% release	1851.08	1853.33	224.67	3.12	14.15
	15% release	1851.08	1853.73	264.78	3.28	18.05
	20% release	1851.08	1854.03	294.33	3.46	20.51
	30% release	1851.08	1854.49	341.11	3.76	23.94
	40% release	1851.08	1854.87	378.33	4.01	26.39
	50% release	1851.08	1855.19	410.89	4.23	28.32
	100% release	1851.08	1856.38	529.56	5.04	34.01
Other Months (Oct, Nov., April, May)	10% release	1851.08	1852.66	157.44	2.63	9.52
	15% release	1851.08	1852.93	185.00	2.83	11.70
	20% release	1851.08	1853.15	206.67	2.99	13.04
	30% release	1851.08	1853.52	243.44	3.17	16.07
	40% release	1851.08	1853.80	271.67	3.32	18.64
	50% release	1851.08	1854.03	294.89	3.47	20.54
	100% release	1851.08	1854.87	379.22	4.01	26.43

Table8.4: Model Output for Different Release Scenarios for Oju – II HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	1567.38	1568.03	64.76	1.50	12.69
	15% release	1567.38	1568.14	75.95	1.64	14.65
	20% release	1567.38	1568.23	85.10	1.75	16.23
	30% release	1567.38	1568.38	99.57	1.92	18.60
	40% release	1567.38	1568.50	111.43	2.06	20.33
	50% release	1567.38	1568.60	121.48	2.17	21.76
	100% release	1567.38	1568.97	159.10	2.59	26.83
Monsoon (June-Sept)	10% release	1567.38	1568.90	151.67	2.51	25.83
	15% release	1567.38	1569.16	177.95	2.78	29.30
	20% release	1567.38	1569.38	199.62	2.99	32.03
	30% release	1567.38	1569.73	235.29	3.30	35.76
	40% release	1567.38	1570.03	265.10	3.54	38.78
	50% release	1567.38	1570.30	291.52	3.72	41.41
	100% release	1567.38	1571.33	394.95	4.34	50.64
Other Months (Oct, Nov., April, May)	10% release	1567.38	1568.45	106.43	2.00	19.60
	15% release	1567.38	1568.63	124.57	2.21	22.19
	20% release	1567.38	1568.77	139.29	2.38	24.21
	30% release	1567.38	1569.01	163.24	2.63	27.37
	40% release	1567.38	1569.21	182.90	2.83	29.96
	50% release	1567.38	1569.38	199.95	2.99	32.06
	100% release	1567.38	1570.04	265.67	3.54	38.84

Table8.5: Model Output for Different Release Scenarios for Niare HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	1200.14	1201.08	93.80	1.88	7.02
	15% release	1200.14	1201.24	110.00	2.07	8.00
	20% release	1200.14	1201.38	123.60	2.21	8.76
	30% release	1200.14	1201.60	145.30	2.44	9.99
	40% release	1200.14	1201.78	163.30	2.61	11.00
	50% release	1200.14	1201.93	178.90	2.75	11.87
	100% release	1200.14	1202.51	237.20	3.24	15.12
Monsoon (June-Sept)	10% release	1200.14	1202.40	225.80	3.15	14.48
	15% release	1200.14	1202.80	266.00	3.47	16.73
	20% release	1200.14	1203.13	298.50	3.73	18.51
	30% release	1200.14	1203.66	351.40	4.13	21.34
	40% release	1200.14	1204.09	394.30	4.44	23.64
	50% release	1200.14	1204.46	431.50	4.69	25.63
	100% release	1200.14	1205.88	573.40	5.55	32.79
Other Months (Oct, Nov., April, May)	10% release	1200.14	1201.70	155.60	2.54	10.58
	15% release	1200.14	1201.98	183.70	2.80	12.14
	20% release	1200.14	1202.21	206.50	2.99	13.42
	30% release	1200.14	1202.58	243.40	3.29	15.47
	40% release	1200.14	1202.88	273.40	3.53	17.14
	50% release	1200.14	1203.13	299.20	3.73	18.54
	100% release	1200.14	1204.10	395.30	4.44	23.68

Table 8.6: Model Output for Different Release Scenarios for Nalo HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	616.62	617.52	89.36	1.61	10.26
	15% release	616.62	617.66	104.16	1.77	11.96
	20% release	616.62	617.78	116.08	1.89	13.35
	30% release	616.62	617.98	135.40	2.08	15.56
	40% release	616.62	618.13	150.92	2.22	17.36
	50% release	616.62	618.26	164.28	2.34	18.90
	100% release	616.62	618.76	214.24	2.74	24.63
Monsoon (June-Sept)	10% release	616.62	618.67	204.52	2.67	23.51
	15% release	616.62	619.01	238.76	2.93	27.44
	20% release	616.62	619.28	266.12	3.13	30.49
	30% release	616.62	619.72	309.68	3.47	34.51
	40% release	616.62	620.07	345.12	3.75	37.39
	50% release	616.62	620.38	375.76	3.98	39.75
	100% release	616.62	621.56	494.28	4.74	49.20
Other Months (Oct, Nov., April, May)	10% release	616.62	618.07	-1.44	2.17	16.60
	15% release	616.62	618.31	-1.69	2.38	19.38
	20% release	616.62	618.50	-1.88	2.54	21.63
	30% release	616.62	618.82	-2.20	2.78	25.25
	40% release	616.62	619.07	-2.45	2.98	28.17
	50% release	616.62	619.29	-2.67	3.14	30.54
	100% release	616.62	620.08	-3.46	3.75	37.43

Table 8.7: Model Output for Different Release Scenarios for Dengser HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	534.53	535.34	81.07	1.39	13.57
	15% release	534.53	535.47	94.14	1.54	15.80
	20% release	534.53	535.58	105.07	1.65	17.59
	30% release	534.53	535.75	122.14	1.82	20.48
	40% release	534.53	535.89	135.86	1.96	22.74
	50% release	534.53	536.00	147.57	2.08	24.49
	100% release	534.53	536.43	190.57	2.51	30.04
Monsoon (June-Sept)	10% release	534.53	536.35	182.07	2.43	29.06
	15% release	534.53	536.65	211.79	2.72	32.45
	20% release	534.53	536.89	236.00	2.96	35.06
	30% release	534.53	537.28	275.21	3.33	38.79
	40% release	534.53	537.60	307.50	3.63	41.72
	50% release	534.53	537.88	335.43	3.89	44.01
	100% release	534.53	538.96	443.50	4.78	51.75
Other Months (Oct, Nov., April, May)	10% release	534.53	535.83	130.07	1.90	21.79
	15% release	534.53	536.04	151.14	2.11	24.98
	20% release	534.53	536.21	168.07	2.28	27.29
	30% release	534.53	536.48	195.14	2.56	30.58
	40% release	534.53	536.70	217.36	2.78	33.05
	50% release	534.53	536.89	236.29	2.96	35.10
	100% release	534.53	537.61	308.07	3.64	41.77

Table 8.8: Model Output for Different Release Scenarios for Subansiri Upper HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	253.75	254.96	120.79	1.07	15.38
	15% release	253.75	255.16	140.84	1.16	18.47
	20% release	253.75	255.32	156.79	1.22	20.89
	30% release	253.75	255.57	181.37	1.34	24.58
	40% release	253.75	255.76	200.68	1.44	27.08
	50% release	253.75	255.93	217.42	1.52	29.22
	100% release	253.75	256.55	279.68	1.78	37.70
Monsoon (June-Sept)	10% release	253.75	256.43	267.58	1.73	36.19
	15% release	253.75	256.85	309.21	1.93	40.95
	20% release	253.75	257.19	343.16	2.08	44.44
	30% release	253.75	257.75	399.47	2.32	49.73
	40% release	253.75	258.22	446.79	2.50	54.01
	50% release	253.75	258.64	488.89	2.65	58.63
	100% release	253.75	260.28	652.58	3.12	74.14
Other Months (Oct, Nov., April, May)	10% release	253.75	255.68	192.53	1.39	26.08
	15% release	253.75	255.98	222.63	1.54	29.92
	20% release	253.75	256.22	246.79	1.65	33.02
	30% release	253.75	256.62	286.21	1.82	38.44
	40% release	253.75	256.92	317.00	1.96	41.76
	50% release	253.75	257.19	343.84	2.08	44.50
	100% release	253.75	258.23	447.68	2.51	54.10

Table 8.9: Model Output for Different Release Scenarios for Subansiri Middle HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	274.94	276.09	114.33	2.24	17.78
	15% release	274.94	276.28	133.33	2.53	19.65
	20% release	274.94	276.44	149.50	2.74	20.93
	30% release	274.94	276.74	179.33	3.00	23.91
	40% release	274.94	277.00	205.50	3.15	27.36
	50% release	274.94	277.22	227.50	3.28	29.47
	100% release	274.94	278.05	311.17	3.82	35.56
Monsoon (June-Sept)	10% release	274.94	277.05	211.00	3.18	27.94
	15% release	274.94	277.47	253.17	3.46	31.31
	20% release	274.94	277.84	289.67	3.66	34.16
	30% release	274.94	278.40	345.83	4.06	37.15
	40% release	274.94	278.89	394.50	4.37	39.25
	50% release	274.94	279.33	438.33	4.62	41.00
	100% release	274.94	281.23	629.17	5.29	49.09
Other Months (Oct, Nov., April, May)	10% release	274.94	276.54	159.67	2.85	21.65
	15% release	274.94	276.87	192.67	3.08	25.83
	20% release	274.94	277.15	220.33	3.24	28.83
	30% release	274.94	277.59	264.50	3.53	32.15
	40% release	274.94	277.96	301.83	3.74	35.01
	50% release	274.94	278.27	332.33	3.97	36.57
	100% release	274.94	279.52	458.17	4.73	41.81

Table 8.10: Model Output for Different Release Scenarios for Kurung I & II HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	617.47	618.37	90.18	1.02	21.96
	15% release	617.47	618.53	105.91	1.12	23.68
	20% release	617.47	618.66	118.82	1.23	25.02
	30% release	617.47	618.88	140.27	1.39	27.33
	40% release	617.47	619.05	158.18	1.50	29.03
	50% release	617.47	619.21	173.73	1.59	30.44
	100% release	617.47	619.82	234.36	1.93	34.95
Monsoon (June-Sept)	10% release	617.47	619.09	162.18	1.52	29.40
	15% release	617.47	619.40	192.64	1.70	31.97
	20% release	617.47	619.65	218.00	1.84	33.83
	30% release	617.47	620.08	260.27	2.08	36.74
	40% release	617.47	620.42	295.00	2.26	39.14
	50% release	617.47	620.72	324.55	2.44	41.11
	100% release	617.47	621.84	436.73	3.07	48.30
Other Months (Oct, Nov., April, May)	10% release	617.47	618.74	126.27	1.29	25.83
	15% release	617.47	618.97	149.27	1.45	28.20
	20% release	617.47	619.16	168.55	1.56	29.99
	30% release	617.47	619.48	200.27	1.75	32.58
	40% release	617.47	619.74	227.09	1.89	34.46
	50% release	617.47	619.97	250.18	2.02	36.06
	100% release	617.47	620.85	337.55	2.52	41.96

Table 8.11: Model Output for Different Release Scenarios for Mili HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	1360.10	1360.64	53.50	1.06	9.49
	15% release	1360.10	1360.73	62.57	1.16	11.07
	20% release	1360.10	1360.80	70.00	1.24	12.36
	30% release	1360.10	1360.92	81.71	1.36	14.36
	40% release	1360.10	1361.01	91.21	1.45	15.81
	50% release	1360.10	1361.09	99.29	1.53	17.04
	100% release	1360.10	1361.39	129.07	1.81	21.35
Monsoon (June-Sept)	10% release	1360.10	1361.03	93.21	1.47	16.11
	15% release	1360.10	1361.19	108.71	1.62	18.49
	20% release	1360.10	1361.32	121.36	1.74	20.28
	30% release	1360.10	1361.52	141.64	1.92	23.03
	40% release	1360.10	1361.69	158.43	2.06	25.08
	50% release	1360.10	1361.83	172.57	2.18	26.82
	100% release	1360.10	1362.36	226.07	2.60	32.59
Other Months (Oct, Nov., April, May)	10% release	1360.10	1360.84	74.21	1.28	13.09
	15% release	1360.10	1360.97	86.57	1.41	15.11
	20% release	1360.10	1361.07	96.57	1.51	16.63
	30% release	1360.10	1361.23	112.64	1.66	19.08
	40% release	1360.10	1361.36	125.79	1.78	20.87
	50% release	1360.10	1361.47	137.00	1.88	22.39
	100% release	1360.10	1361.89	178.86	2.23	27.53

Table 8.12: Model Output for Different Release Scenarios for Sape HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	1108.84	1109.41	56.31	1.49	8.35
	15% release	1108.84	1109.50	65.75	1.64	9.73
	20% release	1108.84	1109.58	73.37	1.75	10.87
	30% release	1108.84	1109.70	85.88	1.92	12.71
	40% release	1108.84	1109.80	95.88	2.04	14.21
	50% release	1108.84	1109.89	104.81	2.15	15.49
	100% release	1108.84	1110.22	137.13	2.49	20.28
Monsoon (June-Sept)	10% release	1108.84	1109.83	98.25	2.07	14.53
	15% release	1108.84	1109.99	114.88	2.26	17.00
	20% release	1108.84	1110.13	128.63	2.41	19.02
	30% release	1108.84	1110.35	150.56	2.63	22.26
	40% release	1108.84	1110.53	168.44	2.80	24.77
	50% release	1108.84	1110.68	183.50	2.95	26.85
	100% release	1108.84	1111.25	240.13	3.46	34.18
Other Months (Oct, Nov., April, May)	10% release	1108.84	1109.62	77.63	1.81	11.51
	15% release	1108.84	1109.76	91.06	1.98	13.47
	20% release	1108.84	1109.86	101.81	2.11	15.06
	30% release	1108.84	1110.03	119.00	2.31	17.62
	40% release	1108.84	1110.18	133.38	2.46	19.72
	50% release	1108.84	1110.30	145.44	2.58	21.51
	100% release	1108.84	1110.75	190.19	3.01	27.77

Table 8.13: Model Output for Different Release Scenarios for Chomi HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	1038.72	1039.34	62.73	0.66	20.13
	15% release	1038.72	1039.45	73.00	0.74	22.73
	20% release	1038.72	1039.52	80.93	0.80	24.55
	30% release	1038.72	1039.66	94.07	0.90	26.86
	40% release	1038.72	1039.76	104.53	0.99	28.45
	50% release	1038.72	1039.85	113.60	1.06	29.53
	100% release	1038.72	1040.20	148.87	1.33	33.19
Monsoon (June-Sept)	10% release	1038.72	1039.78	106.87	1.00	28.73
	15% release	1038.72	1039.96	124.47	1.15	30.74
	20% release	1038.72	1040.11	139.13	1.26	32.25
	30% release	1038.72	1040.36	164.00	1.44	34.47
	40% release	1038.72	1040.56	184.93	1.59	36.11
	50% release	1038.72	1040.75	203.60	1.71	37.53
	100% release	1038.72	1041.48	276.73	2.14	42.78
Other Months (Oct, Nov., April, May)	10% release	1038.72	1039.57	85.67	0.84	25.41
	15% release	1038.72	1039.71	99.33	0.94	27.70
	20% release	1038.72	1039.82	110.47	1.03	29.18
	30% release	1038.72	1040.01	129.00	1.18	31.20
	40% release	1038.72	1040.16	144.67	1.30	32.79
	50% release	1038.72	1040.30	158.20	1.40	34.02
	100% release	1038.72	1040.83	211.93	1.76	38.14

Table 8.14: Model Output for Different Release Scenarios for Chela HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	846.52	847.05	52.43	1.17	17.76
	15% release	846.52	847.14	61.43	1.28	20.38
	20% release	846.52	847.21	68.64	1.37	22.34
	30% release	846.52	847.33	80.64	1.50	25.33
	40% release	846.52	847.43	90.36	1.60	27.62
	50% release	846.52	847.51	98.43	1.69	29.32
	100% release	846.52	847.83	130.36	2.04	34.15
Monsoon (June-Sept)	10% release	846.52	847.45	92.43	1.62	28.10
	15% release	846.52	847.61	108.57	1.80	31.04
	20% release	846.52	847.74	121.86	1.95	33.06
	30% release	846.52	847.96	144.00	2.19	35.77
	40% release	846.52	848.15	162.57	2.38	37.55
	50% release	846.52	848.31	179.07	2.54	39.04
	100% release	846.52	848.96	243.71	3.12	44.25
Other Months (Oct, Nov., April, May)	10% release	846.52	847.25	72.86	1.42	23.48
	15% release	846.52	847.38	85.50	1.55	26.50
	20% release	846.52	847.48	95.93	1.66	28.83
	30% release	846.52	847.65	112.71	1.85	31.68
	40% release	846.52	847.79	126.36	2.00	33.69
	50% release	846.52	847.91	138.71	2.13	35.18
	100% release	846.52	848.39	186.43	2.61	39.71

Table 8.15: Model Output for Different Release Scenarios for Nyepin HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	1012.21	1012.65	43.71	0.82	6.96
	15% release	1012.21	1012.72	51.14	0.89	8.14
	20% release	1012.21	1012.78	56.57	0.96	9.07
	30% release	1012.21	1012.87	65.86	1.05	10.59
	40% release	1012.21	1012.94	73.14	1.13	11.80
	50% release	1012.21	1013.01	79.43	1.19	12.84
	100% release	1012.21	1013.24	102.43	1.42	16.66
Monsoon (June-Sept)	10% release	1012.21	1012.96	75.00	1.15	12.07
	15% release	1012.21	1013.08	87.00	1.27	14.06
	20% release	1012.21	1013.18	96.57	1.36	15.66
	30% release	1012.21	1013.33	112.14	1.50	18.23
	40% release	1012.21	1013.46	124.57	1.61	20.32
	50% release	1012.21	1013.57	135.43	1.69	22.10
	100% release	1012.21	1013.96	175.00	2.01	27.89
Other Months (Oct, Nov., April, May)	10% release	1012.21	1012.81	60.00	0.99	9.60
	15% release	1012.21	1012.91	69.57	1.09	11.20
	20% release	1012.21	1012.99	77.43	1.17	12.50
	30% release	1012.21	1013.11	89.86	1.29	14.56
	40% release	1012.21	1013.21	99.86	1.39	16.22
	50% release	1012.21	1013.29	108.29	1.47	17.64
	100% release	1012.21	1013.61	140.14	1.73	22.86

Table 8.16: Model Output for Different Release Scenarios for Hiya HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	827.09	827.53	44.44	1.39	7.17
	15% release	827.09	827.61	52.00	1.52	8.43
	20% release	827.09	827.67	58.33	1.61	9.45
	30% release	827.09	827.77	68.44	1.75	11.09
	40% release	827.09	827.85	76.56	1.86	12.45
	50% release	827.09	827.93	83.67	1.95	13.60
	100% release	827.09	828.18	109.44	2.27	17.46
Monsoon (June-Sept)	10% release	827.09	827.87	78.33	1.88	12.75
	15% release	827.09	828.01	92.11	2.05	14.99
	20% release	827.09	828.12	102.78	2.18	16.57
	30% release	827.09	828.30	120.67	2.39	18.90
	40% release	827.09	828.44	135.56	2.53	20.83
	50% release	827.09	828.57	148.11	2.66	22.39
	100% release	827.09	829.04	195.22	3.12	27.33
Other Months (Oct, Nov., April, May)	10% release	827.09	827.71	61.89	1.66	10.05
	15% release	827.09	827.81	72.44	1.81	11.78
	20% release	827.09	827.90	81.22	1.92	13.22
	30% release	827.09	828.04	95.22	2.10	15.53
	40% release	827.09	828.16	106.78	2.23	17.07
	50% release	827.09	828.25	116.44	2.34	18.37
	100% release	827.09	828.63	153.67	2.71	23.00

Table 8.17: Model Output for Different Release Scenarios for Tammu HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Dec-March)	10% release	271.52	271.85	33.00	0.96	20.74
	15% release	271.52	271.91	38.60	1.07	23.40
	20% release	271.52	271.96	43.07	1.15	25.55
	30% release	271.52	272.03	50.33	1.28	28.81
	40% release	271.52	272.09	56.53	1.38	31.35
	50% release	271.52	272.14	61.73	1.46	33.29
	100% release	271.52	272.34	81.73	1.75	39.86
Monsoon (June-Sept)	10% release	271.52	272.10	57.87	1.40	31.84
	15% release	271.52	272.21	68.07	1.55	35.45
	20% release	271.52	272.29	76.53	1.67	38.18
	30% release	271.52	272.43	90.33	1.86	42.21
	40% release	271.52	272.54	101.93	2.02	45.03
	50% release	271.52	272.64	112.00	2.15	47.04
	100% release	271.52	273.04	151.27	2.64	53.70
Other Months (Oct, Nov., April, May)	10% release	271.52	271.98	45.67	1.20	26.69
	15% release	271.52	272.06	53.40	1.33	30.12
	20% release	271.52	272.13	60.13	1.43	32.65
	30% release	271.52	272.23	70.33	1.59	36.32
	40% release	271.52	272.32	79.27	1.72	39.12
	50% release	271.52	272.39	87.00	1.82	41.32
	100% release	271.52	272.69	116.40	2.22	47.88

Due to non-availability of river cross sections the computations for Naba HE Project could not be performed. However based on the computations of Niare HE project located upstream and Nalo HE project located downstream of Naba HE Project, the environmental flow requirements for Naba project has been finalized.

8.7 Environmental Flow Assessment

Hydropower schemes alter the hydrological regimes of rivers, hence affecting the aquatic ecosystems to varying degrees. Environmental flows are the flows to be released in rivers and streams that are necessary to maintain healthy aquatic ecosystems.

In Himalayan Rivers, there is spatial and temporal variability in discharge. Also wet and dry spells affect the annual water availability. Species that persist in such rivers generally survive, though not necessarily breed, during years when there is much less water than average. The presence of sequences of wet and dry years supports the suggestion that the biota can survive repeated years when the total annual discharge is less than the average; however, it may not remain unchanged in permanent drought conditions.

Studies in South African rivers (Weeks et al., 1996) showed that major community shifts occur among the fish fauna during droughts, and also during normal low flow seasons. However, provided conditions do not drastically differ from those that have occurred in the past, recovery reflects in the short to medium term. Some studies have shown evidence that a lower than normal flow regime, which still incorporates all the major features of the natural regime, would not permanently change the biota of the river. It is therefore suggested that, other things such as catchment condition being equal, a carefully designed modified flow regime which maintains the ecologically important components of the natural flow regime should be able to maintain a rivers natural biota.

Hence, for assessment of environmental flow, focus should be on the characteristic features of the natural flow regime of the river. The natural flow regime of the river depends upon the type of stream, i.e. whether the stream is perennial or ephemeral. Further, the degree of variability in flow values during the different months, occurrences of flood pulses, magnitude of flow during the lean, monsoon and non-lean-non-monsoon months are the important characteristics of the natural flow regime of the river. The challenge then is establishing the essential or critical components of the "natural flow regime" that are necessary to sustain important biological, hydrologic/hydraulic and other components of the aquatic ecosystem or achieving the desired future condition of the river. Once these essential components are known, a set of environmental flow thresholds can be established to maintain them. Thresholds may operate at different spatial scales - watershed, reach, site, for example, return frequency flows may be important watershed thresholds, annual and seasonal hydrographs may be important reach thresholds, and flow/depth relationships may be important site thresholds. Thresholds may change spatially throughout a watershed - changes in flow time series may have greater impacts on small order streams and less impact on large order streams; channel hydraulics in different reaches result in significant differences in flow depth relationships. Thresholds may change temporally due to change in average flow in the leanest four months, monsoon and other four months in a year.

Fish populations often include a range of species and reflect the integrated effects of environmental changes. Their presence is used to infer the presence of other aquatic organisms, since the adult fish occupy the top of the food chain in most aquatic systems. They also pass through most trophic levels above the primary producer stage during their development from larvae to adults. Fish can thus be regarded as reflecting the integrated environmental health of a river (Karr et al., 1986). Fish species in river can guide to prepare specification of the flows necessary to meet their needs, and be useful in the monitoring and management of those flows. It is often construed that if the flow requirement for fish maintenance is satisfied, then flow requirements for aquatic invertebrates will also be satisfied. This is because of the larger scale of fish habitat.

The approach adopted for environmental flow assessment is based on meeting the needs of dominant fish species with larger habitat requirement. Baseline data on fish fauna in Subansiri basin is discussed in Chapter – 7, where entire Subansiri basin and its tributaries has been divided in two predominant fishes viz. Mahseer and Trout. Mahseer being a large fish requires more flow in all the seasons and this aspect has been kept in mind while recommending environment flow for projects.

8.7.1 Environmental Flow Assessment in Lean Season

Habitat requirement for mahseer and trout is disused in Chapter 7, also there are number of other native fish species requiring diverse habitats and water requirement, but most of them adjusting to changing flow regime, which in any case should not fall below 0.5 m depth. To assess the minimum environment flow requirement in lean season a criteria has been defined that for Mahseer, projects needs to provide a minimum 0.5 m average depth in the initial reach studied and thus sufficing to the needs of almost all other fishes, and for projects in the trout this depth is considered as 0.4m during the lean season. Keeping in view that there are streams of various sizes in Subansiri, a further check is made that the water depth and flow width in post-project scenario should be about 50% of pre-project levels. Pre-project water depth, flow width and flow velocity is assessed by reviewing the results of 100% release scenario.

As discussed in the previous sections, modelling study has given the output in terms of depth, width and flow velocity. Analysis of the modelling output is done with a view to evaluate the depth, and width at 10, 15%, 20% and 30% release scenarios during lean season and the output is listed in **Table 8.18** below for average depth output.

Table 8.18: Average Flow Depth under different release Scenarios during Lean Season

Project	Average Flow Depth (cm)					
	10% release	15% release	20% release	30% release	Pre- project	50% of Pre-project
Oju-I	95.89	112.67	126.11	147.33	236.89	118.44
Oju-II	64.76	75.95	85.10	99.57	159.10	79.55
Niare	93.80	110.00	123.60	145.30	273.70	118.60
Nalo	89.36	104.16	116.08	135.40	214.24	107.12
Dengser	81.07	94.14	105.07	122.14	190.57	95.29
Subansiri Upper	120.79	140.84	156.79	181.37	279.68	139.84
Subansiri Middle	114.33	133.33	149.50	179.33	311.17	155.58
Kurung-I & II	90.18	105.91	118.82	140.27	234.36	117.18
Mili	53.50	62.57	70.00	81.71	129.07	64.54
Sape	56.31	65.75	73.37	85.88	137.13	68.56
Chomi	62.73	73.00	80.93	94.07	148.87	74.44
Chela	52.43	61.43	68.64	80.64	130.36	65.18
Hiya	44.44	52.00	58.33	68.44	109.44	54.72
Nyepin	43.71	51.14	56.57	65.86	102.43	51.21
Tammu	33.00	38.60	43.07	50.33	81.73	40.87

Following can be concluded from the above analysis:

- Considering the criteria of about 50% of pre project depth and 50 cm depth requirements during the leanest four months, more than 50% of the pre-project flow depth is achieved for the 20% release scenario for all the projects except Subansiri middle where the depth is about 48% of pre-project depth. However for Subansiri middle the average depth computed for 20% release is about 150 cm which is about 3 times of the 50 cm depth requirement. Hence 20% release from Subansiri middle is also sufficient to meet the environmental flow requirements
- Tammu HEP will have more than 50 cm of average flow depth under 30% release scenarios for Mahseer.
- For trout, all projects are showing more than 40 cm of depth under 10% release scenarios except Tammu HEP, where it is achieved at 43 cm under 20% release scenario.

- Hence, during the lean season, 20% release of average flow of leanest four months in 90% dependable year is recommended for all the above projects in Subansiri basin except Tammu. For Tammu HE Project the environment flow release should be 30% of average flow of leanest four months in 90% dependable year.

8.7.2 Environmental Flow Assessment in Monsoon Season

Environment flow requirement in monsoon season is different from that of lean season. Lean season flow is mainly base flow and therefore, an average value and constant release can meet the lean season flow requirement. Whereas in monsoon, apart from the base flow, flood peaks are critical for various functions of the river. These flood peaks provide connectivity and wetting of side channels, opening up new habitat, gravel movement, and flushing sediment into side channels. These flows also add organic matter and nutrients through riparian vegetation into the main stream thus providing food to aquatic species. Newly connected side channels provide spawning and rearing habitat for aquatic life. Resident trout, macro-invertebrates, and other species also benefit by increased habitat diversity and clean substrates. These high flows should be planned in conjunction with possible gravel augmentation efforts to maximize benefits. Environmental flow requirement in monsoon months should meet the following requirement:

- It should provide adequate habitat in terms of water depth, velocity and water width of channel for needs of aquatic life, which includes migration, breeding and spawning.
- It should provide flood peaks distributed over the monsoon period for riparian vegetation abundance, to wet side channels and maintain habitat for aquatic species.
- The flows should mimic natural flow pattern that naturally occurred in the rainy season.
- It should meet flow requirements for breeding and spawning of prevalent fish species.

Requirement for environmental flow in monsoon can be established from the hydraulic output i.e. flow width, depth and velocity to meet the habitat requirement. No specific criteria can be established to exactly fix the minimum habitat requirement due to adaptability of the species to varied conditions in the rivers. Habitat requirements have been summarised in Chapter 7; from where it can be concluded that projects should not reduce water depth below 1 m in monsoon and to meet the higher requirement for Mahseer such project should provide about 1.2-1.4 m depth.

Another important characteristic of the monsoon flow is flood peaks; this should also be mimicked in post project scenario. Sufficient flood peaks should be released through out the monsoon period. Limitation is in evaluation of the available flood pulses in monsoon because the discharge data available is ten daily series, which average out the flood peaks in most of the cases. For flood peak analysis twice daily/daily discharge data is considered most suitable. Wherever, daily data is available, data analysis is carried out for flood peak assessment and recommendations are made accordingly. In the absence of such data, higher release recommendations are made than what is assessed to meet base flow requirement to ensure flood peaks are released.

Table 8.19 below gives flow depth in monsoon season for 10%, 15%, 20%, 30%, 40% and 50% release scenarios along with pre-project depth or 100% release scenario. Cells have been highlighted against each project where the adequate depth is available both in terms of flow depth of 120 cm and 50% of pre-project depth to meet the environmental flow requirements. Oju-I, Oju-II, Niare, Nalo, Dengser, Subansiri upper, Subansiri middle (Kamla), Kurung-I&II and Chomi HEPs meet the depth requirement for 10% release scenario, however the depth was reduced to less than 50% of the pre-project level. Hence the higher release has been considered for which depth is 50% or more of the pre-project scenario. Mili, Sape, Chela meet the both criteria for 20% release scenario. Further, though for Oju-I the 50% depth requirement gets just satisfied for 15% release, however to capture the flood pulses it is desirable to release 20% of flow. Accordingly environmental release of 20% is recommended for Oju-I, Oju-II, Niare, Nalo, Dengser, Subansiri upper, Subansiri middle, Kurung-I&II, Mili, Sape, Chomi and Chela HE Projects. For Subansiri middle though the depth for 20% release is about 46% of the pre project depth, however the 290 cm depth is about 2.4 times of the required base depth. Hence 20% environmental release can also be considered adequate for Subansiri middle project. For Naba which lies between Niare and Nalo, environment flow release can be considered as 20%. For Hiya, environmental release of 30% is required to meet the 50% pre-project depth and 120 cm depth criteria. For Nyepin HE project as shown in Fig.8.9, environmental release of 35% is required to meet the 50% pre-project depth and 120 cm depth criteria. For Tammu as shown in Fig.8.10, 60% environmental release is needed to meet the of 120 cm depth requirement.

Table 8.19: Model Output for different Release Scenario during Monsoon

Project	Average Flow Depth (cm)							50% of Pre-project
	10% release	15% release	20% release	30% release	40% release	50% release	Pre-project	
Oju-I	224.67	264.78	294.33	341.11	378.33	410.89	529.56	264.78
Oju-II	151.67	177.95	199.62	235.29	265.10	291.52	394.95	197.48
Niare	225.80	266.00	298.50	351.40	394.30	431.50	573.40	286.70
Nalo	204.52	238.76	266.12	309.68	345.12	375.76	494.28	247.14
Dengser	182.07	211.79	236.00	275.21	307.50	335.43	443.50	221.75
Subansiri Upper	267.58	309.21	343.16	399.47	446.79	488.89	652.58	326.29
Subansiri Middle	211.00	262.60	289.67	359.20	409.80	455.60	629.17	314.58
Kurung-I & II	162.18	192.64	218.00	260.27	295.00	324.55	436.73	218.37
Mili	93.21	108.71	121.36	141.64	158.43	172.57	226.07	113.05
Sape	98.25	114.88	128.63	150.56	168.44	183.50	240.13	120.07
Chomi	106.87	124.47	139.13	164.00	184.93	203.60	276.73	138.37
Chela	92.43	108.57	121.86	144.00	162.57	179.07	243.71	121.86
Hiya	78.33	92.11	102.78	120.67	135.56	148.11	195.22	97.61
Nyepin	75.00	87.00	96.57	112.14	124.57	135.43	175.00	87.50
Tammu	57.87	68.07	76.53	90.33	101.93	112.00	151.27	75.64

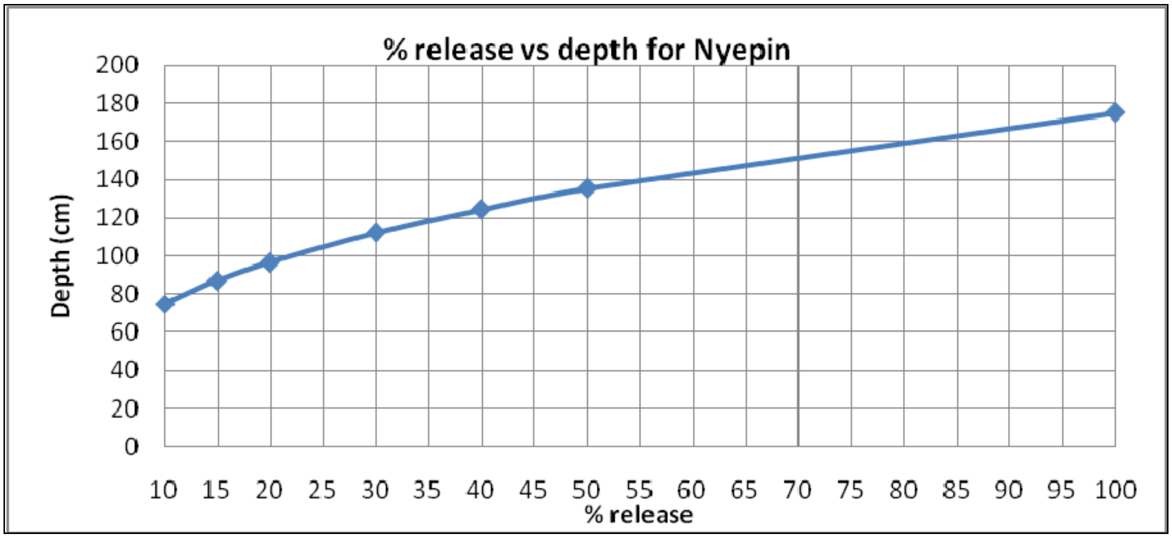

Figure.8.9: Plot of % release during monsoon and resuting flow depth for Nyepin

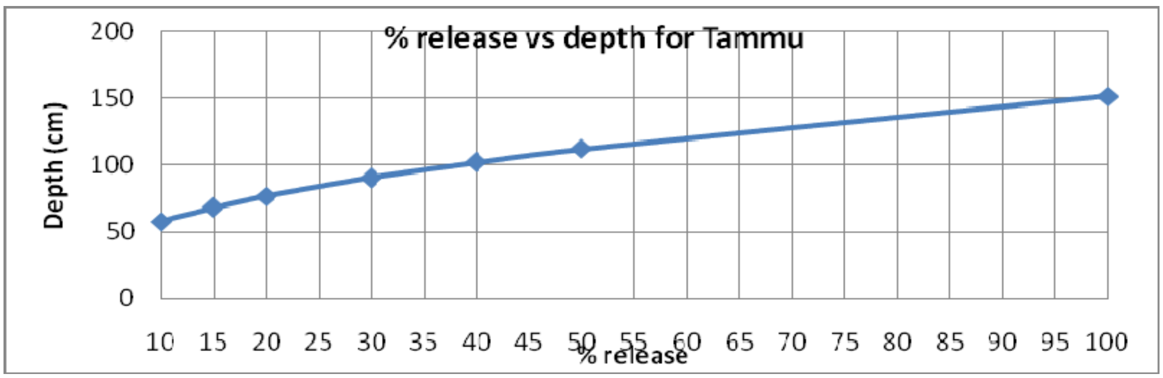

Figure.8.10: Plot of % release during monsoon and resuting flow depth for Tammu

8.8 Environmental Flow in Non-Monsoon and Non Lean Season

To mimic the annual flow cycle of the natural flow regime, the environmental flow in pre-monsoon and post monsoon period are equally important. From the river flow point of view these months are the transition periods from wet season to dry season and vice versa. During pre-monsoon months some small pulses of higher flow are also observed due to intermittent rain spell and increased snow melt in Himalayas. During post-monsoon months the higher flow occurrences are due to increased base flow and intermittent rain spells. Depending upon water temperature, migratory species such as Mahseer and Trout start upward migration during pre-monsoon period and migrate back to lower reaches during post monsoon period. The environmental flow requirements for pre-monsoon and post monsoon period can be established from the hydraulic output i.e. flow width, depth and velocity to meet the habitat requirement. In order to follow the natural flow regime, the environmental flow should be higher than that of the lean season and less than that of the monsoon. Therefore, keeping it slightly lower than monsoon requirement, modelling output has been assessed taking the depth requirement of 65-70 cm for Trout and 90-100 cm for Mahseer. Further, the reduced flow depth and width of the river due to diversion of water should not be less than about 50% of the pre-project scenario.

Also, during this period, the small flood peaks needs to be captured in environment flow as these are the indicators of migration for breeding/spawning. Such flood pulses should also be mimicked in post project scenario with daily flow data. In the absence of such data, higher release recommendations has been made than what is assessed to meet base flow requirement to ensure flood pulses are spilled in the post project scenario.

Table 8.20 below gives flow depth in pre and post monsoon season for 10%, 15%, 20% 30%, 40% and 50% release scenarios along with pre-project depth or 100% release scenario.

Cells have been highlighted against each project where the adequate depth is available both in terms of flow depth of 120 cm and 50% of pre-project depth to meet the environmental flow requirements. Oju-I, Oju-II, Niare, Nalo, Dengser, Subansiri upper, Subansiri middle (Kamala HEP), Kurung-I&II and Chomi HEPs were meeting the base depth requirement for 10% release scenario, however the depth was reduced to less than 50% of the pre-project level. Hence the higher release has been considered for which depth is 50% or more of the pre-project scenario. Mili, Sape, Chela were meeting both the criteria for 20% release scenario. Further in the absence of daily measured data the minor flood peaks could not be captured. Hence in order to ensure the natural flow regime with minor flood peaks environmental release of 20% is recommended for Oju-I, Oju-II, Niare, Nalo, Dengser, Subansiri upper, Kurung-I&II, Mili, Sape, Chomi and Chela HE Projects. For Naba which lies between Niare and Nalo environment flow release can be considered as 20%. For Subansiri middle though for 20% release, depth is 47% of pre-project scenario, however considering the 213 cm depth which is 2.4 times of 90 cm, an environmental flow release of 20% may be considered sufficient. For Hiya and Nyepin environmental release of 30% is required to meet the 50% pre-project depth and 90 cm depth criteria. For Tammu as shown in Fig.8.11, 55% environmental release is needed to meet the of 90 cm depth requirement.

Table 8.20: Model Output for Different Release Scenario during Pre/Post Monsoon

Project	Average Flow Depth (cm)							50% of Pre-project
	10% release	15% release	20% release	30% release	40% release	50% release	Pre-project	
Oju-I	157.44	185.00	206.67	243.44	271.67	294.89	379.22	189.61
Oju-II	106.40	124.27	139.49	163.15	182.47	202.14	259.78	129.89
Niare	155.60	183.70	206.50	243.40	273.40	299.20	395.30	197.65
Nalo	144.48	168.56	188.08	219.68	245.00	266.64	345.68	172.84
Dengser	130.07	151.14	168.07	195.14	217.36	236.29	308.07	154.04
Subansiri Upper	192.53	222.63	246.79	286.21	317.00	343.84	447.68	223.84
Subansiri Middle	152.40	185.60	213.20	258.80	297.00	327.80	454.20	227.10
Kurung-I & II	126.27	149.27	168.55	200.27	227.09	250.18	337.55	168.77
Mili	74.21	86.57	96.57	112.64	125.79	137.00	178.86	89.43
Sape	77.63	91.06	101.81	119.00	133.38	145.44	190.19	95.09
Chomi	85.67	99.33	110.47	129.00	144.67	158.20	211.93	105.97
Chela	72.86	85.50	95.93	112.71	126.36	138.71	186.43	93.21

Project	Average Flow Depth (cm)							50% of Pre-project
	10% release	15% release	20% release	30% release	40% release	50% release	Pre-project	
Hiya	61.89	72.44	81.22	95.22	106.78	116.44	153.67	76.83
Nyepin	60.00	69.57	77.43	89.86	99.86	108.29	140.14	70.07
Tammu	45.67	53.40	60.13	70.33	79.27	87.00	116.40	58.20

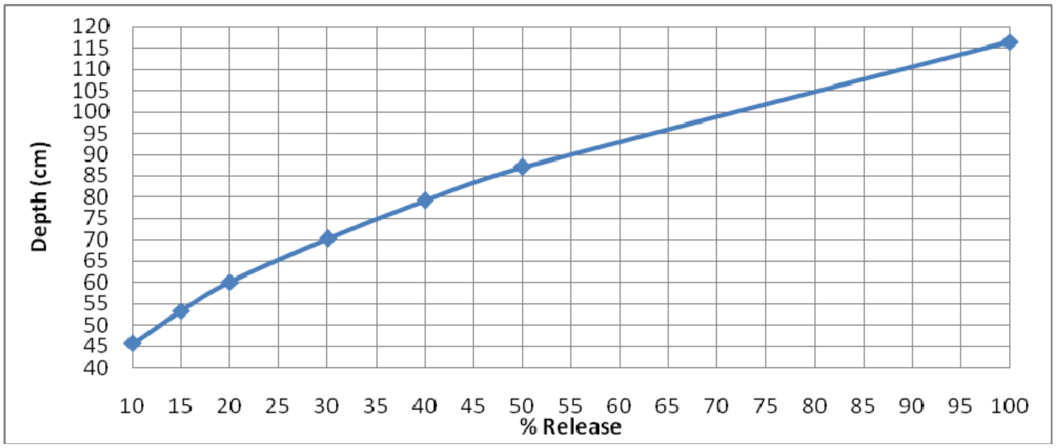

Figure.8.11: Plot of % release during non lean and non monsoon and resuting flow depth for Tammu

8.9 Environment Flow for Subansiri Lower HE Project

Subansiri Lower HE Project comprises of dam toe power house. One unit of power house is proposed to run continuously on partial / full load. Accordingly, depending upon the water availability the continuous release from one unit may vary from 220 to 322 cumec. Hence, the environmental flow simulation has been carried out to estimate the depth of flow, velocity and top flow width in the river reach between Subansiri dam and Brahmaputra confluence during the lean period (November to Feb) for the releases of 180, 200, 220, 240, 260, 280, 300 and 320 cumec. The river reach from Subansiri dam site up to Brahmaputra confluence has been represented in HEC-RAS model using the surveyed cross sections. The Manning's n has been adopted as 0.04. Apart from the above release the lean period discharge of various Nallah/rivers joining Subansiri river in the study reach has also been considered as lateral inflow in model set up. The lean period (Nov-Feb) average discharge of the Nallah/rivers joining Subansiri river downstream of Subansiri lower HE Project as obtained from NHPC is as follows:

Name	Area (sq.km)	Distance d/s of Subansiri Lower Dam (km)	Flow (cumec) - Nov to Feb
Garuka Nala	6.64	2.50	1
Dulang Nala	60.21	4.89	10
Dirpai Nala	16.33	5.35	3
Chauldha Nala	13.89	5.55	2
Gaghar Nala	61.47	26.38	10
Bogi Nadi & Dirgha Nala	131.45	30.00	21
Kokoi Nala	23.66	35.50	4

Name	Area (sq.km)	Distance d/s of Subansiri Lower Dam (km)	Flow (cumec) - Nov to Feb
Total	314		51

The simulation results are given in **Table-8.21**.

Table 8.21: Model output for different release scenario from Subansiri lower HEP

River	Ch d/s of Subansiri Lower Dam axis	Profile	Total discharge	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Subansiri	-10000	PF180 cumec release	196	98.27	101.09	282	0.4	319.24
Subansiri	-20000	PF180 cumec release	196	95.43	99.05	362	0.64	164.26
Subansiri	-30000	PF180 cumec release	227	91.6	94.62	302	0.88	167.34
Subansiri	-40000	PF180 cumec release	231	89.01	91.57	256	0.43	352.29
Subansiri	-60000	PF180 cumec release	231	79.57	83.53	396	0.44	367.61
Subansiri	-70000	PF180 cumec release	231	76.91	80.72	381	0.82	140.87
Subansiri	-80000	PF180 cumec release	231	72.45	78.25	580	0.42	365.2
Subansiri	-89500	PF180 cumec release	231	72.39	77.65	526	0.19	768.14
					Average	385.625		
River	Ch d/s of Subansiri Lower Dam axis	Profile	Total discharge	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Subansiri	-10000	PF200 cumec release	216	98.27	101.2	293	0.42	321.82
Subansiri	-20000	PF200 cumec release	216	95.43	99.16	373	0.67	168.02
Subansiri	-30000	PF200 cumec release	247	91.6	94.73	313	0.9	170.37
Subansiri	-40000	PF200 cumec release	251	89.01	91.65	264	0.45	359.86
Subansiri	-60000	PF200 cumec release	251	79.57	83.64	407	0.44	393.1
Subansiri	-70000	PF200 cumec release	251	76.91	80.85	394	0.84	144.45
Subansiri	-80000	PF200 cumec release	251	72.45	78.38	593	0.41	407.29
Subansiri	-89500	PF200 cumec release	251	72.39	77.84	545	0.19	830.13
					Average	397.75		

River	Ch d/s of Subansiri Lower Dam axis	Profile	Total discharge	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
River	Ch d/s of Subansiri Lower Dam axis	Profile	Total discharge	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Subansiri	-10000	PF220 cumec release	236	98.27	101.3	303	0.43	324.3
Subansiri	-20000	PF220 cumec release	236	95.43	99.27	384	0.69	171.63
Subansiri	-30000	PF220 cumec release	267	91.6	94.82	322	0.92	173.24
Subansiri	-40000	PF220 cumec release	271	89.01	91.73	272	0.46	367.73
Subansiri	-60000	PF220 cumec release	271	79.57	83.75	418	0.44	422.58
Subansiri	-70000	PF220 cumec release	271	76.91	80.95	404	0.86	147.61
Subansiri	-80000	PF220 cumec release	271	72.45	78.51	606	0.41	446.37
Subansiri	-89500	PF220 cumec release	271	72.39	78.02	563	0.18	885.32
					Average	409		
River	Ch d/s of Subansiri Lower Dam axis	Profile	Total discharge	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Subansiri	-10000	PF240 cumec release	256	98.27	101.4	313	0.44	326.71
Subansiri	-20000	PF240 cumec release	256	95.43	99.4	397	0.7	177.05
Subansiri	-30000	PF240 cumec release	287	91.6	94.95	335	0.91	191.2
Subansiri	-40000	PF240 cumec release	291	89.01	91.8	279	0.47	375.48
Subansiri	-60000	PF240 cumec release	291	79.57	83.86	429	0.44	452.24
Subansiri	-70000	PF240 cumec release	291	76.91	81.02	411	0.9	149.66
Subansiri	-80000	PF240 cumec release	291	72.45	78.63	618	0.41	461.68
Subansiri	-89500	PF240 cumec release	291	72.39	78.18	579	0.18	935.48
					Average	420.125		
River	Ch d/s of Subansiri	Profile	Total discharge	Bed Elevation	Water surface	Water depth	Flow Velocity	Flow Top Width

River	Ch d/s of Subansiri Lower Dam axis	Profile	Total discharge	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
	Lower Dam axis				Elevation			
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Subansiri	-10000	PF260 cumec release	276	98.27	101.5	323	0.45	328.61
Subansiri	-20000	PF260 cumec release	276	95.43	99.52	409	0.71	182.01
Subansiri	-30000	PF260 cumec release	307	91.6	95.06	346	0.91	205.31
Subansiri	-40000	PF260 cumec release	311	89.01	91.88	287	0.48	383.25
Subansiri	-60000	PF260 cumec release	311	79.57	83.94	437	0.45	461.87
Subansiri	-70000	PF260 cumec release	311	76.91	81.09	418	0.93	151.94
Subansiri	-80000	PF260 cumec release	311	72.45	78.76	631	0.4	486.97
Subansiri	-89500	PF260 cumec release	311	72.39	78.3	591	0.18	1044.73
					Average	430.25		
Subansiri	-10000	PF280 cumec release	296	98.27	101.59	332	0.46	329.32
Subansiri	-20000	PF280 cumec release	296	95.43	99.64	421	0.73	186.32
Subansiri	-30000	PF280 cumec release	327	91.6	95.16	356	0.92	218.67
Subansiri	-40000	PF280 cumec release	331	89.01	91.95	294	0.49	387.47
Subansiri	-60000	PF280 cumec release	331	79.57	84.02	445	0.45	472.04
Subansiri	-70000	PF280 cumec release	331	76.91	81.19	428	0.94	155.37
Subansiri	-80000	PF280 cumec release	331	72.45	78.88	643	0.4	531.65
Subansiri	-89500	PF280 cumec release	331	72.39	78.42	603	0.17	1131.81
					Average	440.25		
River	Ch d/s of Subansiri Lower Dam axis	Profile	Total discharge	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Subansiri	-10000	PF300 cumec release	316	98.27	101.68	341	0.47	330.01
Subansiri	-20000	PF300 cumec release	316	95.43	99.74	431	0.74	191.31

River	Ch d/s of Subansiri Lower Dam axis	Profile	Total discharge	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Subansiri	-30000	PF300 cumec release	347	91.6	95.24	364	0.93	227.48
Subansiri	-40000	PF300 cumec release	351	89.01	92.01	300	0.5	390.25
Subansiri	-60000	PF300 cumec release	351	79.57	84.09	452	0.46	480.07
Subansiri	-70000	PF300 cumec release	351	76.91	81.28	437	0.96	158.39
Subansiri	-80000	PF300 cumec release	351	72.45	78.96	651	0.4	554.71
Subansiri	-89500	PF300 cumec release	351	72.39	78.52	613	0.17	1144.37
					Average	448.625		
River	Ch d/s of Subansiri Lower Dam axis	Profile	Total discharg e	Bed Elevation	Water surface Elevation	Water depth	Flow Velocity	Flow Top Width
	(m)		(m3/s)	(m)	(m)	(cm)	(m/s)	(m)
Subansiri	-10000	PF320 cumec release	336	98.27	101.77	350	0.48	330.69
Subansiri	-20000	PF320 cumec release	336	95.43	99.83	440	0.76	195.51
Subansiri	-30000	PF320 cumec release	367	91.6	95.34	374	0.92	237.83
Subansiri	-40000	PF320 cumec release	371	89.01	92.13	312	0.5	427.12
Subansiri	-60000	PF320 cumec release	371	79.57	84.19	462	0.45	496.46
Subansiri	-70000	PF320 cumec release	371	76.91	81.42	451	0.96	175.46
Subansiri	-80000	PF320 cumec release	371	72.45	79.04	659	0.4	583.56
Subansiri	-89500	PF320 cumec release	371	72.39	78.61	622	0.18	1158.58
					Average	458.75		

The Gangetic dolphin (*Platanista gangetica*), is one of the important flagship species of Gangetic riverine ecosystem in northern India and is one of the four freshwater dolphins in the world, facing extinction, and included as Schedule-I animal in the Wildlife (Protection) Act-1972. It has been recognized as Endangered by IUCN Red List of threatened species and listed in Appendix I of CITES. The Ganges river dolphin has been notified as the national aquatic animal by government of India and also state aquatic animal in Assam since 2008, when their population was estimated to be around 2000 individuals in Ganges and Brahmaputra river systems in India. Locally called a souns or susu in Hindi, it is distributed along Ganges, Brahmaputra, Karnali-Sangu and

Meghna river systems and their tributaries in foothills of Himalayas. Their existing population is fragmented as earlier these were found in large numbers and now their estimated population is approximately 2000 individuals found in India, where as in Brahmaputra alone it is estimated to be nearly 250-400 individuals.

Various studies showed best estimate of 250 dolphins in Brahmaputra river system with 197 in Brahmaputra mainstream, 27 dolphins in Kulsi River and 26 in Subansiri River. Out of the 197 dolphins in Brahmaputra mainstream, 21 dolphins were recorded in Assam-Arunachal Border to Balijan, 16 dolphins from Balijan to Dikhowmukh, 28 dolphins in between Dikhowmukh to Dhansirimukh, 40 dolphins in between Dhansirimukh to Gabhorumukh, 16 dolphins from Gabhorumukh to Guwahati, 29 dolphins from Guwahati to Pancharatna and 47 dolphins were recorded in between Pancharatna to India-Bangladesh border (Wakid[61], 2009). Other studies recorded estimate of 264 dolphins in the same stretches of Brahmaputra river system with 212 dolphins in the Brahmaputra mainstream, 29 in Kulsi River and 23 in Subansiri River Wakid and Braulik (2009). Out of recorded 212 dolphins in Brahmaputra mainstream, a best estimate of 25 dolphins were recorded in the Brahmaputra river stretch from Tengapanimukh-Oiramghat (Assam - Arunachal Pradesh border) to Balijan, 22 dolphins from Balijan to Dikhowmukh, 28 dolphins from Dikhowmukh to Dhansirimukh, 42 dolphins from Dhansirimukh to Tezpur, 24 dolphins from Tezpur to Guwahati, 36 dolphins from Guwahati to Jugighopa and 35 dolphins from Jugighopa to Dhubri. The ecological requirement of Gangetic River Dolphin for sustenance in river Subansiri is adequate water availability throughout the year to sustain its habitat. As per various studies, currently Dolphins are mainly confined to 100-110 km upstream of the confluence of Brahmaputra in Subansiri River. The dolphins prefer deeper pools of the river Subansiri as natural habitats, which are available downstream. The species need constant source of water flow for sustainability of its habitat and other aquatic biodiversity downstream, which required maintaining minimum average flow discharge to the tune of 240 cumec on constant basis throughout the year. There have been no confirmed reports which suggest presence of Dolphins in upstream of Lower Subansiri HEP as checked through various publications and discussions with fishermen.

Following are the major ecological requirements of Gangetic Dolphin in context to Subansiri:

1. A constant source of aquatic flow discharge to maintain the critical water flow to the tune of 240 Cumec at all the time on continuous basis to provide protection to its habitat and conservation of aquatic biodiversity downstream of Subansiri lower HE Project.
2. Availability of water depth/cover of at least minimum of 3 meter (Biswas et al, 1997) during lean season for Gangetic Dolphin habitat especially downstream of lower Subansiri proposed HEP for maintaining its ecological activities and sustenance of aquatic ecosystem. A few studies showed maximum sightings of Gangetic Dolphins in Brahmaputra in the depth range of 4.1-6.0m (Wakid A., 2009)
3. Availability of fishes and other biodiversity components in its habitat, on which Gangetic Dolphins forage.

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[61] *Wakid., A., (2009) Status and distribution of the endangered Gangetic Dolphin (Platanista gangetica gangetica) in the Brahmaputra River within India in 2005. Current Science, Vol. 97, No. 8, 25 October 2009*

From the hydraulic simulation results given in **Table 8.21** it is estimated that for about 240 cumec continuous release need to be ensured from Subansiri lower HE Project in order to get an average depth of about 4.2 m for habitat requirement of Dolphins and sustenance of aquatic ecosystem.

8.10 Overall Recommendation for Environment Flow

As can be seen from above discussion, flow requirement has been assessed project wise, separately for three seasons i.e. lean, monsoon and other months (pre-monsoon and post-monsoon) based on habitat simulation and hydraulic modelling. The project wise environmental flow recommendation to meet the base depth, 50% pre-project depth and flow width requirements for three seasons are summarized in **Table 8.22**. Due to non-availability of daily discharge data, which is essential to capture the flood pulses, slightly higher recommendations are made for environmental flow release during monsoon and pre/post monsoon period. Projects where hydraulic modelling has not been carried out due to non-availability of data, recommendations has been made based on the upstream and downstream projects in vicinity.

8.11 Recommendations for Aquatic biodiversity

As evident from aquatic studies (Chapter 7) and its correlation with environmental flow in different release scenario, it is recommended that special attention is required in consistency and uninterrupted average flow depth in various identified release scenarios should maintain 0.5m minimum depth in lean season to safeguard the habitat of aquatic biodiversity including riparian flora as in monsoon and other season there certainly will have more water availability through natural means. The emphasis is overall maintenance of existing fisheries especially endemic, native and migratory species whose water requirement should be near natural to help them in performing their biological functions normally. It is important that regulated environmental flow should not hamper the growth of planktons and benthic organisms, on which fishes thrive.

The areas which needs special attention in terms of presence of migratory fish species *Schizothorax richardsonii* and *Schizothorax esonicus* are Dengser, Niare, Naba, Nyepin and Hiya; and for recorded presence of migratory fish species *Tor tor, T. putitora, T. progenies, N. hexagonalepis* are Middle Subansiri, Upper Subansiri, Naba, Tago-1, Lower Subansiri, Nalo, Nyepin and Hiya. Above mentioned areas also have endemic fish species and require adequate flow maintenance.

It is again reiterated here that from Lower Subansiri project, continuous release of about 240 cumec should be ensured to safeguard the aquatic biodiversity in downstream reaches of Subansiri River.

Flow depth, flow velocity and flow top width for lean discharge release condition, Monsoon discharge release condition and other four months discharge release condition of HEPs in Subansiri Basin is given in **Annexure 9.2**.

Table-8.22: Environmental flow release recommendations

	Lean Environmental Flow Release (EFR)					Pre-monsoon and Post-monsoon Environmental Flow Release (EFR)					Monsoon Environmental Flow Release (EFR)				
	EFR	flow width (m)	50% of Pre-project flow width (m)	Flow depth (cm)	50% of Pre-project flow depth (cm)	EFR	flow width (m)	50% of Pre-project flow width (m)	Flow depth (cm)	50% of Pre-project flow depth (cm)	EFR	flow width (m)	50% of Pre-project flow width (m)	Flow depth (cm)	50% of Pre-project flow depth (cm)
Oju-I	20%	7.50	7.68	126.11	118.44	20%	13.04	13.21	206.67	186.02	20%	20.51	17	294.33	264.78
Oju-II	20%	16.22	13.41	85.10	79.55	20%	24.20	19.42	139.49	129.89	20%	32.03	25.31	199.62	197.48
Niare	20%	8.76	7.56	123.60	118.60	20%	13.42	11.84	206.50	191.19	20%	18.51	16.40	298.50	286.70
Nalo	20%	13.35	12.32	116.08	107.12	20%	21.64	18.72	188.08	139.90	20%	30.49	24.60	266.12	247.14
Dengser	20%	17.60	15.02	105.07	95.29	20%	27.28	20.88	168.07	158.74	20%	35.05	25.87	236.00	221.75
Subansiri Upper	20%	20.89	18.85	156.79	139.84	20%	33.02	27.05	246.79	227.38	20%	44.44	37.07	343.16	326.29
Subansiri Middle	20%	20.93	17.78	149.50	155.58	20%	28.83	20.90	213.20	235.72	20%	34.16	24.55	289.67	314.56
Kurung-I & II	20%	25.02	17.48	118.82	117.18	20%	30	20.98	168.55	169.53	20%	33.83	24.15	218.00	218.37
Mili	20%	13.46	10.68	70.00	64.54	20%	17.93	13.76	96.57	92.38	20%	21.74	16.30	121.36	113.05
Sape	20%	10.87	10.14	73.37	68.56	20%	15.06	13.88	101.81	92.98	20%	19.02	17.09	128.63	120.07
Chomi	20%	24.55	16.60	80.93	74.43	20%	29.18	19.07	110.47	105.97	20%	32.25	21.39	139.13	138.37
Chela	20%	22.34	17.07	68.64	65.18	20%	28.82	19.85	95.93	93.29	20%	33.06	22.12	121.86	121.86
Hiya	20%	9.45	8.73	58.33	54.72	30%	15.53	11.50	95.22	73.11	30%	18.90	13.66	120.67	97.61
Nyepin	20%	9.07	8.33	56.57	51.21	30%	14.56	11.43	89.86	62.76	35%	19	13.95	120	87.50
Tammu	30%	28.80	19.93	50.33	40.87	55%	44	23.94	90	58.05	60%	49	26.85	120	75.64

- For Naba HE Project which lies between Niare and Nalo Environmental flow release should be (20% in lean), (20% in Pre and post monsoon) and (20% in monsoon)
- Subansiri lower consist of dam toe power house hence one unit of turbine should continuously run to ensure at least about 240 cumec release in Subansiri River downstream of Subansiri lower HE Project for sustenance of aquatic ecosystem.

Chapter 9: Impact Study for Subansiri and Brahmaputra River due to Hydroelectric Projects in Subansiri basin

9.0 Introduction

About nineteen major hydroelectric projects have been planned in Subansiri basin. These projects are the part of cascade development of Subansiri and Kamala rivers along with their tributaries. The average discharge of Brahmaputra River during the monsoon period is more than 20000 cumec. Hence, the peaking release of the hydroelectric projects which is of the order of 1000 to 2000 cumec is not likely to make any significant change in the flow pattern of Brahmaputra River. During the non-monsoon period (November to April) the average discharge of Brahmaputra River near Guwahati is generally of the order of 5300 cumec. Hence some change in flow pattern may be expected due to peaking releases from the Projects in the basin. In order to quantify these changes with respect to natural condition of river, the downstream impact study has been carried out to estimate the change in discharge and water level pattern at salient locations of Subansiri and Brahmaputra River during the non-monsoon peaking release. These salient locations have been selected as Subansiri River near North Lakhimpur, Brahmaputra River near downstream end of Kaziranga, Tezpur and Guwahati. The surveyed cross sections of Subansiri and Brahmaputra rivers used for the present study have been provided by Central Water Commission.

9.1 Hydrological considerations for downstream impact study

Out of nineteen HE projects of the Subansiri basin, Subansiri lower is the downstream most hydroelectric project on Subansiri River near Gerukamukh. Other Mega projects planned in the basin are Subansiri Upper near Menga, Subansiri Middle (Kamla HEP) near Tamen. The Oju-I, Oju-II, Niare, Naba, Nalo and Dengser are planned on Subansiri river upstream of Subansiri upper Project. While Kurang-I, Kurang-II, Nyepin, Hiya, Mili and Sape are proposed upstream of Kamala HE Project on the tributaries of Kamala river. All the above projects are ROR projects with pondage provisions to meet the peaking requirements only except the Subansiri Middle and Subansiri Upper HE Projects which have the provisions of flood cushions of 15 m and 10 m respectively for the flood mitigation measures apart from the pondage provisions. Hence for downstream impact study due to peaking releases from these projects during the non-monsoon the following considerations have been made:

- Environmental flow and peaking releases of all the projects located upstream of Subansiri Upper HE Project will be re-regulated from Subansiri upper HE Project to meet its environmental flow and peaking discharge requirements

- Environmental flow and peaking releases of all the projects located upstream of Subansiri Middle (Kamala HE Project) will be re-regulated from Subansiri middle HE Project to meet its environmental flow and peaking discharge requirements

- Environmental flow and peaking releases of Subansiri upper and Subansiri middle HE Projects will be re-regulated from Subansiri lower HE Project for its environmental flow release and peaking release requirements

- Water availability at Subansiri lower HE Project shall be the sum of water availability of Subansiri upper HE project, Subansiri middle HE Project and contribution of intermediate catchment

Subansiri upper and Subansiri middle HE Projects are proposed about 90 km and 75 km upstream of Subansiri lower HE project on Subansiri and Kamala River respectively. The locations of Subansiri upper, Subansiri Middle (Kamala HEP) and Subansiri lower HE Projects is shown in **Figure 9.1**.

Figure 9.1: Location of Subansiri upper, Subansiri middle and Subansiri Lower HE Projects

The typical tentative 24 hour environmental and peaking releases during the non-monsoon period from Subansiri upper, Subansiri middle and Subansiri lower HE Projects as obtained from the concerned project authorities are as follows:

Table 9.1: Non-monsoon Environmental release and peaking release from projects

Time (hr)	Non-monsoon release from Subansiri upper HE Project (cumec)	Non-monsoon release from Subansiri middle HE Project (cumec)	Non-monsoon release from Subansiri lower HE Project (cumec)
1	17.67	48.6	240.00
2	17.67	48.6	240.00
3	17.67	48.6	240.00
4	17.67	48.6	240.00
5	17.67	48.6	240.00
6	17.67	48.6	240.00
7	17.67	48.6	240.00
8	17.67	48.6	240.00
9	17.67	48.6	240.00
10	17.67	48.6	240.00

Time (hr)	Non-monsoon release from Subansiri upper HE Project (cumec)	Non-monsoon release from Subansiri middle HE Project (cumec)	Non-monsoon release from Subansiri lower HE Project (cumec)
11	1080	1162.3	240.00
12	1080	1162.3	2579.20
13	1080	1162.3	2579.20
14	17.67	48.6	2579.20
15	17.67	48.6	240.00
16	17.67	48.6	240.00
17	17.67	48.6	240.00
18	17.67	48.6	240.00
19	17.67	48.6	240.00
20	17.67	48.6	240.00
21	17.67	48.6	240.00
22	17.67	48.6	240.00
23	17.67	48.6	240.00
24	17.67	48.6	240.00

For the above discharge series the daily volume of water released from Subansiri upper, Subansiri middle and Subansiri lower HE Projects will be about 13 MCM, 16.23 MCM and 60.35 MCM respectively. Further, in case of three hours peaking from Subansiri lower HE Project the daily released volume of water will be about 52.23 MCM. Hence the peaking and environmental flow release requirement of Subansiri lower project can only be met out of the release from Subansiri upper and Subansiri middle projects along with inflow contribution from the intermediate catchment. The average water availability during the November to April at Subansiri lower HE Project is shown in **Table 9.2**.

Table 9.2: Average 10 daily discharge series from November to April at Subansiri Lower HE Project

Month	10-daily	Discharge (cumec)	Volume (MCM)
Nov	I	649.22	560.93
	II	553.93	478.59
	III	492.69	425.69
Dec	I	458.90	396.49
	II	412.36	356.28
	III	384.73	365.65
Jan	I	364.73	315.13
	II	350.94	303.21
	III	372.95	354.46
Feb	I	403.22	348.38
	II	405.44	350.30
	III	428.13	295.93
Mar	I	572.10	494.29
	II	633.69	547.51
	III	679.71	645.99
Apr	I	757.27	654.28
	II	802.55	693.40
	III	959.34	828.87
Average		537.88	

The storage of Subansiri lower project between FRL and MDDL is about 645 MCM. From the above water availability series and 60.35 MCM daily water requirements for 4 hour peaking and environmental release and 52.23 MCM daily water requirements for 3hours peaking and environmental release, it is quite clear that 4 hours peaking will be possible in 3rd 10 daily of March and April months only. Further, with the planned use of available storage between FRL and MDDL along with the water availability series at Subansiri lower site, the 3 hours peaking can be expected for rest of the non-monsoon duration.

9.2 Discharge series adopted for downstream impact study

From the discussions of para 2.0, it is clear that for downstream impact study due to peaking releases from the projects in Subansiri basin, only the net release from the lower most project of the basin i.e Subansiri lower project will matter. Accordingly the downstream impact study has been carried out for the following two cases:

1. Peaking release of 2579.2 cumec for 3 hours and environmental flow release of 240 cumec for rest of the 21 hours for every 24 hours cycle, from Subansiri lower HE Project

2. Peaking release of 2579.2 cumec during the 4 hours and environmental flow release of 240 cumec for rest of the 20 hours for every 24 hours cycle, from Subansiri lower HE Project

The above two release conditions from Subansiri Lower HE Project has been hydro dynamically channel routed along with the available natural flow in post project condition at different downstream locations to get the resulting discharge and water level pattern at salient locations of Subansiri and Brahmaputra rivers, using the HEC-RAS software developed by HEC, US Army Corps of Engineers. The same has been compared with the average non-monsoon discharge and water level pattern at these locations in pre project (natural condition) scenario.

The pre project (natural condition) discharge at salient locations has been computed in catchment area proportion based on the Pandu G&D site discharge data provided by CWC and approved water availability series of Siang lower and Subansiri lower HE Projects. Pandu G&D site is located on river Brahmaputra near Guwahati where the catchment area is about 417100 sq.km. The catchment area at Siang lower HE project is 250594 sq.km. The average flow at Pandu G&D site and at Siang lower HE project site during November to April is given in **Table 9.3**.

Table 9.3: Average non-monsoon flow at Pandu G&D site and Siang Lower HE Project

Month	Average flow at Pandu G&D Site (cumec)	Average flow at Siang Lower HE project Site (cumec)
November	7713	1936
December	4845	1285
January	3506	1021
February	3184	1004
March	4352	1284
April	8663	2040
Average	5377	1428

The catchment area of Brahmaputra River near Kaziranga, Tezpur and Guwahati (Pandu G&D Site) has been approximated as 363958, 379088 and 417100 sq.km respectively. Accordingly, on the basis of catchment area proportion the pre project (natural condition) average non-monsoon flow in Brahmaputra near Kaziranga, Tezpur and Guwahati (Pandu G&D Site) has been worked out as 4117, 4447 and 5377 cumec respectively. For the Subansiri River the average non-monsoon flow has been adopted as 538 cumec from the approved series of Subansiri lower HEP. The same have been used for hydro dynamic simulation in HEC-RAS to estimate the natural condition scenario.

For the post project scenario the average natural non-monsoon flow of Subansiri river has been considered to be released as peaking and environmental flow. Hence, the average post project non-monsoon flow in Brahmaputra near Kaziranga, Tezpur and Guwahati (Pandu G&D Site) has been adopted 3579, 3937 and 4839 cumec respectively for the HEC-RAS simulation, which is about 538 cumec less than the pre project scenario.

9.3 HEC-RAS Model

Hydrologic Engineering Center's River Analysis System (HEC-RAS) software is designed to perform one-dimensional steady, unsteady flow hydraulics, sediment transport/mobile bed computations, and water temperature modeling.

HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. *Unsteady Flow Simulation* component of the HEC-RAS modeling system is capable of simulating one-dimensional unsteady flow through a full network of open channels. The model can perform mixed flow regime (subcritical, supercritical, hydraulic jumps, and draw downs) calculations in the unsteady flow computations module.

The physical laws which govern the flow of water in a stream are: (1) the principle of conservation of mass (continuity), and (2) the principle of conservation of momentum. These laws are expressed mathematically in the form of partial differential equations, known as the continuity and momentum equations. These equations are:

i. **Continuity equation**

$$(\partial Q/\partial X) + \partial (A + A_0) / \partial t - q = 0$$

ii. **Momentum equation**

$$(\partial Q/\partial t) + \{\partial (Q^2/A)/\partial X\} + g\, A\, ((\partial h/\partial X) + S_f + S_c) = 0$$

Where Q = discharge; A = active flow area; A_0 = inactive storage area;
h = water surface elevation; q= lateral outflow;
x = distance along waterway; t = time; S_f = friction slope;
S_c = expansion contraction slope; g = gravitational acceleration

The most successful and accepted procedure for solving the one dimensional unsteady flow equations is the four-point implicit scheme, also known as the box scheme. The same has been used in HEC-RAS. The river reach in the model is represented by a number of cross sections. The solution of flow parameters like time series of discharge, and water level is computed by the model for the upstream and downstream boundary conditions.

Upstream boundary conditions are required at the upstream end of all reaches that are not connected to other reaches or storage areas. An upstream boundary condition is applied as a flow hydrograph of discharge versus time.

Downstream boundary conditions are required at the downstream end of all reaches which are not connected to other reaches or storage areas. Four types of downstream boundary conditions can be specified:

- a stage hydrograph
- a flow hydrograph
- a single-valued rating curve
- normal depth from Manning's equation

9.4 HEC-RAS Model set up for downstream impact study

The study river reach of Subansiri and Brahmaputra River from Subansiri lower HE Project up to downstream of Guwahati has been represented in HEC-RAS model by the surveyed river cross sections. The Subansiri River from Subansiri lower HE project up to its Confluence with Brahmaputra has been represented by 9 numbers of cross sections at an interval of 10 km. The length of river in this reach is about 90 km. The Brahmaputra river from Subansiri-Brahmaputra confluence up to downstream of Guwahati has been represented by 8 number of river cross sections. The length of this reach of river is about 260 km. The Manning's roughness coefficient for the entire river reach has been assumed as 0.030. The peaking and environmental flow release of 24 hour cycle repeated for 30 days has been applied as upstream boundary of the model set up at the first cross section of Subansiri River located about 0.2 km downstream of Subansiri lower HE Project. The average post project non-monsoon discharge of 3579, 3937 and 4839 cumec has been applied as lateral inflow at river cross sections near Kaziranga, Tezpur and Guwahati respectively. The downstream boundary of the model set up, which has been assumed as normal depth, applied at the downstream most cross section of the set up. The HEC-RAS Model set up is shown in **Figure 9.2**. The plot of river cross sections at salient locations is given at **Annexure 9.1**.

9.5 Simulation results – Pre project scenario (natural condition of river)

For pre project scenario i.e natural condition of river the water levels has been simulated at different locations of river for an average non-monsoon discharge of 538 cumec in Subansiri, 4117 cumec in Brahmaputra near Kaziranga, 4447 cumec in Brahmaputra near Tezpur and 5377 cumec in Brahmaputra near Guwahati. The simulation results of pre project scenario as obtained from HEC-RAS are given in **Table 9.4**. These estimated water levels will be compared to indicate the relative fluctuation pattern in water level at salient locations downstream of Subansiri lower HE project due to peaking releases in post project scenario.

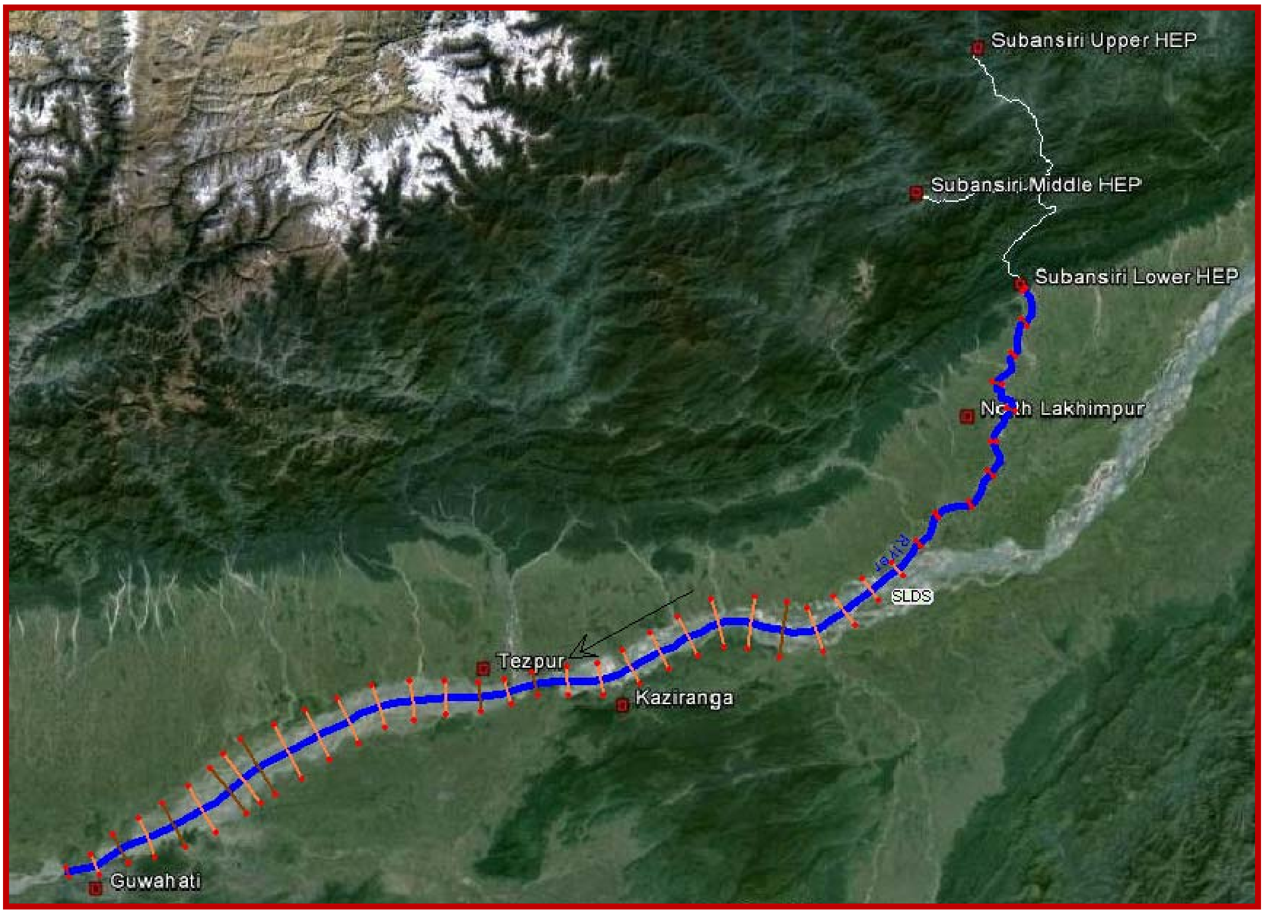

Figure 9.2: HEC-RAS Model set up for downstream impact study

Table 9.4: Discharge and simulated water level at different locations in pre project scenario (natural condition) of river

River	Chainage d/s of Subansiri Lower HEP	Nearest Place	Avg Non-monsoon discharge in Natural condition	Approximate bed level	Estimated water level
	[m]		[cumec]	[m]	[m]
Subansiri	40000	North Lakhimpur	538	89.01	92.55
Subansiri	89500	u/s of Brahmaputra confluence	538	72.39	83.72
Brahmaputra	188160	Bokaghat, Kaziranga	4117	71.80	81.99
Brahmaputra	221180	Tezpur	4475	67.22	74.92
Brahmaputra	328300	Guwahati	5377	30.96	40.63

9.6 Simulation results – Post project scenario (3 hours peaking)

For the post project scenario of 3 hours peaking the release from Subansiri lower HE Project has been considered as 2579.2 cumec for 3 hours and 240 cumec for rest of the 21 hours in a 24 hours cycle. The average post project non-monsoon flow in Brahmaputra near Kaziranga, Tezpur and Guwahati (Pandu G&D Site) has been adopted as 3579, 3937 and 4839 cumec respectively and the same applied as lateral inflow in the model set up. The time series of discharge and water level obtained at salient locations are discussed in subsequent paragraphs.

9.7 Simulation results of post project scenario at Subansiri river near North Lakhimpur for 3 hours peaking

The location Subansiri River near North Lakhimpur is about 40 km downstream of Subansiri lower HE Project. For three hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge at Subansiri River near North Lakhimpur as obtained from HEC-RAS hydro dynamic simulation is plotted in **Figure 9.3**. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-40000 Flow represent the simulated discharge series in Subansiri river near North Lakhimpur, which is about 40000 m d/s of Subansiri lower HE project. The consequent time series of water level in Subansiri river near North Lakhimpur is shown in **Figure 9.4**, represented by notation River SLDS-40000 Stage.

For 24 hours cycle of 3 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Subansiri river near North Lakhimpur is given in **Table 9.5**, which shows that variation in discharge near North Lakhimpur is from 465 to 830 cumec, and consequent water level varies from 92.26 to 93.21m. The pre project scenario (natural condition) discharge and water level at this location is 538 cumec and 92.55 m respectively.

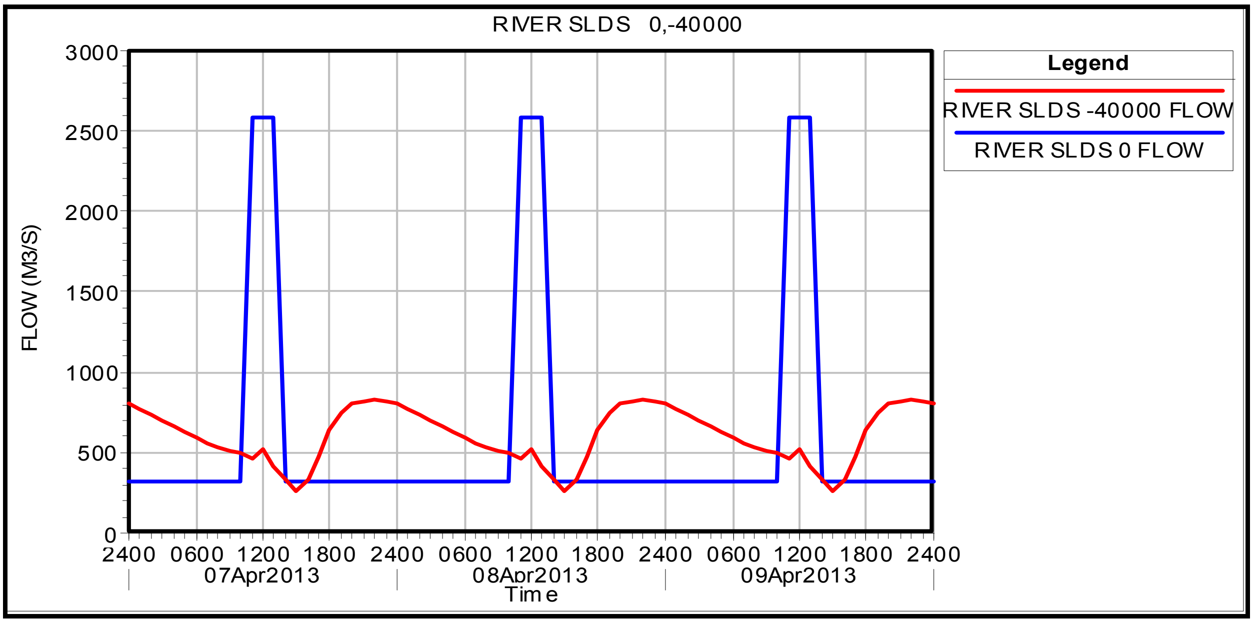

Figure 9.3: Release from Subansiri lower HE Project for 3 hours peaking and simulated discharge series in Subansiri River near North Lakhimpur

(Note: the dates shown on time axis are not the absolute dates but the dates as used for HEC-RAS simulation)

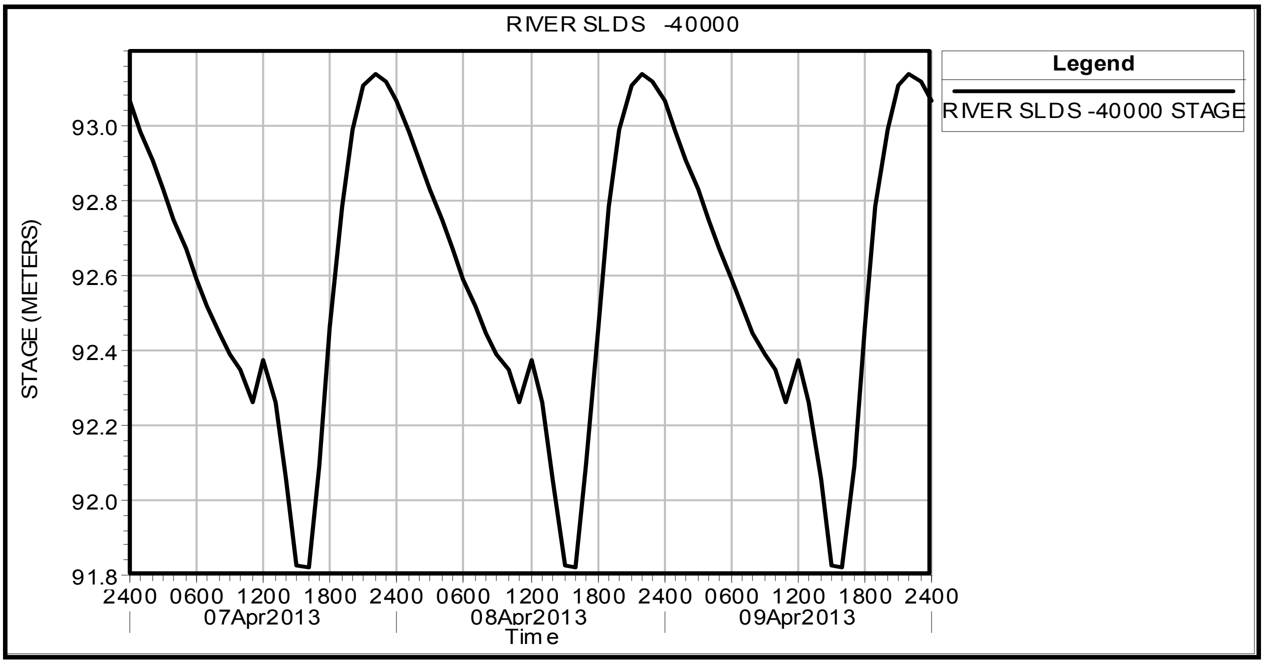

Figure 9.4: Simulated water level series in Subansiri River near North Lakhimpur due to 3 hours peaking release from Subansiri lower HE Project

Table 9.5: Release from Subansiri lower HE Project for 3 hour peaking and simulated discharge and water level in Subansiri River near North Lakhimpur

Time	Release from Subansiri lower HEP	Simulated discharge series in Subansiri River near North Lakhimpur	Simulated water level series in Subansiri River near North Lakhimpur
(hr)	(cumec)	(cumec)	(m)
1	240.00	800.80	93.06
2	240.00	770.55	92.99
3	240.00	739.24	92.91
4	240.00	701.25	92.83
5	240.00	663.85	92.75
6	240.00	627.01	92.67

Time	Release from Subansiri lower HEP	Simulated discharge series in Subansiri River near North Lakhimpur	Simulated water level series in Subansiri River near North Lakhimpur
(hr)	(cumec)	(cumec)	(m)
7	240.00	591.98	92.59
8	240.00	559.50	92.52
9	240.00	534.47	92.45
10	240.00	514.20	92.39
11	240.00	495.89	92.35
12	2579.20	464.48	92.26
13	2579.20	527.59	92.37
14	2579.20	418.69	92.26
15	240.00	336.62	92.06
16	240.00	266.05	91.83
17	240.00	327.56	91.82
18	240.00	471.15	92.09
19	240.00	639.38	92.46
20	240.00	750.11	92.78
21	240.00	801.07	92.99
22	240.00	821.78	93.11
23	240.00	829.98	93.14
24	240.00	822.34	93.12

9.8 Simulation results of post project scenario at Subansiri River Just upstream of Brahmaputra confluence for 3 hours peaking

The location Subansiri River just upstream of Brahmaputra confluence is about 89.5 km downstream of Subansiri lower HE Project. For 3 hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge in Subansiri River at this location as obtained from HEC-RAS hydro dynamic simulation is plotted in Figure-4. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-89500 Flow represent the simulated discharge series in Subansiri river just upstream of Brahmaputra confluence. The consequent time series of water level in Subansiri river just upstream of Brahmaputra confluence is shown in Figure-4.1, represented by notation River SLDS-89500 Stage.

For 24 hours cycle of 3 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Subansiri river just upstream of Brahmaputra confluence is given in Table-6, which shows that variation in discharge near Brahmaputra confluence is from 405 to 758 cumec, and consequent water level varies from 83.76 to 83.77m hardly 1 cm. The pre project scenario (natural condition) discharge and water level at this location is 538 cumec and 83.72m respectively.

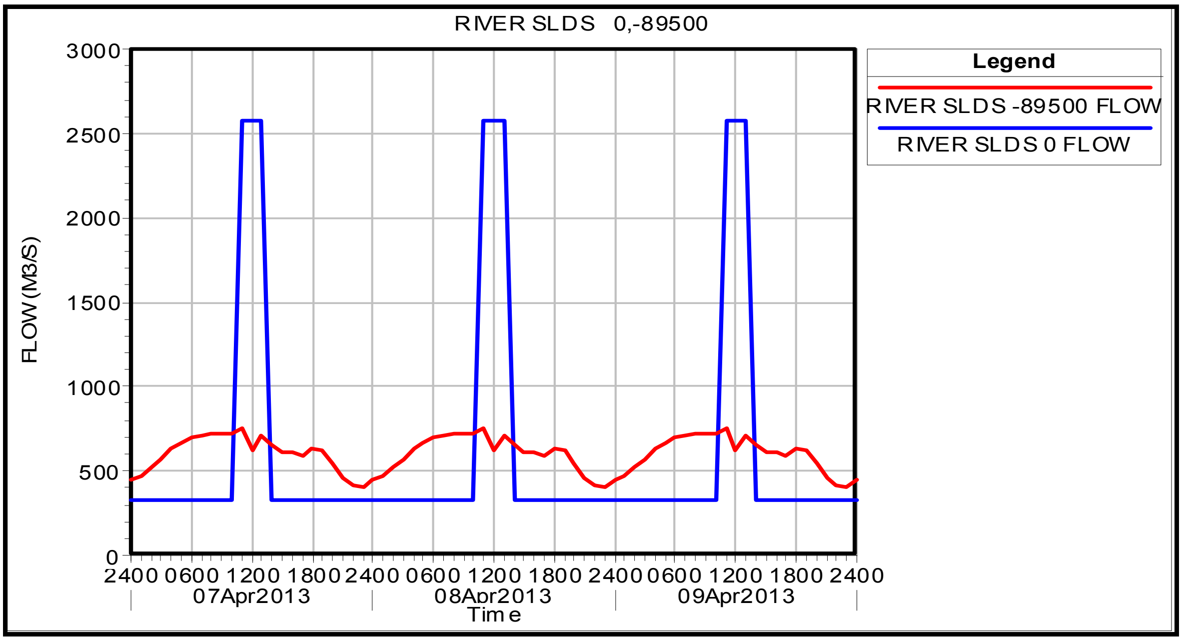

Figure 9.5: Release from Subansiri lower HE Project for 3 hours peaking and simulated discharge series in Subansiri River just upstream of Brahmaputra confluence

(Note: the dates shown on time axis are not the absolute dates but the dates as used for HEC-RAS simulation)

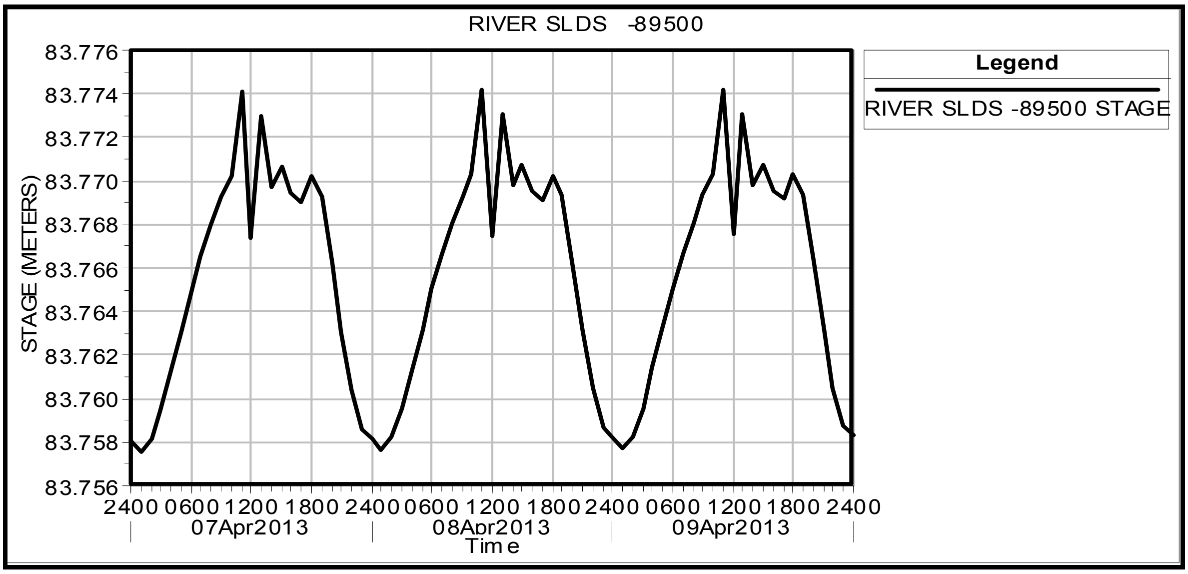

Figure 9.6: Simulated water level series in Subansiri River just upstream of Brahmaputra confluence due to 3 hours peaking release from Subansiri lower HE Project

Table 9.6: Release from Subansiri lower HE Project for 3 hour peaking and simulated discharge and water level in Subansiri river near North Lakhimpur

Time	Release from Subansiri lower HEP	Simulated discharge series in Subansiri River just upstream of Brahmaputra confluence	Simulated water level series in Subansiri River just upstream of Brahmaputra confluence
(hr)	(cumec)	(cumec)	(m)
1	240.00	443.41	83.76
2	240.00	474.00	83.76
3	240.00	518.76	83.76
4	240.00	571.72	83.76
5	240.00	627.42	83.76

Time	Release from Subansiri lower HEP	Simulated discharge series in Subansiri River just upstream of Brahmaputra confluence	Simulated water level series in Subansiri River just upstream of Brahmaputra confluence
6	240.00	669.08	83.76
7	240.00	697.93	83.76
8	240.00	713.56	83.77
9	240.00	720.95	83.77
10	240.00	722.40	83.77
11	240.00	719.18	83.77
12	2579.20	757.83	83.77
13	2579.20	625.03	83.77
14	2579.20	706.80	83.77
15	240.00	656.08	83.77
16	240.00	610.03	83.77
17	240.00	605.62	83.77
18	240.00	590.30	83.77
19	240.00	634.39	83.77
20	240.00	621.49	83.77
21	240.00	540.94	83.77
22	240.00	456.72	83.76
23	240.00	411.07	83.76
24	240.00	404.42	83.76

9.9 Simulation results of post project scenario at Brahmaputra near Kaziranga for 3 hours peaking

The location Brahmaputra near Kaziranga is about 188 km downstream of Subansiri lower HE Project. For 3 hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge in Brahmaputra near Kaziranga as obtained from HEC-RAS hydro dynamic simulation is plotted. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-188160 Flow represent the simulated discharge series in Brahmaputra near Kaziranga. The consequent time series of water level in Brahmaputra near Kaziranga is shown in **Figure 9.7** & **Figure 9.8**, represented by notation River SLDS-188160 Stage.

For 24 hours cycle of 3 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Brahmaputra near Kaziranga is given in **Table 9.7**, which shows that variation in discharge near Kaziranga is from 4172 to 4186 cumec, and consequent water level varies from 82.04 m to 82.05 m hardly 1 cm. The pre project scenario (natural condition) discharge and water level at this location is 4177 cumec and 81.99 m respectively. Hence at this location there is practically no change in discharge and water level pattern due to peaking release from Subansiri lower HE Project.

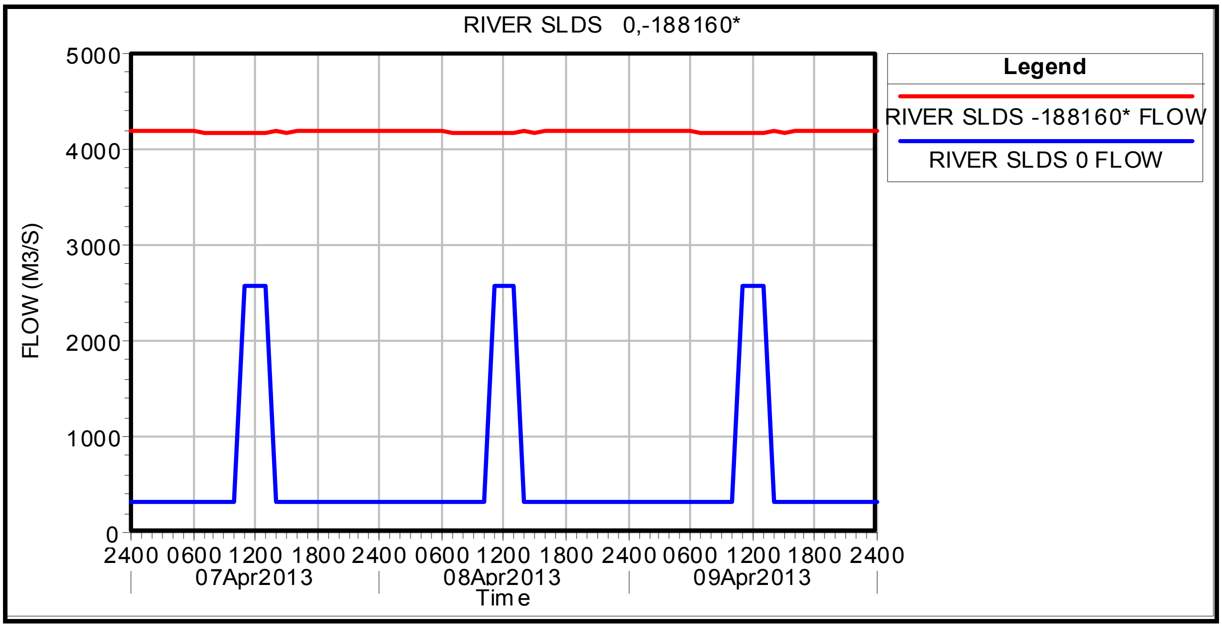

Figure 9.7: Release from Subansiri lower HE Project for 3 hours peaking and simulated discharge series in Brahmaputra near Kaziranga

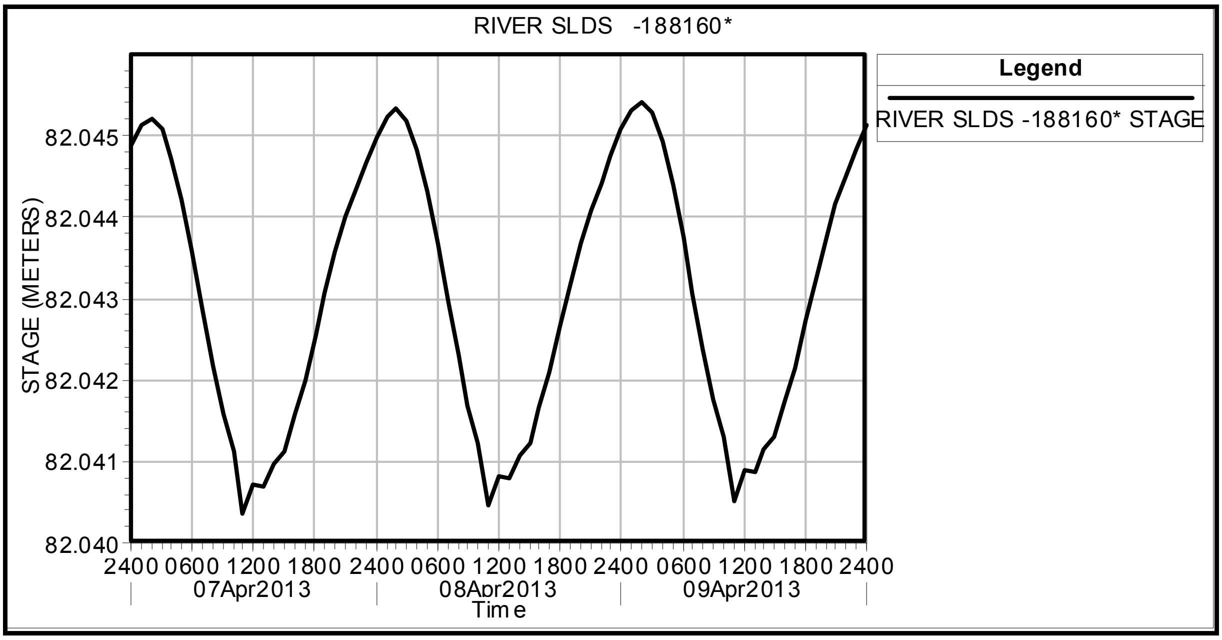

Figure 9.8: Simulated water level series in Brahmaputra near Kaziranga due to 3 hours peaking release from Subansiri lower HE Project

Table 9.7: Release from Subansiri lower HE Project for 3 hour peaking and simulated discharge and water level in Brahmaputra near Kaziranga

Time	Release from Subansiri lower HEP	Simulated discharge series in Brahmaputra near Kaziranga	Simulated water level series in Brahmaputra near Kaziranga
(hr)	(cumec)	(cumec)	(m)
1	240.00	4185.69	82.04
2	240.00	4185.69	82.05
3	240.00	4185.27	82.05
4	240.00	4184.36	82.05
5	240.00	4183.26	82.04
6	240.00	4182.08	82.04
7	240.00	4180.98	82.04
8	240.00	4179.93	82.04
9	240.00	4179.17	82.04

Time	Release from Subansiri lower HEP	Simulated discharge series in Brahmaputra near Kaziranga	Simulated water level series in Brahmaputra near Kaziranga
10	240.00	4178.71	82.04
11	240.00	4178.57	82.04
12	2579.20	4171.54	82.04
13	2579.20	4180.38	82.04
14	2579.20	4179.15	82.04
15	240.00	4181.10	82.04
16	240.00	4179.34	82.04
17	240.00	4181.92	82.04
18	240.00	4182.35	82.04
19	240.00	4183.57	82.04
20	240.00	4183.97	82.04
21	240.00	4184.69	82.04
22	240.00	4184.89	82.04
23	240.00	4185.04	82.04
24	240.00	4185.47	82.04

9.10 Simulation results of post project scenario at Brahmaputra near Tezpur for 3 hours peaking

The location Brahmaputra near Tezpur is about 221 km downstream of Subansiri lower HE Project. For 3 hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge in Brahmaputra near Tezpur as obtained from HEC-RAS hydro dynamic simulation is plotted in Figure-6. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-221180 Flow represent the simulated discharge series in Brahmaputra near Tezpur. The consequent time series of water level in Brahmaputra near Tezpur is shown in **Figure 9.9** & **Figure 9.10**, represented by notation River SLDS-221180 Stage.

For 24 hours cycle of 3 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Brahmaputra river near Tezpur is given in **Table 9.8**, which shows that variation in discharge near Tezpur is from 4538 to 4543 cumec, and consequent water level remains constant at EL 74.95 m. The pre project scenario (natural condition) discharge and water level at this location is 4475 cumec and 74.92 m respectively. Hence at this location also there is practically no change in discharge and water level pattern due to peaking release from Subansiri lower HE Project.

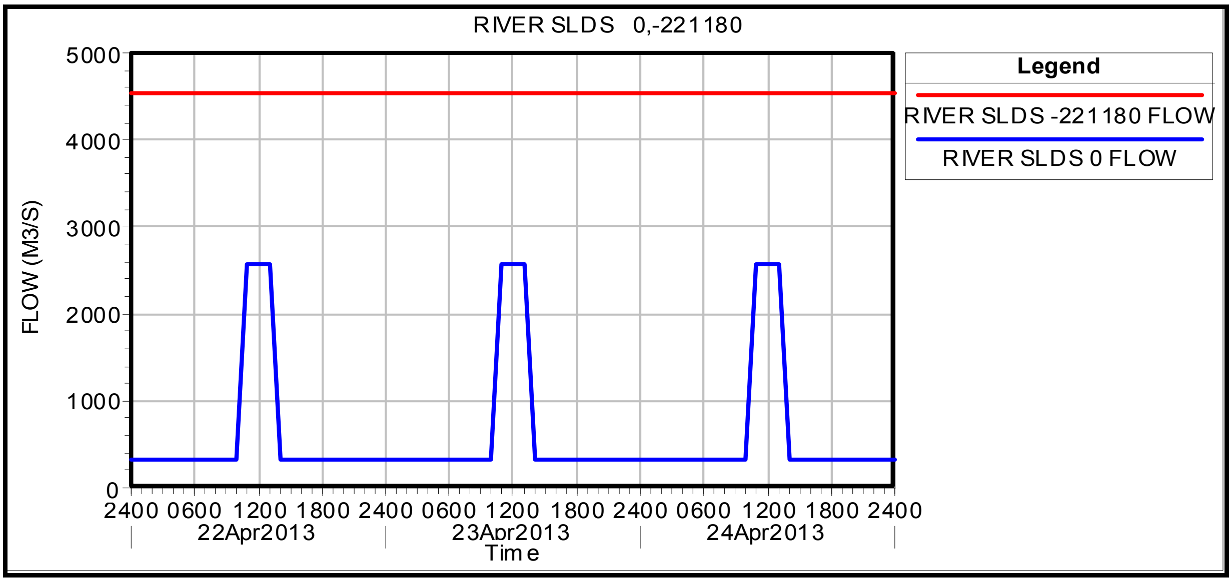

Figure 9.9: Release from Subansiri lower HE Project for 3 hours peaking and simulated discharge series in Brahmaputra near Tezpur

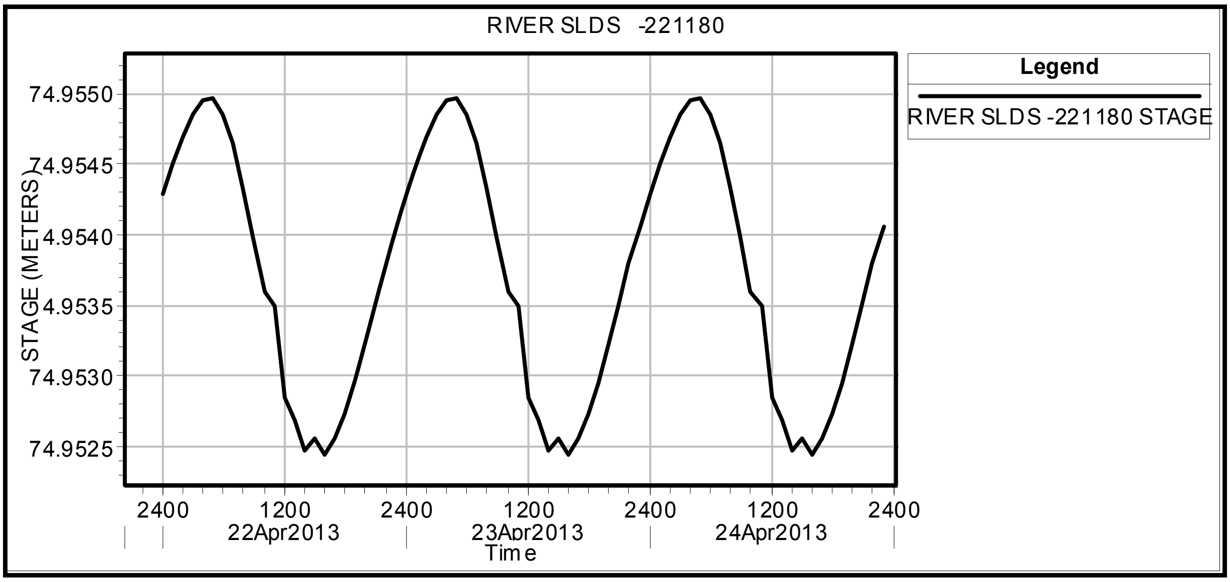

Figure 9.10: Simulated water level series in Brahmaputra near Tezpur due to 3 hours peaking release from Subansiri lower HE Project

Table 9.8: Release from Subansiri lower HE Project for 3 hour peaking and simulated discharge and water level in Brahmaputra near Tezpur

Time	Release from Subansiri lower HEP	Simulated discharge series in Brahmaputra near Tezpur	Simulated water level series in Brahmaputra near Tezpur
(hr)	(cumec)	(cumec)	(m)
1	240.00	4542.02	74.95
2	240.00	4542.45	74.95
3	240.00	4542.87	74.95
4	240.00	4543.19	74.95
5	240.00	4543.40	74.95
6	240.00	4543.37	74.95
7	240.00	4543.10	74.95
8	240.00	4542.62	74.95
9	240.00	4541.95	74.95
10	240.00	4541.20	74.95
11	240.00	4540.39	74.95
12	2579.20	4541.22	74.95
13	2579.20	4538.96	74.95
14	2579.20	4538.63	74.95
15	240.00	4538.01	74.95
16	240.00	4538.73	74.95
17	240.00	4538.06	74.95
18	240.00	4538.39	74.95
19	240.00	4538.73	74.95
20	240.00	4539.23	74.95
21	240.00	4539.79	74.95
22	240.00	4540.37	74.95
23	240.00	4540.98	74.95
24	240.00	4541.53	74.95

9.11 Simulation results of post project scenario at Brahmaputra near Guwahati for 3 hours peaking

The location Brahmaputra near Guwahati is about 328 km downstream of Subansiri lower HE Project. For 3 hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge in Brahmaputra near Guwahati as obtained from HEC-RAS hydro dynamic simulation is plotted in Figure-7. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-328300 Flow represent the simulated discharge series in Brahmaputra near Guwahati. The consequent time series of water level in Brahmaputra near Guwahati is shown in **Figure 9.11** & **Figure 9.12**, represented by notation River SLDS-328300 Stage.

For 24 hours cycle of 3 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Brahmaputra river near Guwahati is given in **Table 9.9**, which shows discharge near Guwahati is about 5443 cumec, and consequent water level remains constant at EL 40.66 m. The pre project scenario (natural condition) discharge and water level at this location is 5377 cumec and 40.63 m respectively. Hence at this location also there is practically no change in discharge and water level pattern due to peaking release from Subansiri lower HE Project.

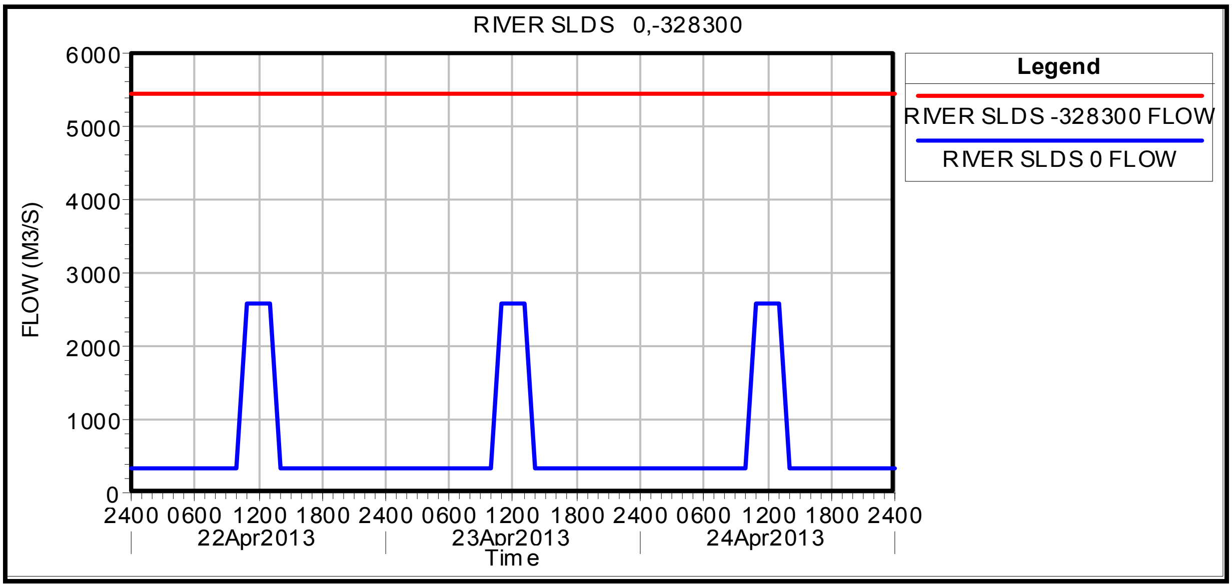

Figure 9.11: Release from Subansiri lower HE Project for 3 hours peaking and simulated discharge series in Brahmaputra near Guwahati

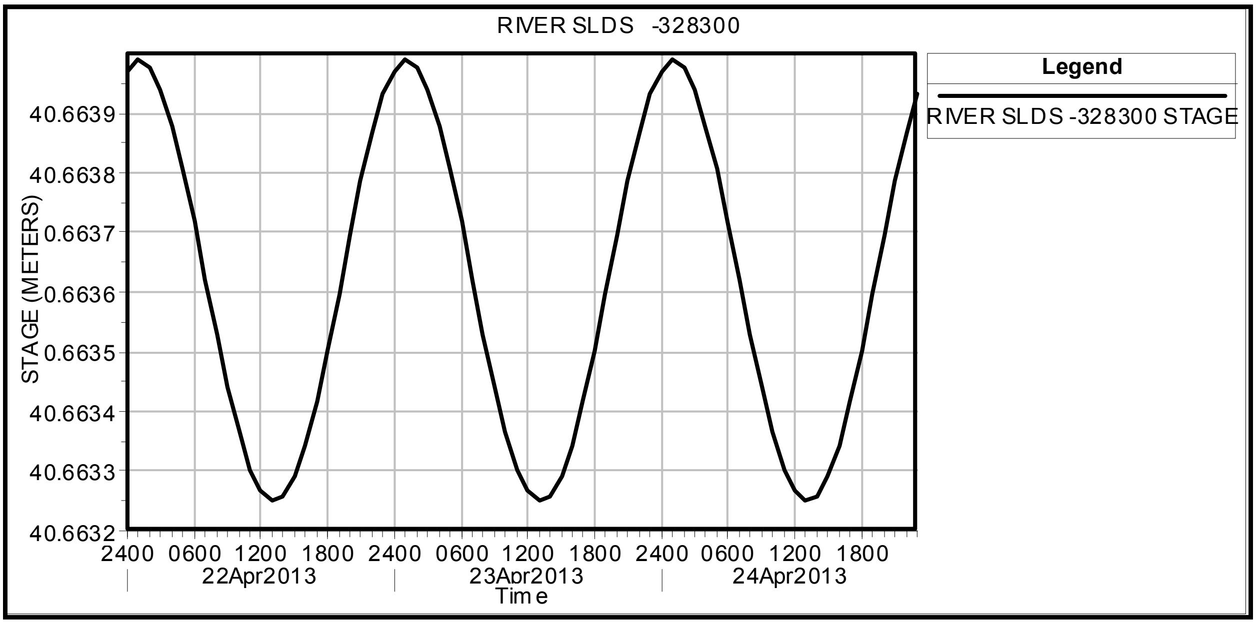

Figure 9.12: Simulated water level series in Brahmaputra near Guwahati due to 3 hours peaking release from Subansiri lower HE Project

Table 9.9: Release from Subansiri lower HE Project for 3 hour peaking and simulated discharge and water level in Brahmaputra near Guwahati

Time	Release from Subansiri lower HEP	Simulated discharge series in Brahmaputra near Guwahati	Simulated water level series in Brahmaputra near Guwahati
(hr)	(cumec)	(cumec)	(m)
1	240.00	5443.38	40.66
2	240.00	5443.39	40.66
3	240.00	5443.34	40.66
4	240.00	5443.26	40.66
5	240.00	5443.14	40.66
6	240.00	5442.99	40.66
7	240.00	5442.82	40.66
8	240.00	5442.65	40.66
9	240.00	5442.48	40.66
10	240.00	5442.34	40.66
11	240.00	5442.20	40.66
12	2579.20	5442.12	40.66
13	2579.20	5442.06	40.66
14	2579.20	5442.05	40.66
15	240.00	5442.08	40.66
16	240.00	5442.16	40.66
17	240.00	5442.27	40.66
18	240.00	5442.42	40.66
19	240.00	5442.58	40.66
20	240.00	5442.76	40.66
21	240.00	5442.93	40.66
22	240.00	5443.09	40.66
23	240.00	5443.23	40.66
24	240.00	5443.32	40.66

9.12 Simulation results – Post project scenario (4 hours peaking)

In this case the downstream impacts have been estimated for the non-monsoon peaking of 4 hour durations. Accordingly, the release from Subansiri lower HE Project has been considered as 2579.2 cumec for 4 hours and 240 cumec for rest of the 20 hours in a 24 hours cycle. The average post project non-monsoon flow in Brahmaputra near Kaziranga, Tezpur and Guwahati (Pandu G&D Site) has been adopted as 3579, 3937 and 4839 cumec respectively and the same applied as lateral inflow in the model set up. The findings are as follows.

9.13 Simulation results of post project scenario at Subansiri River near North Lakhimpur for 4 hours peaking

For 4 hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge at Subansiri River near North Lakhimpur as obtained from HEC-RAS hydro dynamic simulation is plotted in Figure-8. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-40000 Flow represent the simulated discharge series in Subansiri river near North Lakhimpur, The consequent time series of water level in Subansiri river near North Lakhimpur is shown in **Figure 9.13** & **Figure 9.14**, represented by notation River SLDS-40000 Stage.

For 24 hours cycle of 4 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Subansiri river near North Lakhimpur is given in **Table 9.10**, which shows that variation in discharge near North Lakhimpur is from 338 to 995 cumec, and consequent water level varies from 91.90 to 93.33 m. The fluctuation in water level is of the order of 1.43 m. The pre project scenario (natural condition) discharge and water level at this location is 538 cumec and 92.55 m respectively. In 24 hour cycle, the water level is about 0.6 m less in some of the hours and 0.8 m more in some of the hours in comparison to average natural condition water level.

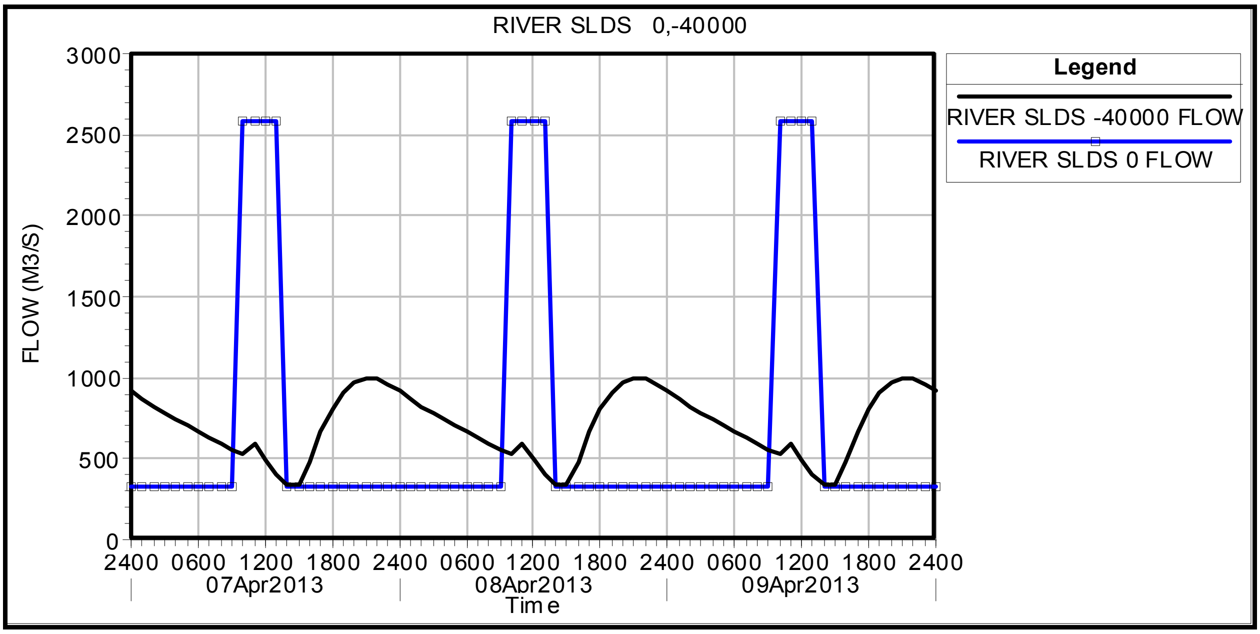

Figure 9.13: Release from Subansiri lower HE Project for 4 hours peaking and simulated discharge series in Subansiri River near North Lakhimpur

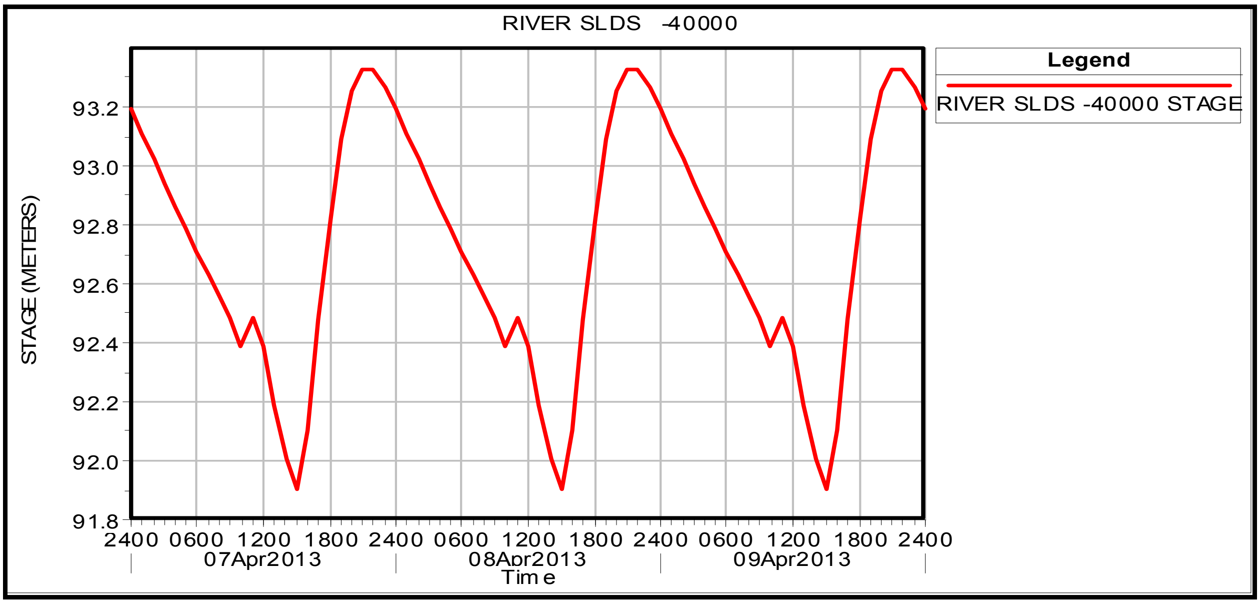

Figure 9.14: Simulated water level series in Subansiri River near North Lakhimpur due to 4 hours peaking release from Subansiri lower HE Project

Table 9.10: Release from Subansiri Lower HE Project for 4 hours peaking and simulated discharge and water level in Subansiri River near North Lakhimpur

Time	Release from Subansiri lower HEP	Simulated discharge series in Subansiri River near North Lakhimpur	Simulated water level series in Subansiri River near North Lakhimpur
(hr)	(cumec)	(cumec)	(m)
1	240.00	916.18	93.19
2	240.00	870.03	93.11
3	240.00	825.45	93.02
4	240.00	779.22	92.94
5	240.00	741.28	92.86
6	240.00	703.09	92.79

Time	Release from Subansiri lower HEP	Simulated discharge series in Subansiri River near North Lakhimpur	Simulated water level series in Subansiri River near North Lakhimpur
(hr)	(cumec)	(cumec)	(m)
7	240.00	665.09	92.71
8	240.00	628.01	92.63
9	240.00	592.49	92.56
10	240.00	559.73	92.48
11	2579.20	530.77	92.39
12	2579.20	587.26	92.48
13	2579.20	492.28	92.38
14	2579.20	401.64	92.19
15	240.00	337.45	92.00
16	240.00	337.77	91.90
17	240.00	473.61	92.11
18	240.00	663.64	92.48
19	240.00	808.35	92.82
20	240.00	908.51	93.09
21	240.00	971.58	93.26
22	240.00	994.66	93.33
23	240.00	992.80	93.33
24	240.00	964.16	93.27

9.14 Simulation results of post project scenario at Subansiri river Just upstream of Brahmaputra confluence for 4 hours peaking

As per the HEC-RAS model set up the location Subansiri River just upstream of Brahmaputra confluence is about 89.5 km downstream of Subansiri lower HE Project. For 4 hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge in Subansiri River at this location as obtained from HEC-RAS hydro dynamic simulation is plotted in Figure-9. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-89500 Flow represent the simulated discharge series in Subansiri river just upstream of Brahmaputra confluence. The consequent time series of water level in Subansiri river just upstream of Brahmaputra confluence is shown in **Figure 9.15** & **Figure 9.16**, represented by notation River SLDS-89500 Stage.

For 24 hours cycle of 4 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Subansiri river just upstream of Brahmaputra confluence is given in Table-11, which shows that variation in discharge near Brahmaputra confluence is from 461 to 866 cumec, and consequent water level varies from 83.82 to 83.84 m, approximately 2 cm. The pre project scenario (natural condition) discharge and water level at this location is 538 cumec and 83.72m respectively. From pre project scenario the water level is about 10 cm more.

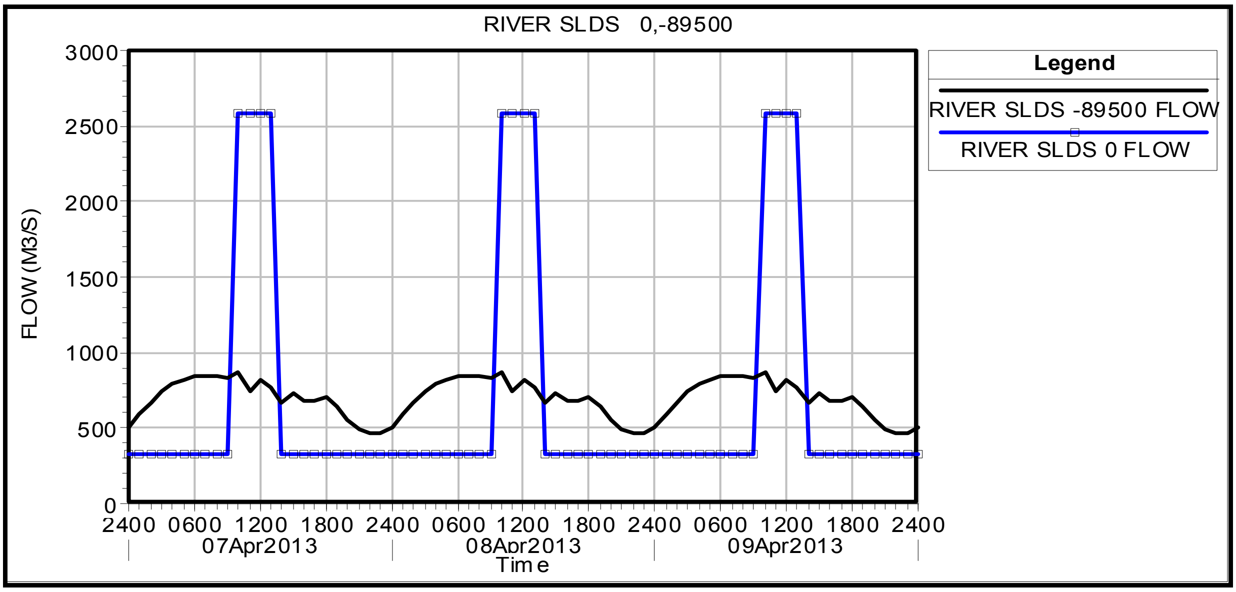

Figure 9.15: Release from Subansiri lower HE Project for 4 hours peaking and simulated discharge series in Subansiri River just upstream of Brahmaputra confluence

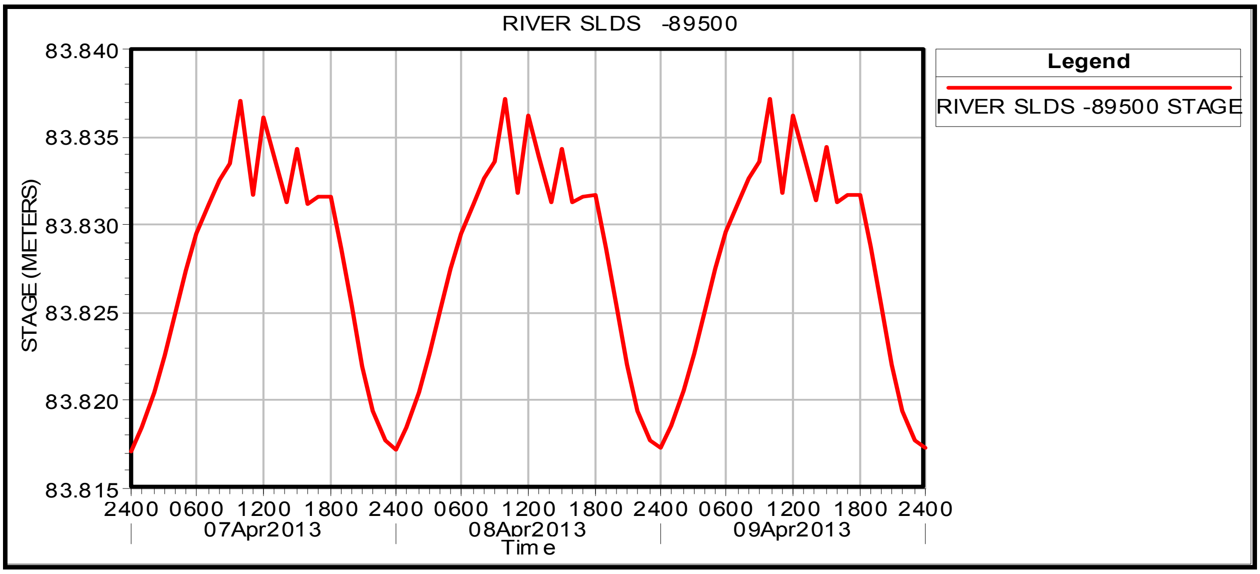

Figure 9.16: Simulated water level series in Subansiri River just upstream of Brahmaputra confluence due to 4 hours peaking release from Subansiri lower HE Project

Table 9.11: Release from Subansiri lower HE Project for 3 hour peaking and simulated discharge and water level in Subansiri River just upstream of Brahmaputra confluence

Time	Release from Subansiri lower HEP	Simulated discharge series in Subansiri River just upstream of Brahmaputra confluence	Simulated water level series in Subansiri River just upstream of Brahmaputra confluence
(hr)	(cumec)	(cumec)	(m)
1	240.00	510.36	83.82
2	240.00	588.57	83.82
3	240.00	673.15	83.82
4	240.00	738.42	83.82
5	240.00	788.24	83.83
6	240.00	823.14	83.83
7	240.00	842.74	83.83
8	240.00	848.43	83.83
9	240.00	845.53	83.83

Time	Release from Subansiri lower HEP	Simulated discharge series in Subansiri River just upstream of Brahmaputra confluence	Simulated water level series in Subansiri River just upstream of Brahmaputra confluence
(hr)	(cumec)	(cumec)	(m)
10	240.00	835.33	83.83
11	2579.20	866.08	83.84
12	2579.20	748.09	83.83
13	2579.20	816.47	83.84
14	2579.20	769.10	83.83
15	240.00	673.63	83.83
16	240.00	726.12	83.83
17	240.00	680.64	83.83
18	240.00	681.43	83.83
19	240.00	700.07	83.83
20	240.00	638.40	83.83
21	240.00	556.57	83.83
22	240.00	486.32	83.82
23	240.00	460.94	83.82
24	240.00	467.46	83.82

9.15 Simulation results of post project scenario at Brahmaputra near Kaziranga for 4 hours peaking

Brahmaputra near Kaziranga is about 188 km downstream of Subansiri lower HE Project. For 4 hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge in Brahmaputra near Kaziranga as obtained from HEC-RAS hydro dynamic simulation is plotted in **Figure 9.17**. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-188160 Flow represent the simulated discharge series in Brahmaputra near Kaziranga. The consequent time series of water level in Brahmaputra near Kaziranga is shown in **Figure 9.18**, represented by notation River SLDS-188160 Stage. For 24 hours cycle of 4 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Brahmaputra near Kaziranga is given in **Table 9.12**, which shows that variation in discharge near Kaziranga is from 4265 to 4281 cumec, and consequent water level stabilizes at EL 82.12 m. The pre project scenario (natural condition) discharge and water level at this location is 4177 cumec and 81.99 m respectively. Hence, at Tezpur the change in discharge and water level pattern due to peaking release from Subansiri lower HE Project is about 100 cumec and 13 cm respectively.

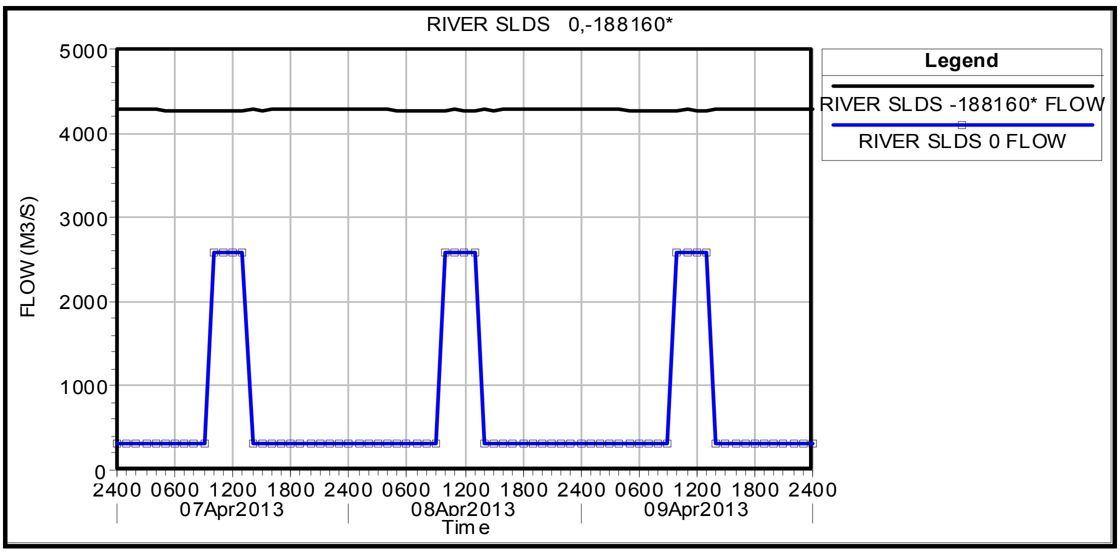

Figure 9.17: Release from Subansiri lower HE Project for 4 hours peaking and simulated discharge series in Brahmaputra near Kaziranga

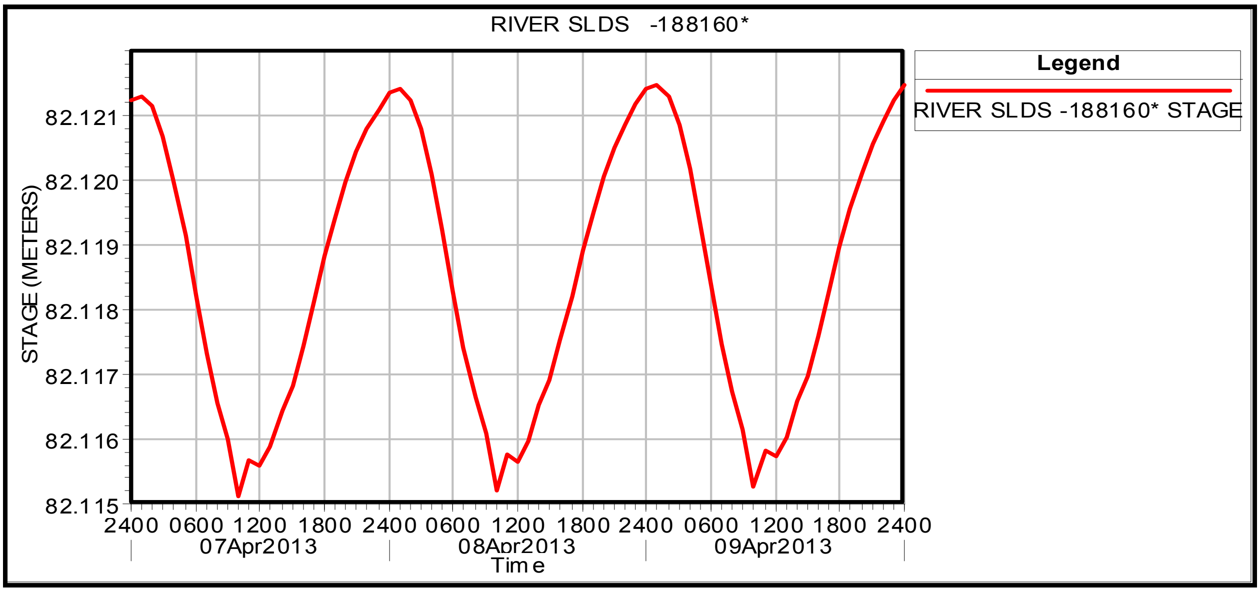

Figure 9.18: Simulated water level series in Brahmaputra near Kaziranga due to 4 hours peaking release from Subansiri lower HE Project

Table 9.12: Release from Subansiri Lower HE Project for 4 hours peaking and simulated discharge and water level in Brahmaputra near Kaziranga

Time	Release from Subansiri lower HEP	Simulated discharge series in Brahmaputra near Kaziranga	Simulated water level series in Brahmaputra near Kaziranga
(hr)	(cumec)	(cumec)	(m)
1	240.00	4280.95	82.12
2	240.00	4280.40	82.12
3	240.00	4279.42	82.12
4	240.00	4278.03	82.12
5	240.00	4276.46	82.12
6	240.00	4274.88	82.12
7	240.00	4273.50	82.12
8	240.00	4272.57	82.12
9	240.00	4272.08	82.12
10	240.00	4271.95	82.12
11	2579.20	4264.76	82.12
12	2579.20	4275.17	82.12
13	2579.20	4273.03	82.12
14	2579.20	4274.24	82.12
15	240.00	4276.98	82.12
16	240.00	4275.07	82.12
17	240.00	4277.54	82.12
18	240.00	4278.59	82.12
19	240.00	4279.38	82.12
20	240.00	4279.85	82.12
21	240.00	4280.38	82.12
22	240.00	4280.56	82.12
23	240.00	4280.86	82.12
24	240.00	4281.03	82.12

9.16 Simulation results of post project scenario at Brahmaputra near Tezpur for 4 hours peaking

As per HEC-RAS model set up the location Brahmaputra near Tezpur is about 221 km downstream of Subansiri lower HE Project. For 4 hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge in Brahmaputra near Tezpur as obtained from HEC-RAS hydro dynamic simulation is plotted in **Figure 9.19**. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-221180 Flow represent the simulated discharge series in Brahmaputra near Tezpur. The consequent time series of water level in Brahmaputra near Tezpur is shown in **Figure 9.20**, represented by notation River SLDS-221180 Stage.

For 24 hours cycle of 4 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Brahmaputra river near Tezpur is given in **Table 9.13**, which shows that variation in discharge near Tezpur is from 4632 to 4639 cumec, and consequent water level remains constant at EL 75 m. The pre project scenario (natural condition) discharge and water level at this location is 4475 cumec and 74.92 m respectively. Hence, at this location the change in discharge and water level pattern due to peaking release from Subansiri lower HE Project is about 165cumec and 8 cm respectively.

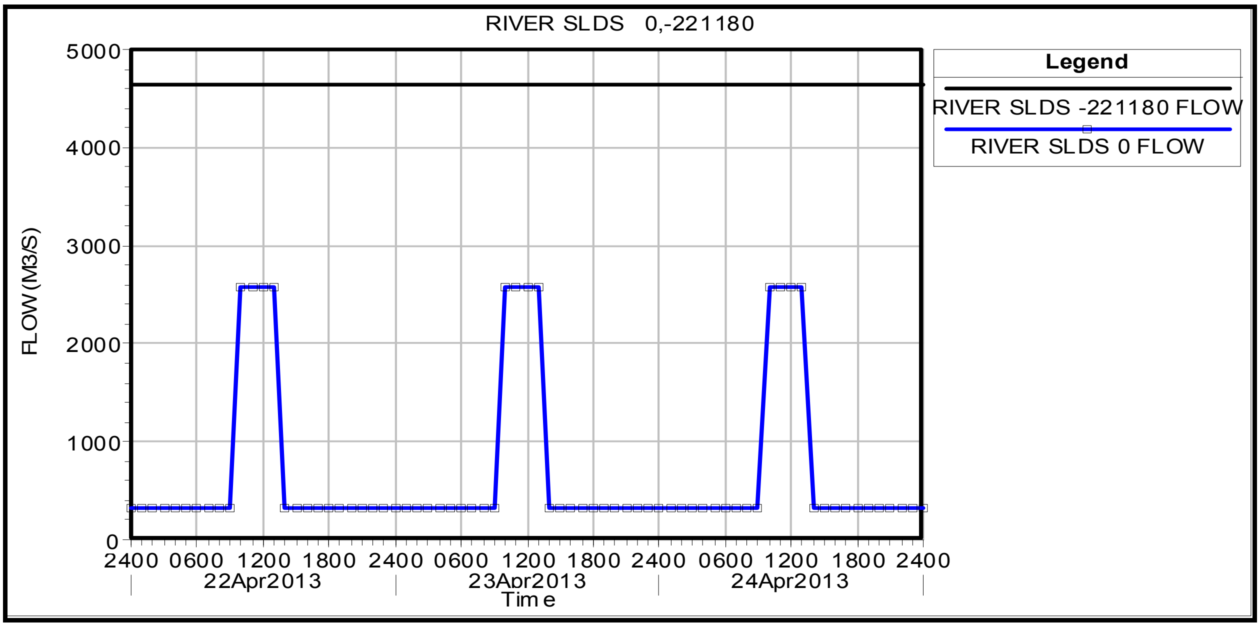

Figure 9.19: Release from Subansiri lower HE Project for 4 hours peaking and simulated discharge series in Brahmaputra near Tezpur

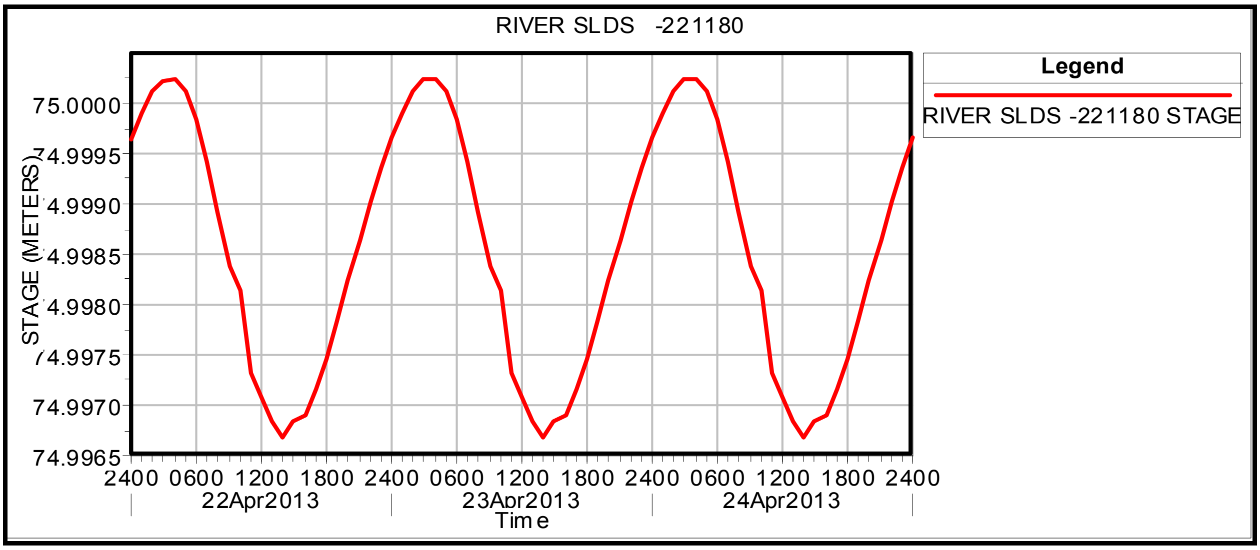

Figure 9.20: Simulated water level series in Brahmaputra near Tezpur due to 4 hours peaking release from Subansiri lower HE Project

Table 9.13: Release from Subansiri Lower HE Project for 4 hours peaking and simulated discharge and water level in Brahmaputra near Tezpur

Time	Release from Subansiri lower HEP	Simulated discharge series in Brahmaputra near Tezpur	Simulated water level series in Brahmaputra near Tezpur
(hr)	(cumec)	(cumec)	(m)
1	240.00	4637.52	75.00
2	240.00	4637.99	75.00
3	240.00	4638.35	75.00
4	240.00	4638.55	75.00
5	240.00	4638.50	75.00
6	240.00	4638.17	75.00
7	240.00	4637.57	75.00
8	240.00	4636.72	75.00
9	240.00	4635.74	75.00
10	240.00	4634.71	75.00
11	2579.20	4635.29	75.00
12	2579.20	4632.70	75.00
13	2579.20	4632.40	75.00
14	2579.20	4631.97	75.00
15	240.00	4631.59	75.00
16	240.00	4632.29	75.00
17	240.00	4632.25	75.00
18	240.00	4632.78	75.00
19	240.00	4633.41	75.00
20	240.00	4634.15	75.00
21	240.00	4634.91	75.00
22	240.00	4635.66	75.00
23	240.00	4636.37	75.00
24	240.00	4636.99	75.00

9.17 Simulation results of post project scenario at Brahmaputra near Guwahati for 4 hours peaking

The location Brahmaputra near Guwahati is about 328 km downstream of Subansiri lower HE Project. For 4 hours peaking, the time series of release from Subansiri lower HE Project and simulated discharge in Brahmaputra near Guwahati as obtained from HEC-RAS hydro dynamic simulation is plotted in **Figure 9.21**. In the plot River SLDS-0 Flow represent the release pattern from Subansiri lower HE project, while River SLDS-328300 Flow represent the simulated discharge series in Brahmaputra near Guwahati. The consequent time series of water level in Brahmaputra near Guwahati is shown in **Figure 9.22**, represented by notation River SLDS-328300 Stage.

For 24 hours cycle of 4 hours peaking, hourly release pattern from Subansiri lower HE Project and consequent discharge and water level series in Brahmaputra river near Guwahati is given in **Table 9.14**, which shows discharge near Guwahati is about 5537 cumec, and consequent water level remains constant at EL 40.72 m. The pre project scenario (natural condition) discharge and water level at this location is 5377 cumec and 40.63 m respectively. Hence, at Guwahati the change in discharge and water level pattern due to peaking release from Subansiri lower HE Project is about 160 cumec and 9 cm respectively.

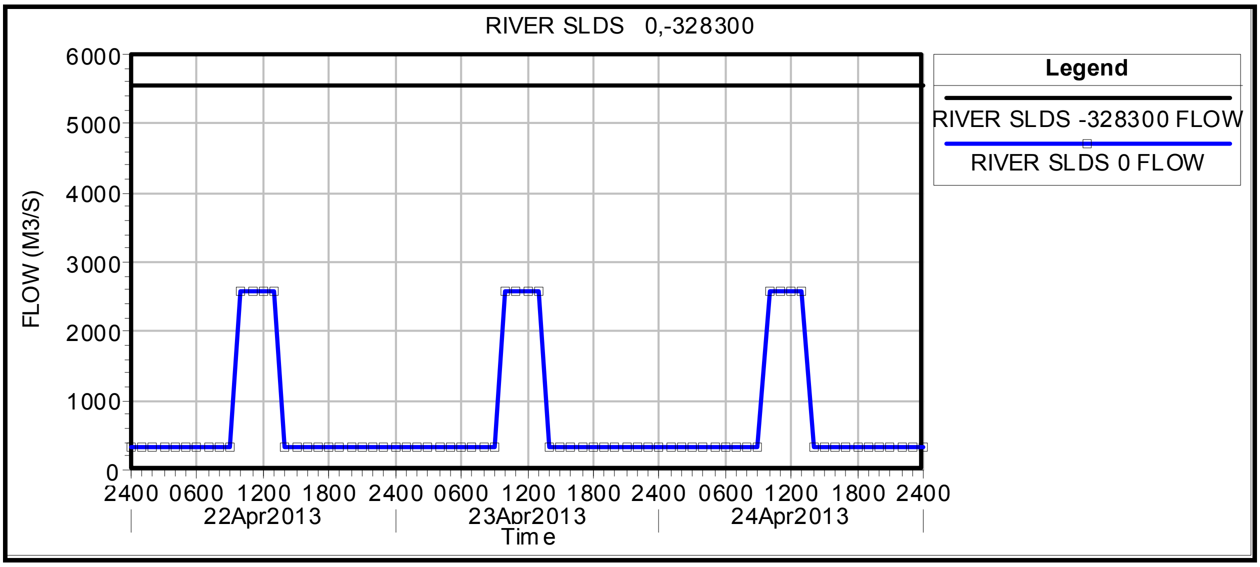

Figure 9.21: Release from Subansiri lower HE Project for 4 hours peaking and simulated discharge series in Brahmaputra near Guwahati

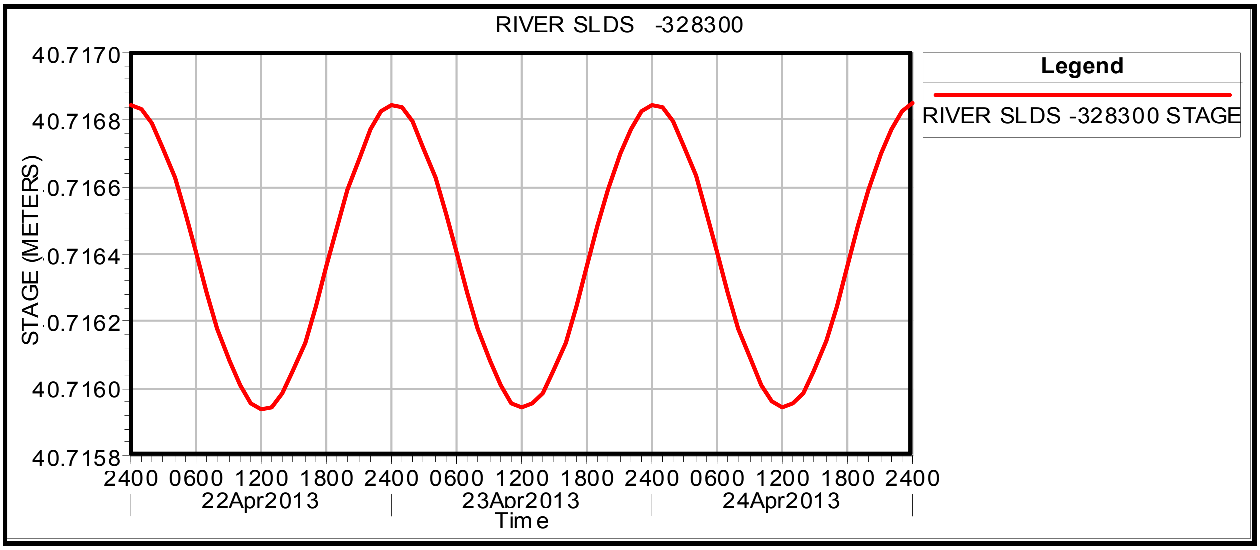

Figure 9.22: Simulated water level series in Brahmaputra near Guwahati due to 4 hours peaking release from Subansiri lower HE Project

Table 9.14: Release from Subansiri lower HE Project for 3 hour peaking and simulated discharge and water level in Brahmaputra near Guwahati

Time	Release from Subansiri lower HEP	Simulated discharge series in Brahmaputra near Guwahati	Simulated water level series in Brahmaputra near Guwahati
(hr)	(cumec)	(cumec)	(m)
1	240.00	5538.04	40.72
2	240.00	5537.99	40.72
3	240.00	5537.90	40.72
4	240.00	5537.75	40.72
5	240.00	5537.56	40.72
6	240.00	5537.36	40.72
7	240.00	5537.14	40.72
8	240.00	5536.94	40.72
9	240.00	5536.75	40.72
10	240.00	5536.59	40.72
11	2579.20	5536.48	40.72
12	2579.20	5536.41	40.72

Time	Release from Subansiri lower HEP	Simulated discharge series in Brahmaputra near Guwahati	Simulated water level series in Brahmaputra near Guwahati
(hr)	(cumec)	(cumec)	(m)
13	2579.20	5536.40	40.72
14	2579.20	5536.44	40.72
15	240.00	5536.52	40.72
16	240.00	5536.67	40.72
17	240.00	5536.84	40.72
18	240.00	5537.05	40.72
19	240.00	5537.27	40.72
20	240.00	5537.47	40.72
21	240.00	5537.67	40.72
22	240.00	5537.83	40.72
23	240.00	5537.96	40.72
24	240.00	5538.03	40.72

Flow depth, flow velocity and flow top width for lean discharge release condition, Monsoon discharge release condition and other four months discharge release condition of HEPs in Subansiri Basin is given in **Annexure 9.2**.

9.18 Summary of simulation results of pre and post project scenario

A summary of simulation results of non-monsoon discharge and water level pattern of pre project (natural condition) and post project scenario is summarized in **Table 9.15**.

Table 9.15: Discharge and water level at salient locations for pre and post project scenario

Location	Chainage d/s of Subansiri lower HEP	River Bed level	Pre Project Scenario (natural condition)		Post Project Scenario			
					3 hours peaking @2579.20 cumec/hr		4 hours peaking @ 2579.20 cumec/hr	
			Discharge	Water level	Discharge	Water level	Discharge	Water level
	(km)	(m)	(cumec)	(m)	(cumec)	(m)	(cumec)	(m)
North Lakhimpur	40	89.01	538	92.55	465-830	92.26-93.21	338-995	91.90-93.33
Subansiri just before Brahmaputra confluence	89.5	72.39	538	83.72	405-758	83.76-83.77	461-866	83.82-83.84
Kaziranga	188.16	71.8	4117	81.99	4172-4186	82.05	4265-4281	82.12
Tezpur	221.18	67.22	4475	74.92	4538-4543	74.95	4632-4639	75
Guwahati	328.30	30.96	5377	40.63	5443	40.66	5537	40.72

From the above summary it can be seen that in general the peaking release have impact on discharge and water level pattern of Subansiri river up to about 1st 40 km downstream of the Subansiri HE Project. After 1st 40 km and up to the Subansiri Brahmaputra confluence the discharge and water level pattern tends to stabilize and fluctuation in water level diminishes. In Brahmaputra the impact of peaking release is almost nil as fluctuation in discharge is only few cumec. The consequent daily fluctuation in water level is at different locations along Brahmaputra is only 1 to 2 cm.

9.19 Conclusion

From the detailed hydrodynamic simulations of natural condition flow of pre-project scenario and peaking releases from the hydroelectric projects in post project scenario the following conclusions have been drawn:

- The peaking will have insignificant impact beyond 40 km. downstream of Subansiri Lower Project in the river reach during the non-monsoon period when the average natural condition discharge in Subansiri river is of the order of about 500-600 cumec

- The non-monsoon peaking release from the projects in Subansiri basin will cause the fluctuations in discharge and water level up to first 40 km downstream of Subansiri lower HE Project. In this reach of river the daily fluctuation in water level may be about 1.5 m to 2 m.

- For the Subansiri river from 40 km downstream of Subansiri lower HE project and up to the Subansiri Brahmaputra confluence the daily fluctuation in water level will progressively decrease to 1 or 2 cm near the Subansiri Brahmaputra confluence

- The Subansiri-Brahmaputra confluence is about 90 km downstream of Subansiri lower HE project. Guwahati is about 328 km downstream of Subansiri lower HE Project. For the river reach of Brahmaputra from Subansiri-Brahmaputra confluence and up to the Guwahati, due to very wide reach of Brahmaputra River, the impact of peaking release will be damped. The fluctuations in daily discharge will be less than 15 cumec, while the fluctuation in daily water level will be hardly 1-2 cm.

- The natural condition average non-monsoon discharge in Brahmaputra at Kaziranga, Tezpur and Guwahati is about 4117, 4475 and 5377 cumec respectively. Due to 3 hours peaking releases the average non-monsoon discharge at these locations will be about 4180, 4550 and 5440 cumec respectively. The same for 4 hours peaking releases will be about 4275, 4635 and 5540 cumec respectively. From these simulated discharge patterns it has been concluded that increase in flow at these locations will be less than 200 cumec only. The consequent increase in water level in comparison to natural condition will be about 5 to 12 cm at these locations.

9.20 Limitations

The discharge and water level pattern simulated in the present study should be looked in relative term only for the purpose of comparing the same with the natural condition of the river and consequent assessment of impact. Due to very wide reach of Brahmaputra river and variability in river cross section along the study reach the water level and discharge estimates should not be looked in absolute value terms. The water level estimate for a particular discharge depends upon the finite difference solution algorithm of energy and momentum equations of flow. There are many computer software to solve these equations, which uses the different finite difference solution algorithms. Hence, depending upon the solution algorithm water level estimates obtained from different software for a particular discharge at same location may vary in absolute terms. However, the estimate of differential increase in water level from different software for two discharge values at same location will remain almost same.

Chapter 10: Cumulative Impact Assessment

10.1 Introduction

Significance of India's and Eastern Himalaya's biodiversity is underscored by its recognition and designation as Megadiversity Country (India), Biodiversity Hotspot, Ecoregion, Crisis Ecoregion, Endemic Bird Area, Important Bird Area, Centre of Plant Diversity, Important Plant Area, Intact Forest Landscape and the Last of the Wild areas. A brief description of globally identified areas rich in biological diversity in relation to Arunachal Pradesh and Subansiri Basin is provided. By virtue of Arunachal Pradesh and Subansiri basin being located in these globally significant areas and their relevance, the same is described below for the purposes of Cumulative Impact Assessment.

1 Megadiversity Countries

Megadiversity Countries is a term used to refer to the world's top biodiversity - rich countries in the world. This country - based method raises national awareness for biodiversity conservation in nations with high biological diversity, with many species unique to a specific country. This concept complements that of biodiversity hotspots and high-biodiversity wilderness areas to achieve significant coverage of the world's biological resources and was first proposed in 1988.

Global in extent covering 17 countries[62], the identified Megadiverse countries are: United States of America, Mexico, Colombia, Ecuador, Peru, Venezuela, Brazil, Democratic Republic of Congo, South Africa, Madagascar, India, Malaysia, Indonesia, Philippines, Papua New Guinea, China, and Australia (Figure 10.1). The principle criterion is endemism, first at the species level and then at higher taxonomic levels such as genus and family. To qualify as a Megadiverse country, a country must have at least 5000 of the world's plants as endemics.

[62] *Mittermeier, R.A. 1988. Primate Diversity and the Tropical Forest: Case Studies from Brazil and Madagascar and the Importance of the Megadiversity Countries. In:* Biodiversity *(Ed. E.O. Wilson). National Academy Press, Washington, DC. 145-154.*

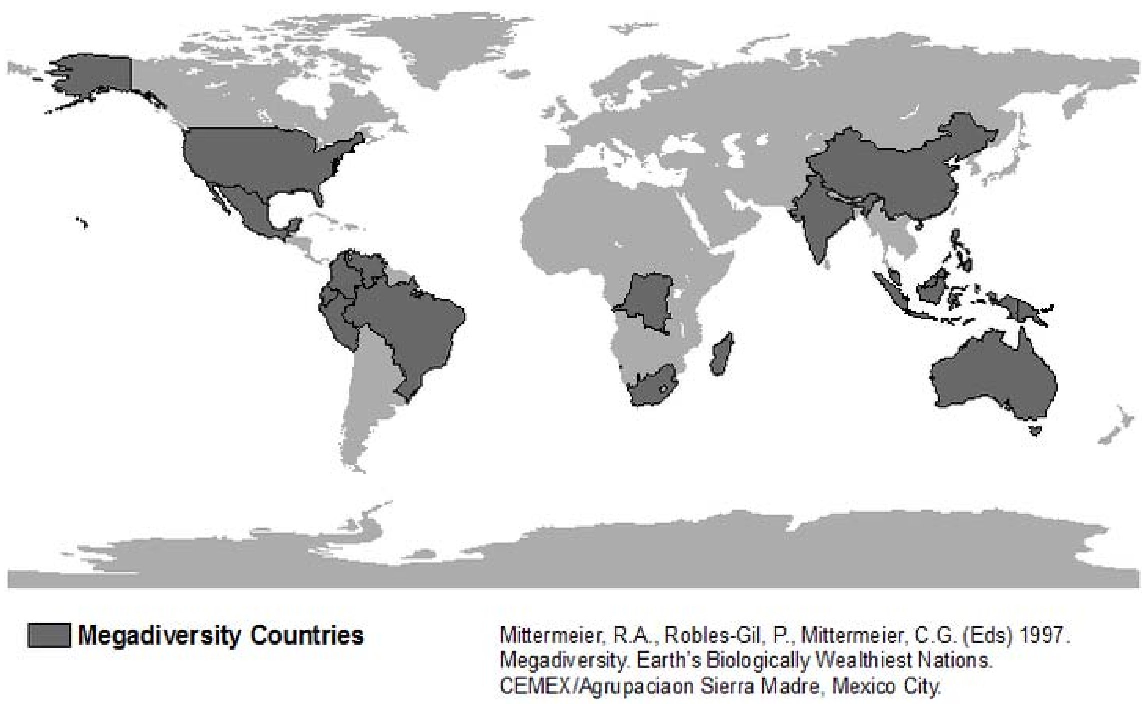

Figure 10.1.: Megadiversity countries
Source: http://www.biodiversitya-z.org/areas/26

2. Biodiversity hotspots

Biodiversity hotspots are a method to identify those regions of the world where attention is needed to address biodiversity loss and to guide investments in conservation. First developed by Norman Myers in 1988 to identify tropical forest 'hotspots' characterized both by exceptional levels of plant endemism and by serious levels of habitat loss. Myers subsequently updated the concept in 1990, adding eight hotspots, including four in Mediterranean regions. Subsequently, an extensive global review was undertaken, which introduced quantitative thresholds for the designation of biodiversity hotspots.[63] Currently, 34 biodiversity hotspots have been identified, most of which occur in tropical forests (Figure 10.2). Between them they contain around 50% of the world's endemic plant species and 42% of all terrestrial vertebrates, but have lost around 86% of their original habitat[64].

[63] *Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca G.A.B., Kent, J. (2000) Biodiversity Hotspots for Conservation Priorities. Nature403(6772):853-8*

[64] *Mittermeier, R.A., Gil, P.R., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J., da Fonseca, G.A.B. (2004) Hotspots revisited. Cemex: Mexico City, Mexico.*

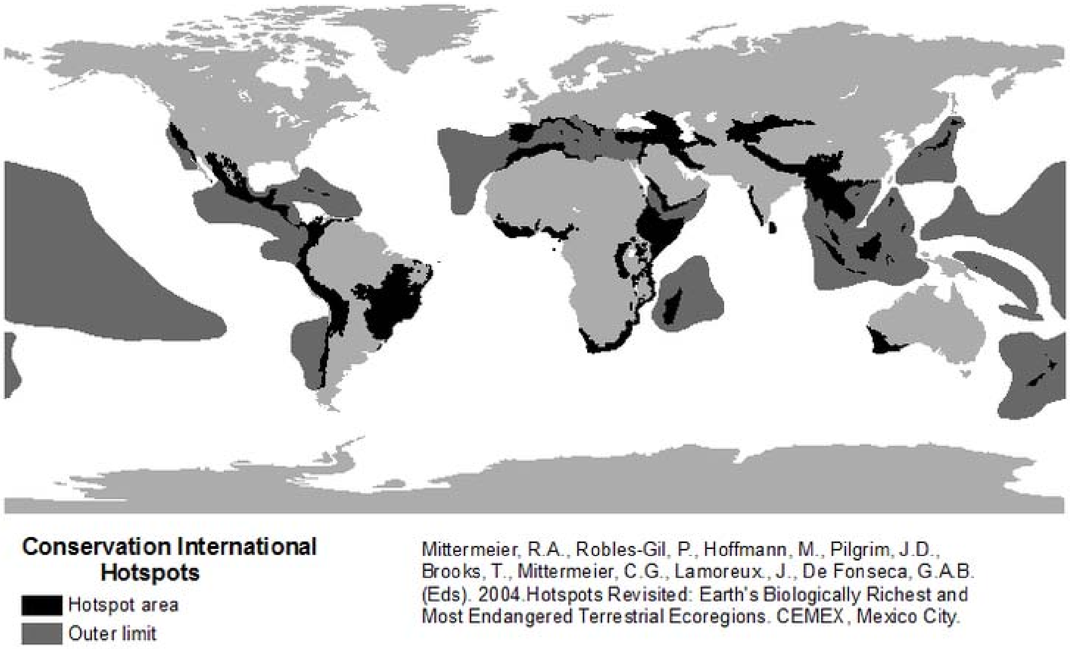

Figure 10.2: Biodiversity Hotspot

Three of 34 biodiversity hotspots regions fall in India namely 1. Himalaya (hotspot no.12), 2. Indo-Burma (hotspot no.14), 3. Western Ghats and Sri Lanka hotspot no.34) as shown in Figure 10.3.

Figure 10.3: Biodiversity Hotspots in India

The hotspot of north-eastern states is now divided into two regions. The Himalaya (covering states of West Bengal, Sikkim, Assam, and Arunachal Pradesh),' and Indo-Burma (covering the states of Manipur, Mizoram, Tripura, Meghalaya, Nagaland and south Assam) which alongwith Western Ghats form the three hotspot zones in India. Arunachal Pradesh is part of the Himalaya Hotspot. The Himalaya Hotspot covering about 741,706 sq.km area stretches in an arc shape from northern Pakistan, Nepal, Bhutan and the north-western and north-eastern states of India. Home to world's highest peak Mt. Everest or Sagarmatha, this immense mountain range has been divided into two regions: the Eastern Himalaya, which covers parts of Nepal Bhutan, the north-east Indian states of West Bengal, Sikkim, Assam, and Arunachal Pradesh, south-east Tibet (China), and northern Myanmar; and the Western Himalaya, covering the Kumaon-Garhwal, north-west Kashmir and northern Pakistan. The Himalayan hotspot is home to 10,000 species of plants, of which about 3,160 are endemic, 980 bird species of which 15 are endemic and 300 mammal species of which a dozen are endemic[65].

The map of Himalaya Hotspot is given in Figure 10.4.

Figure10.4: The Himalaya Hotspot including Arunachal Pradesh

Criteria: To qualify as a hotspot, a region must meet two strict criteria: it must contain at least 1,500 species of vascular plants (> 0.5% of the world's total) as endemics, and it has to have lost ≥ 70% of its original native habitat[66].

3. Global Ecoregions

The Global Ecoregions is a science-based global ranking of the Earth's most biologically outstanding terrestrial, freshwater and marine habitats. It provides a critical blueprint for biodiversity conservation at a global scale. Developed by WWF scientists in collaboration with regional experts around the world, the Global Ecoregions is the first comparative analysis of biodiversity to cover every major habitat type, spanning 5 continents. The aim of the Global Ecoregions analysis is to ensure that the full range of ecosystems is represented

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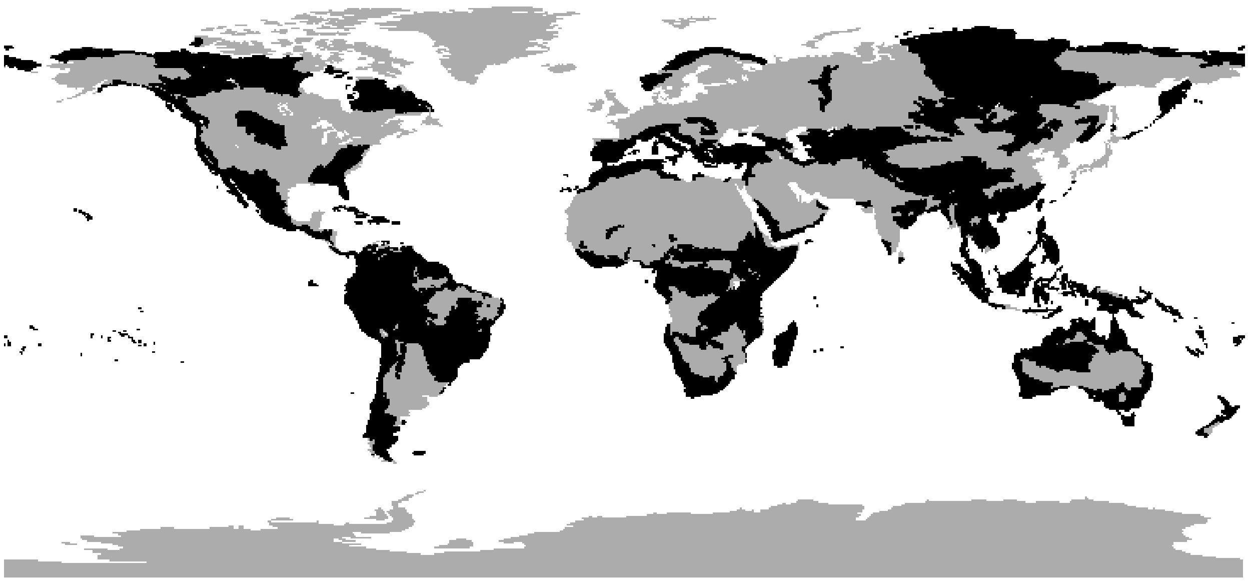
[65] *Himanshu Rai and Rajan Kumar Gupta 2011 (Eds), Biodiversity, An Overview, published By LK. International Publishing House Pvt. Ltd., New Delhi, ISBN 978-93-80578-88-0.*
[66] *Information by Conservation International on biodiversity hotspots, including an overview of all those identified, and area legally protected per hotspot*

within regional conservation and development strategies, so that conservation efforts around the world contribute to a global biodiversity strategy.

Among the terrestrial ecoregions in India, under Temperate Broadleaf and Mixed Forests, Eastern Himalayan Broadleaf & Conifer Forests ecoregion no.67 has been identified (Figure 10.5). This ecoregion is spread over 170,000 sq. km (65,000 sq. miles) in Bhutan, China, India, Myanmar and Nepal. The habitat type is Temperate Broadleaf and Mixed Forests and its conservation Status is Vulnerable.



WWF Global 200 Ecoregions

Olson, D. M. and E. Dinerstein. The Global 200: Priority ecoregions for global conservation. (PDF file) Annals of the Missouri Botanical Garden 89:125-126

Figure 10.5: Global Ecoregions

The Eastern Himalayan Broadleaf and Conifer Forests blanket the lowlands to the foothills of the Himalayas in northern India, Nepal, and Bhutan. This Global ecoregion is made up of 4 terrestrial ecoregions: Eastern Himalayan subalpine conifer forests; Eastern Himalayan broadleaf forests; Northern Triangle temperate forests; and Northeastern Himalayan subalpine conifer forests.

The Eastern Himalayan Broadleaf Forests ecoregion has several 'floral hotspots' - lush areas covered with endemic plant species. It contains one of the world's richest varieties of plants, birds, and mammals. Fifteen protected areas, including several large national parks in Bhutan, extend into this ecoregion, helping to preserve its richness.

Under Montane Grasslands and Shrublands, Eastern Himalayan Alpine Meadows Ecoregion no 112 has been identified. This ecoregion is spread over 121,000 sq. km (47,000 sq. miles) in South-Central Eurasia, stretching through parts of Bhutan, China, India, Myanmar, and Nepal Its habitat type is Montane Grasslands and Shrublands. Its Conservation Status is Relatively Stable/Intact.

4. Crisis Ecoregions

Crisis ecoregions are places where extensive habitat conversion and limited habitat protection suggest that substantial, irreversible and irreplaceable losses of significant biodiversity and ecological function are likely without successful conservation intervention (Figure 10.6).

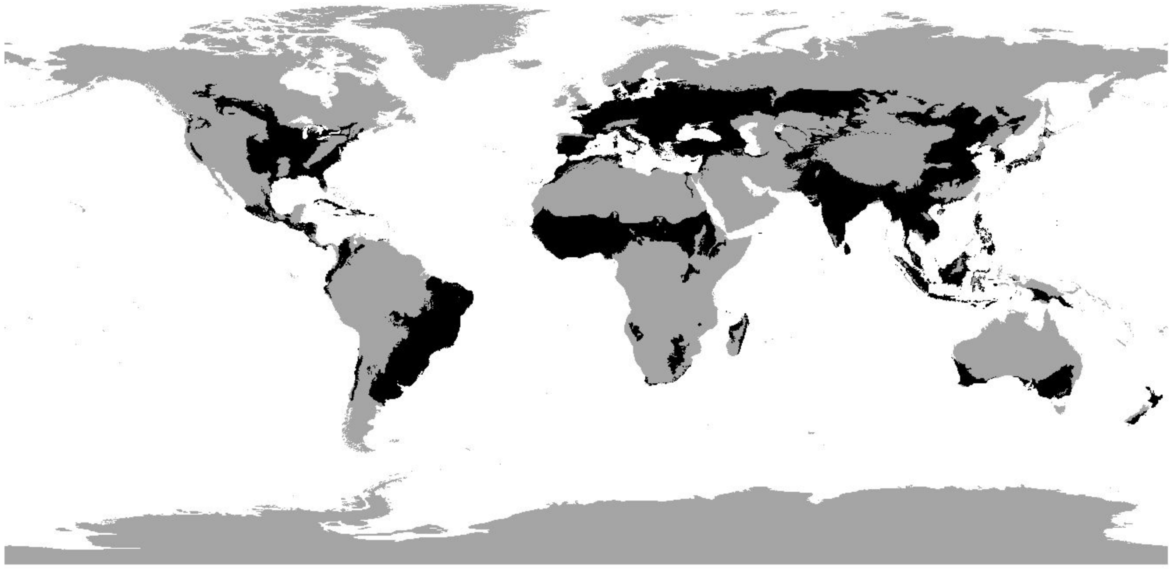


Figure 10.6: Crisis Ecoregions

Source: Brooks, T. M., Mittermeier, R. A. , da Fonseca, G. A. B., Gerlach, J., Hoffmann, M., Lamoreux, J. F., Mittermeier, C. G., Pilgrim, J. D. and Rodrigues, A. S. L. (2006) Global Biodiversity Conservation Priorities. Science 313 (5783), 58.

5. Endemic Bird Areas (EBAs)

EBAs are regions of the world that represent natural areas of bird endemism where the distributions of two or more restricted-range bird species overlap. A restricted-range species is defined as one having a historical breeding range of no more than 50,000 km[67]. BirdLife International's Biodiversity project, which began in 1987, identified a total of 218 EBAs with most (77%) of them located in the tropics and subtropics[68]. EBAs vary in size (from a few square kilometres to more than 100,000 sq. km) and in the numbers of restricted-range species they support (from two to 80). Nearly all of the world's restricted-range species occur within identified EBAs; the remainder occur in 'Secondary Areas', defined by the presence of single restricted-range species whose distributions do not overlap with any others. These areas of high bird endemism are also important for other endemic taxa, and are thus priorities for broad-scale ecosystem conservation.

EBAs are defined and identified as:

An area which encompasses the overlapping breeding ranges of restricted-range bird species, such that the complete ranges of two or more restricted-range species are entirely included within the boundary.

6. Important Bird Areas (IBAs)

IBAs are key sites for the conservation of bird species, identified through the BirdLife International IBA programme. These sites are small enough to be conserved in their entirety, often form part of a protected-area network, and are, as far as possible, different in

[67] *http://www.birdlife.org//worldwide/science*
[68] *Stattersfield, A.J., Crosby, M.J., Long, A. J., Wege, D.C. (1998) Endemic Bird Areas of the World: Priorities for Biodiversity Conservation (BirdLife Conservation Series) (no. 7). BirdLife International, Cambridge.*

character or habitat or ornithological importance from the surrounding area. The IBAs are an important subset of the KBA approach to identify key areas for site-scale biodiversity conservation. The identification of IBAs is based on a set of internationally agreed, standardised criteria and is an ongoing process. Inventories of IBAs have now been produced for most of the terrestrial and freshwater regions of the world[69].

7. Intact Forest Landscape (IFL)

(IFL) is an unbroken expanse of natural ecosystems within the zone of current forest extent, showing no signs of significant human activity and large enough that all native biodiversity, including viable populations of wide-ranging species, could be maintained. Although all IFLs are within the forest zone, some may contain extensive naturally tree-less areas, including grasslands, wetlands, lakes, alpine areas, and ice[70][71] This definition builds on the definition of Frontier Forest, the remaining large, ecologically intact natural forest ecosystems that were identified through an assessment carried out by the World Resources Institute (WRI) in 1997[72]. The Frontier Forest's definition captured several fundamental ecological characteristics of forest ecosystems: stability, biodiversity, and resistance to natural disturbances. The IFL definition was developed for two additional important objectives[73]. First, to formalise a replicable procedure for analysis of disturbance and fragmentation in forest landscapes at a regionally and nationally relevant scale. Second, to produce a globally consistent map of remaining intact areas that is suitable for underpinning the targeting of conservation work at these levels (Figure 10.7 and 10.8).

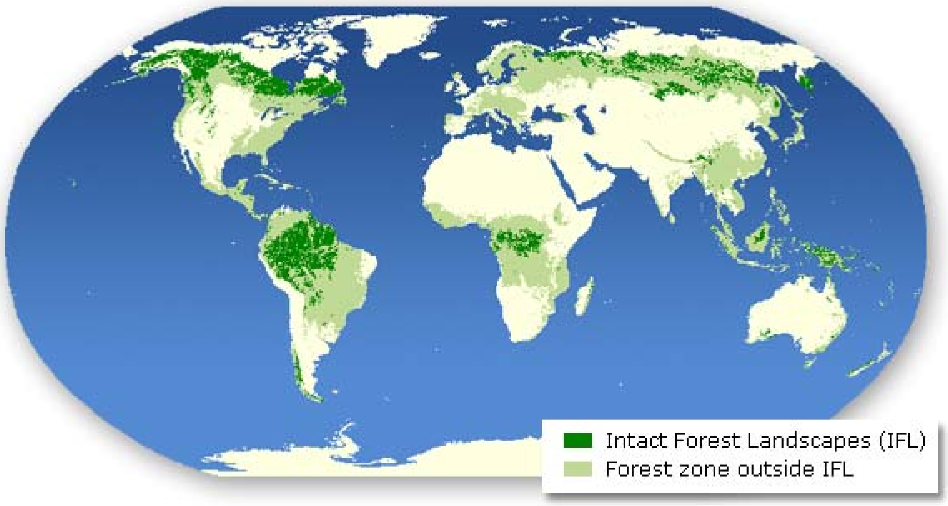


Figure 10.7: Intact Forest Landscape (IFL**)**

Source: http://www.biodiversitya-z.org/areas/21

Arunachal Pradesh has been identified as an Intact Forest landscape as shown in Figure 10.8.

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[69]*http://www.birdlife.org//worldwide/science*

[70] *Potapov, P., Laestadius, L., Yaroshenko, A., Turubanova, S (2009) Global Mapping and Monitoring the Extent of Forest Alteration: the Intact Forest Landscapes Method, FRA Working Paper 166. FAO, Rome, Italy.*

[71] *http://www.intactforests.org*

[72] *Bryant D, Nielson D, Tangley L. (1997) The Last Frontier Forests. Ecosystems and Economies on the Edge. World Resources Institute, Washington, DC, U.S.A.*

[73] *Potapov, P., A. Yaroshenko, S. Turubanova, M. Dubinin, L. Laestadius, C. Thies, D. Aksenov, A. Egorov, Y. Yesipova, I. Glushkov, M. Karpachevskiy, A. Kostikova, A. Manisha, E. Tsybikova, and I. Zhuravleva. (2008) Mapping the World's Intact Forest Landscapes by Remote Sensing. Ecology and Society 13(2): 51.*

Figure 10.8: Intact Forest landscape in Arunachal Pradesh.

8. The Last of the Wild areas

The Last of the Wild areas were identified by the Wildlife Conservation Society (WCS) and the Center for International Earth Science Information Network (CIESIN) at Columbia University (Figure 10.9). They represent the 10% wildest areas of the terrestrial planet – those areas with the least amount of human influence. This approach identifies large, intact tracts of relatively undisturbed ecosystems that are considered important for biological diversity[74]. They are intended to guide opportunities for effective conservation where the widest range of biodiversity can be conserved with minimum conflict.

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[74] *Sanderson, E.W., Jaiteh, M., Levy, M.A., Redford, K.H., Wannebo, A.V. and Woolmer, G. (2003) The Human Footprint and The Last of the Wild.BioScience 52 (10): 891-904*

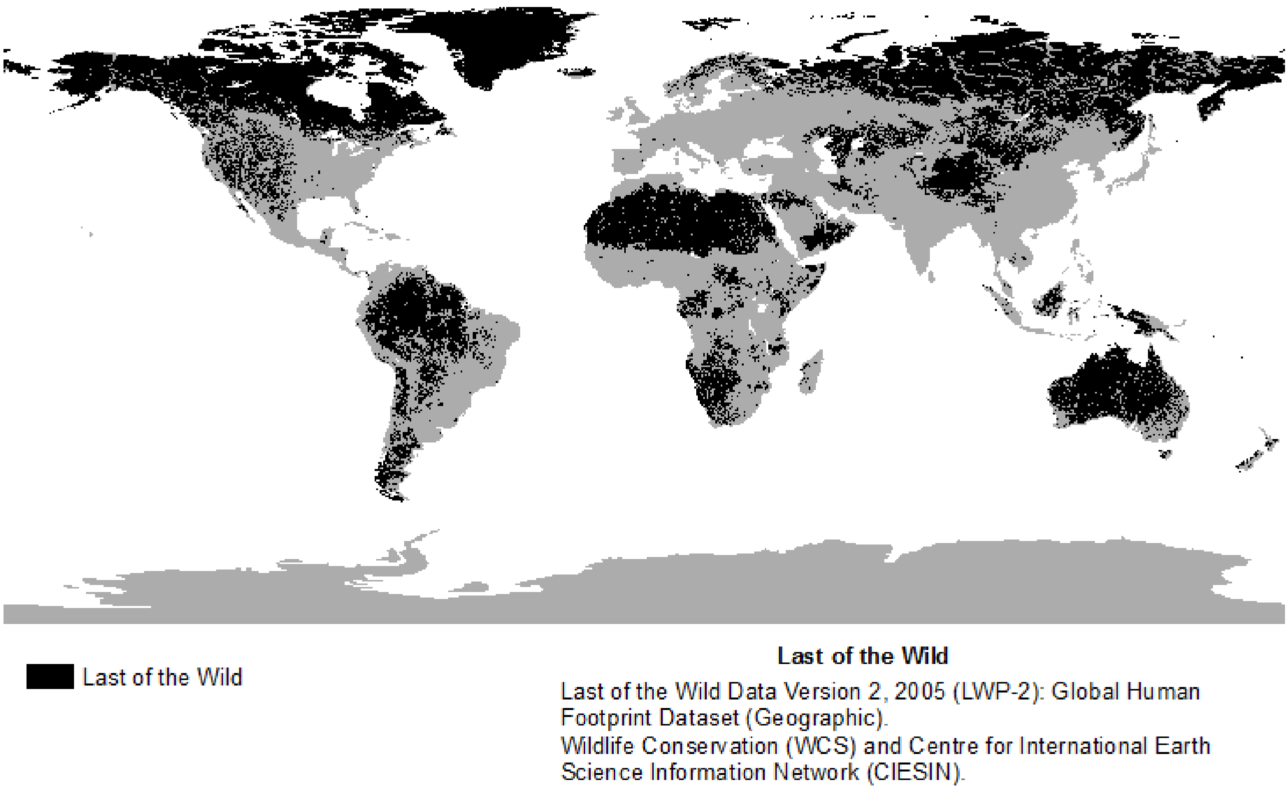

Figure 10.9: The Last of the Wild areas

Source: http://www.biodiversitya-z.org/areas/23

Criteria

These areas have been identified by systematically mapping and measuring the human influence on the Earth's land surface through proxies such as human population density, settlements, roads, and other access points, and including factors such as the size and remoteness of an area. According to this analysis, approximately 17% of the Earth's land's surface is relatively less influenced by human beings. For each regionally defined natural biome that were differentiated within larger biogeographic realms (e.g. Paleartic, Indo-Malay, Neotropic etc.) the '10% wildest areas' within this map of human footprint were found. Of these, the 10 largest contiguous areas within each biome were identified as the 'last of the Wild' sites[75].

Biodiversity and its significance in India and Arunachal Pradesh.

India is recognized as one of the 12 mega biodiversity centers in the world comprising three "Hot spots" regions namely 1. Himalaya (hot spot no.12), 2. Indo-Burma (hot spot no.14), 3. Western Ghats and Sri Lanka hot spot no.34). Arunachal Pradesh with an area of 83,743 Sq. km., is located in the Eastern Himalayas, and is particularly representative of all characteristics of the region. The State has the resources in abundance with the highest forest cover in the country and is least populated. It is a nature's laboratory unto it. As in the region, it has many endemics and vast areas are still unexplored. It is in this state that one can still hope to find new species and records hitherto unknown to the world.

An estimated number of 5000 flowering plants, 600 orchids, 400 ferns, 48 gymnosperms and an equally high number of unexplored algae, fungi, lichens and bryophytes inhabit the diverse habitats that occur in at least six broad forest types of Arunachal Pradesh. The eastern Himalayan state contains more than 33% of the total Indian flora out of which about

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[75] *Brooks, T. M., Mittermeier, R. A. , da Fonseca, G. A. B., Gerlach, J., Hoffmann, M., Lamoreux, J. F., Mittermeier, C. G., Pilgrim, J. D. and Rodrigues, A. S. L. (2006) Global Biodiversity Conservation Priorities. Science 313 (5783), 58.*

30% are endemic to the state. Besides, the flora of the state is considered to be the representative of the entire Indo – Malayan region. The floristic feature of Arunachal Pradesh is unique in many ways and has maximum diversity in comparison to the other states of north eastern region. This region has been considered by many as the cradle of speciation and center of origin for some of our useful plants which are a basic source for crop improvement. All the facts have contributed to consider the north eastern region of India – Arunachal Pradesh in particular as one of the eighteen "Biodiversity Hotspots" in the world.

The different habitat and ecosystem types of Arunachal Pradesh in particular described above are home to more than 100 species of mammal, 650 birds, 83 snakes/reptiles, 213 fishes and 7 non-human primates and innumerable species of insects and other life forms.[76]

In the abovesaid global and national context of significance of biodiversity of India and Arunachal Pradesh, the Cumulative Impact Assessment on terrestrial biodiversity has been done at the landscape level (Arunachal Pradesh) and Subansiri Basin, Subansiri Sub basin using the available information and at the project level wherever information is available. Biodiversity Characterisation at landscape level has been done for North-East India including Arunachal Pradesh using Satellite Remote Sensing (RS) and Geographic Information System (GIS) by Indian Institute for Remote Sensing (IIRS), Dehradun in 2002[77]. Given the scale and scope of cumulative impact assessment at the basin level, the approach of Biodiversity Characterisation at landscape level has been adopted to understand the disturbance, fragmentation and biological richness in Arunachal Pradesh, Subansiri Basin and Subansiri Sub basin. This approach uses the established and credible secondary data at the landscape level using RS and GIS to set the context and baseline for undertaking Cumulative Impact Assessment at the basin level. Further, the updated data from State of Forest Report, 2013 for Arunachal Pradesh and Subansiri basin has been used to understand the status of forest and trends in Subansiri basin. This approach has been adopted to set the baseline, understand level and trend of disturbance, fragmentation and biological richness in the basin for undertaking Cumulative Impact Assessment on terrestrial ecology. Moreover, secondary and primary data at Subansiri Sub basin level and at HEPs level has been used for Cumulative Impact Assessment on terrestrial and aquatic biodiversity as described below.

10.2 Cumulative Impact Assessment on Terrestrial Biodiversity

Cumulative impact assessment on Terrestrial Biodiversity has been done using Biodiversity Characterisation at landscape level in Arunachal Pradesh. Primary and secondary data has been sourced from Pre-feasibility report, EIA/EMP report, Detailed Project Report, Terms of Reference issued by Expert Appraisal Committee- River Valley and Hydroelectric projects, MOEF, etc. Cumulative Impact Assessment on terrestrial biodiversity is given below:

Vegetation Mapping

IRS-IC/ID LISS-III digital data were used by Indian Institute for Remote Sensing (IIRS, Dehradun) for classification as shown in **Figure 10.10**. The Subansiri basin boundary and proposed HEPs have been overlaid on the FCC.

The digital classification was carried out using hybrid approach (supervised, unsupervised and knowledge base). Temperate broad leaved has the highest percentage area (24.82%), followed by sub tropical evergreen (20.3%) and degraded forest (17.32%). Other vegetation / landcover types occupy the area ranging between 5.28%- 0.03%.

[76] State Biodiversity Strategy and Action Plan, Arunachal Pradesh

[77] Indian Institute of Remote Sensing (National Remote Sensing Agency) Department of Space, Government of India Dehradun-248001, Uttaranchal January, 2002

Various forest and non forest classes mapped are shown in **Figure 10.11** and the area extent of the classes is given in **Figure 10.12**. The Subansiri basin boundary and proposed HEPs has been overlaid on satellite imageries received from IIRS.

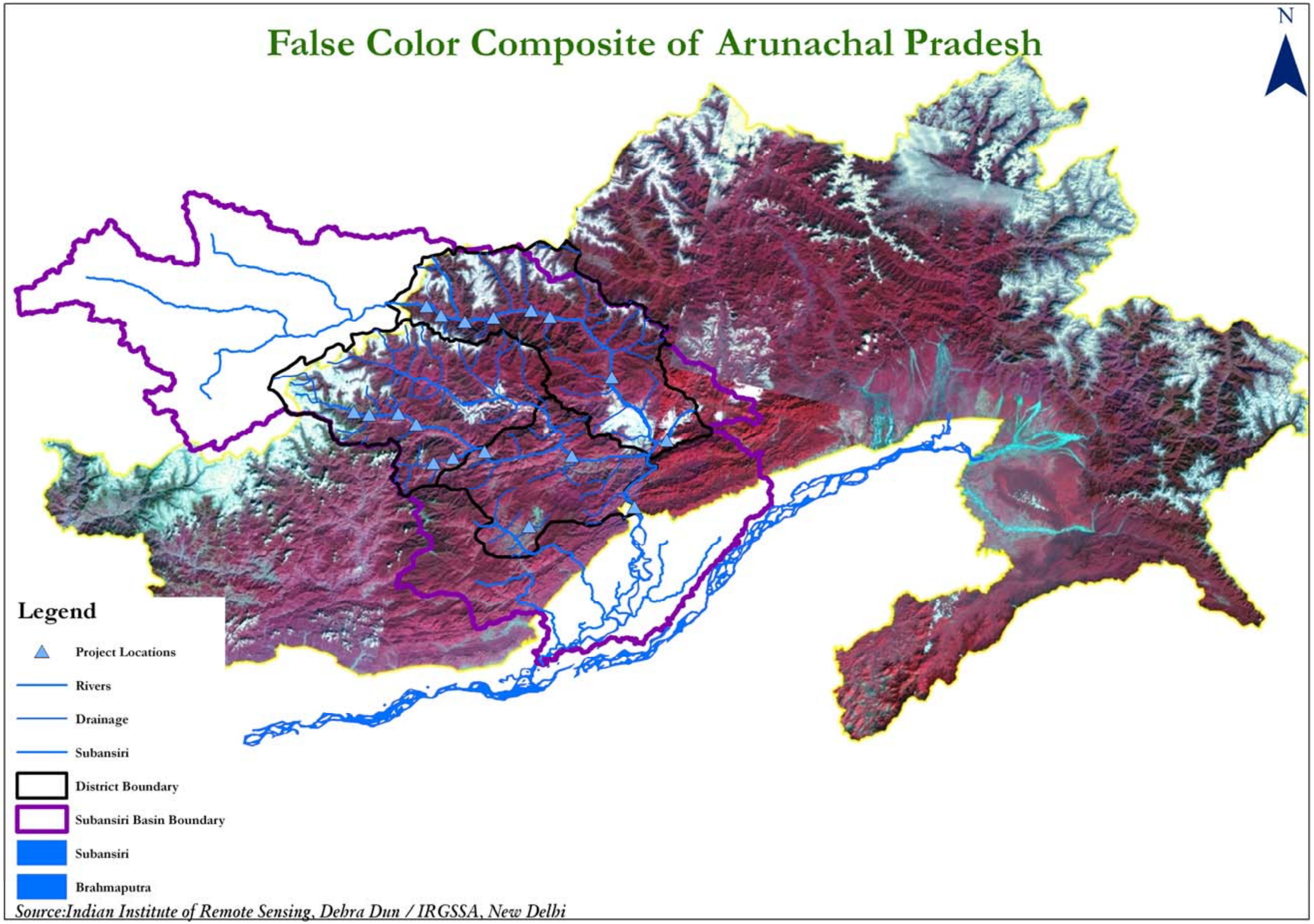

Figure 10.10: False Color Composite of Arunachal Pradesh

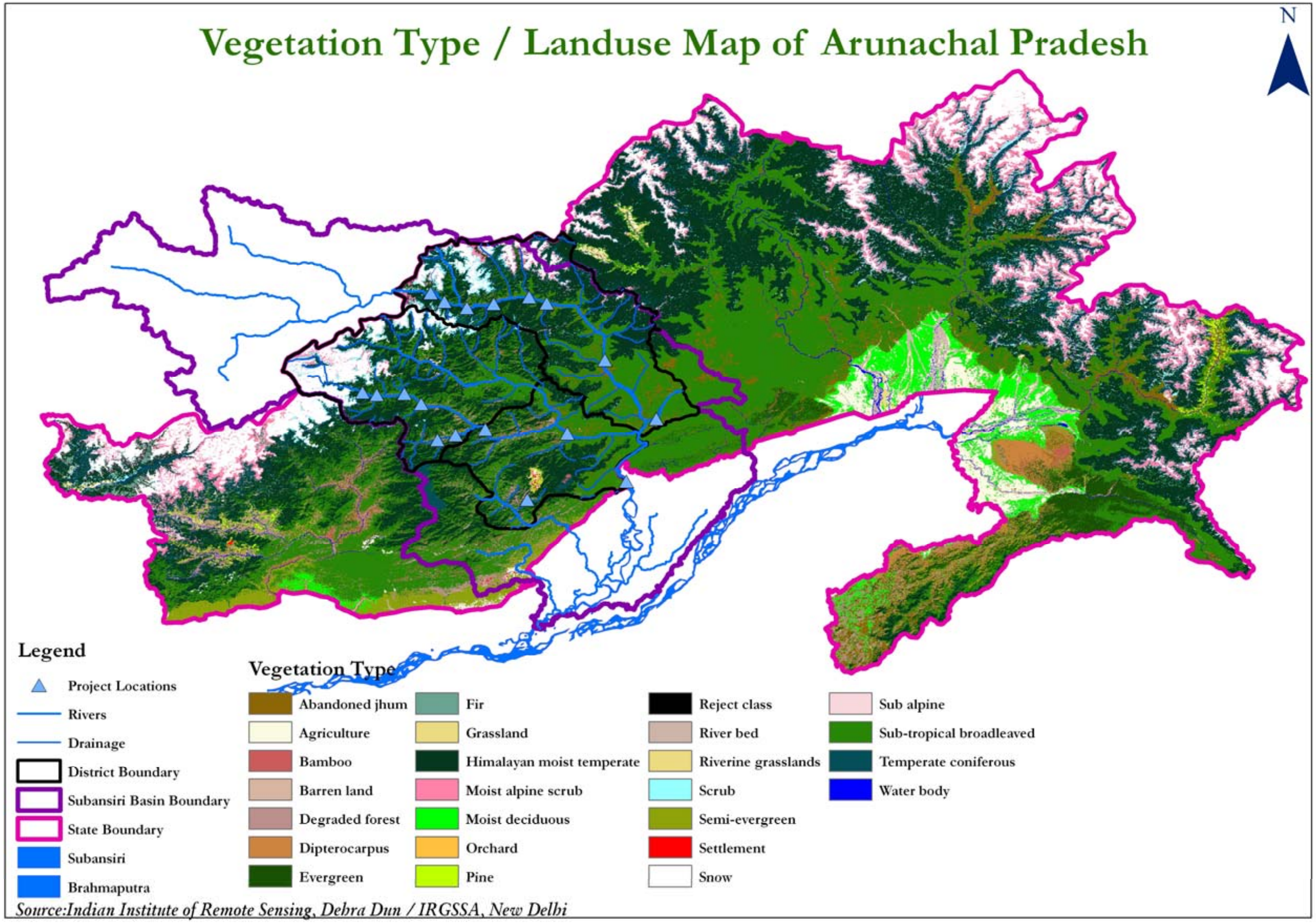

Figure 10.11: Vegetation type/land use map of Arunachal Pradesh

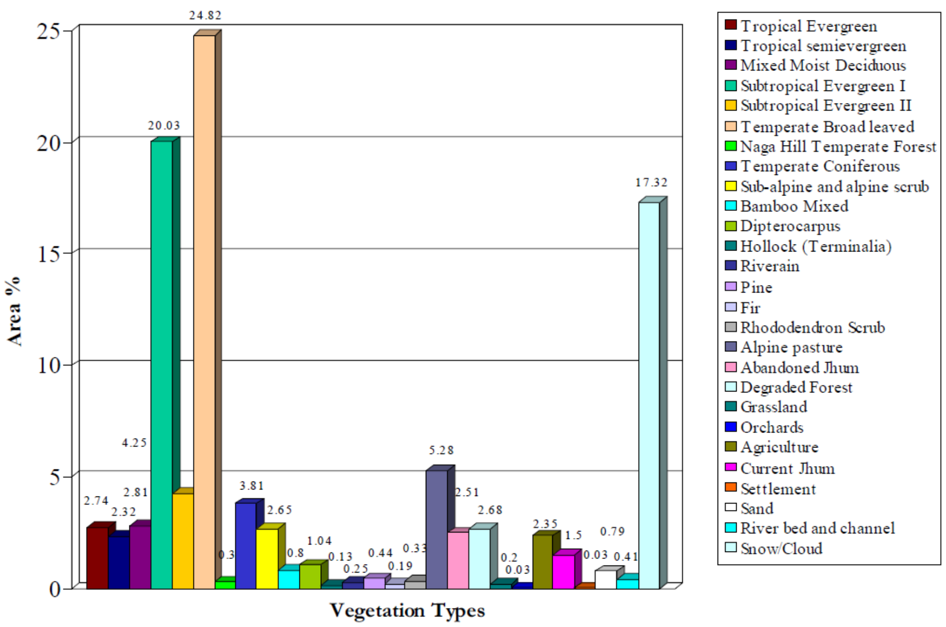

Figure 10.12: Area under different vegetation/land cover types

Landscape Mapping

Landscape commonly refers to the landforms of a region in aggregate or to the land surface and its habitats at various scales ranging from hectares to many square kilometers[78]. Landscape analysis using parameters like fragmentation, porosity, disturbance from roads and settlements, interspersion and juxtaposition have been generated to understand the disturbance regimes and biologically rich areas.

Disturbance Index

Major disturbance to biodiversity is caused by human activities. A relationship exists between the biodiversity and the disturbance in an area. Human activities like agriculture, shifting cultivation, housing, road, rail and other development activities cause depletion of biodiversity. These disturbances cause splitting of forest area into patches. These patches depending upon their size, shape, number *etc.* exhibit different biological diversity. Fragmentation and Disturbance index maps and the forest type wise fragmentation statistics (shown as Figures 10.13, 10.14 and 10.15 respectively), of Arunachal Pradesh and Subansiri basin gives a clear picture of both anthropogenic and natural disturbances and their spatial extent at various levels. The Subansiri basin boundary and proposed HEPs have been overlaid on satellite imageries received from IIRS. *Forest types in Subansiri Basin is mostly intact except for a small patch in Kurung Kumey district where intact to medium fragmentation has been recorded as shown in Figure 10.13.*

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Forman, T.T.R. and Godron, M. 1986. Landscape Ecology. Wiley and Sons, New York.

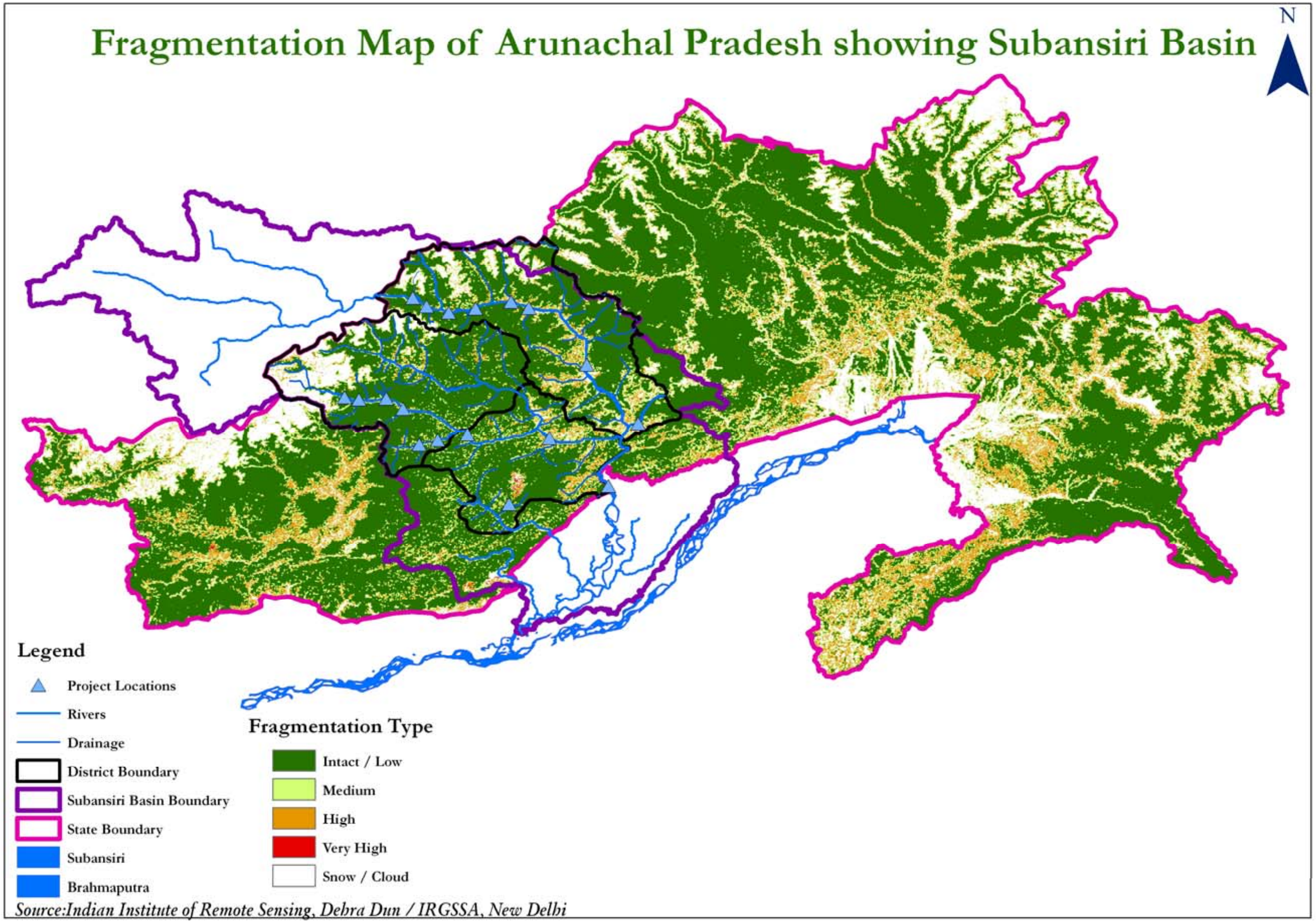

Figure 10.13: Fragmentation Map of Arunachal Pradesh showing Subansiri Basin.

Disturbance image of Arunachal Pradesh (Figure 10.14) shows highly disturbed areas in most of Tirap and lower-outer reaches of Changlang and Lohit districts. West Kameng, East Kameng and Lower Subansiri Districts have high disturbance along agriculture and shifting cultivation areas. Namdapha area in tropical region and higher reaches of other districts are relatively less disturbed. Extent of disturbance regimes in all forest types are assessed mostly as falling under non disturbed category. The Subansiri basin boundary and proposed HEPs have been overlaid on satellite imageries received from IIRS. Extent of disturbance regimes in different vegetation type is given in Figure 10.15.*The Disturbance Index map of Subansiri Basin given in Figure 10.14 shows that the Upper Subansiri District in Subansiri Basin is mostly intact. However, intact to medium level of disturbance is recorded in Lower Subansiri and Kurung Kumey districts*. Eight HEPs are proposed in Upper Subansiri district namely Oju – I, Oju – II, Niare, Naba, Subansiri Upper, Nalo, Dengser and Tammu with a total installed capacity of 6467 MW. Four HEPs namely Middle Subansiri (Kamala HEP), Lower Subansiri, Tamen and Tago I with a total installed capacity of 3958 MW are proposed in Lower Subansiri district and seven proposed HEPs namely Mili, Sape, Chomi, Chela, Kurang I and II, Nyepin and Hiya (with a total installed capacity of 671 MW) in Kurung Kumey district which totals to 19 projects with installed capacity of 11,096 MW are anticipated to impact on the said districts in Subansiri Basin.

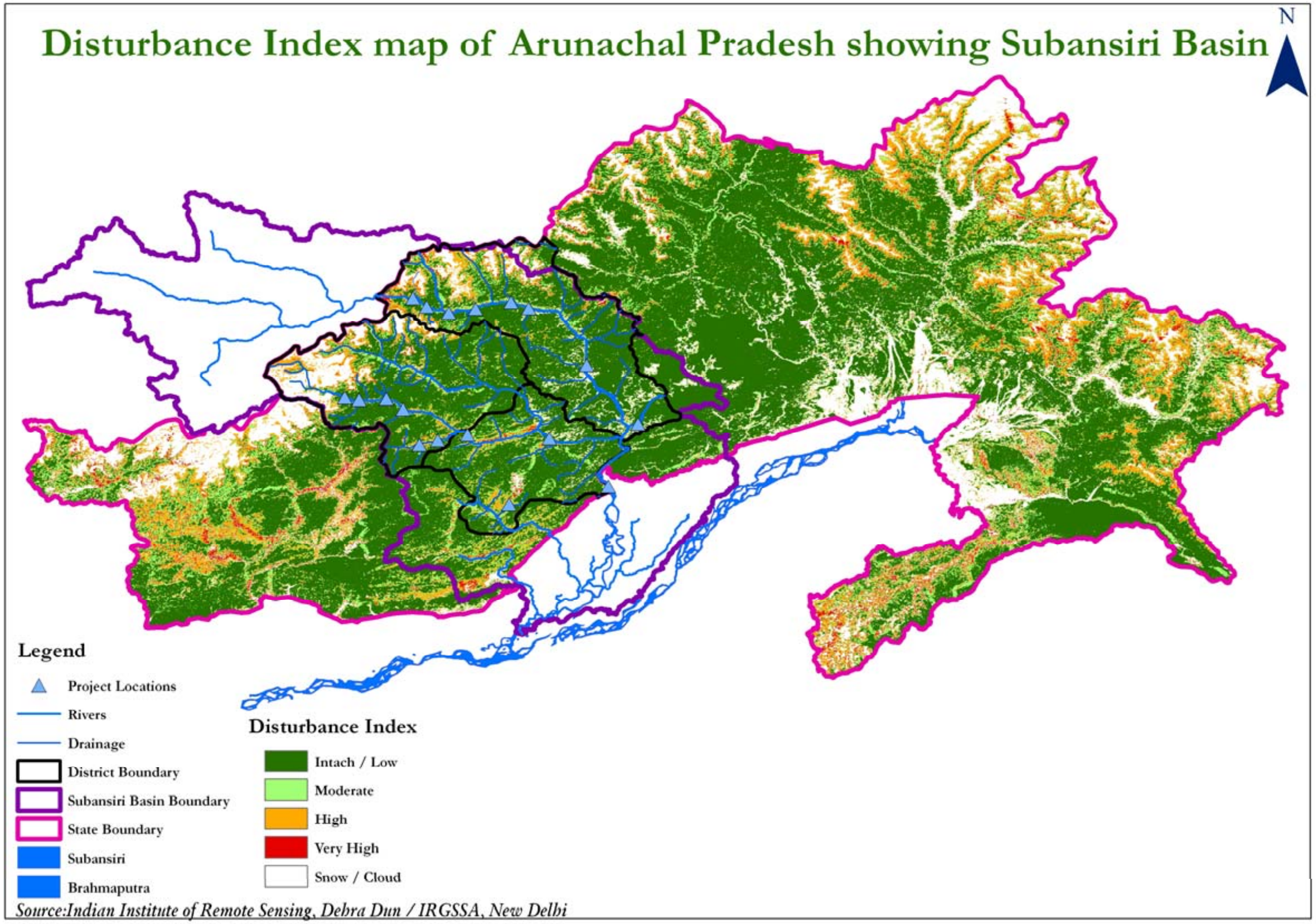

Figure 10.14: Disturbance Index map of Arunachal Pradesh showing Subansiri Basin.

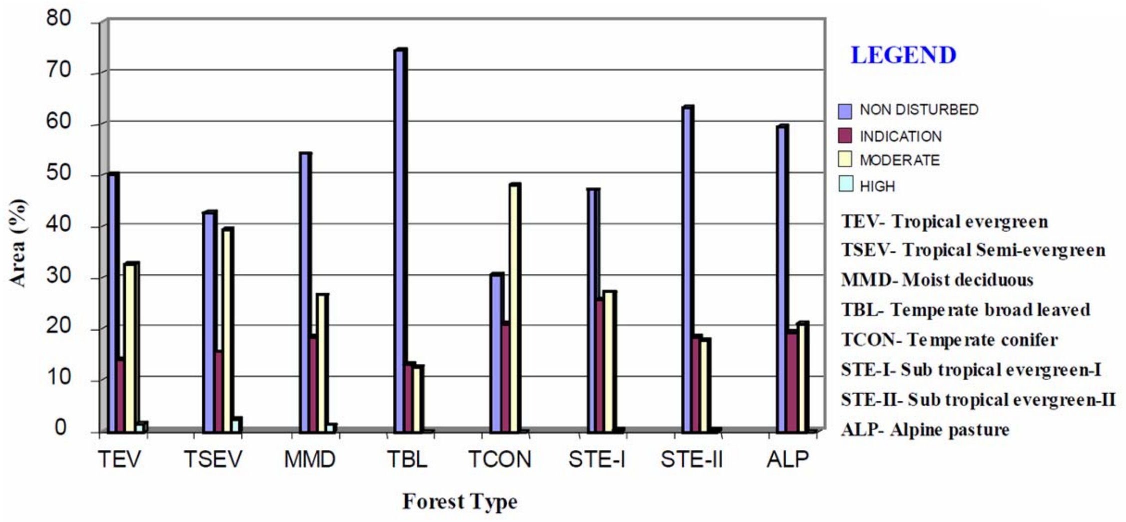

Figure 10.15: Extent of disturbance regimes in different vegetation type

Biological richness

Biological richness has been based on the ecosystem uniqueness, biological value, terrain complexity and disturbance regime image Weightages have been assigned to these parametres on the basis of their uniqueness and biological value. In doing this, guidelines have been drawn from the number of endemic species, ecologically important species *etc.* Tropical evergreen forests are acclaimed world over for their biodiversity richness and uniqueness. The analysis carried out using landscape parameters in conjunction with field data and literature survey indicates that these forests are extremely rich and occur in Namdapha National Park and border areas of Lower Subansiri, West Kameng, East Siang and Lohit District. Alpine pastures and temperate conifer area also indicate high richness. Moderately rich area forms the largest area in the state spreading throughout the state. Less rich area are formed mainly by the moist deciduous forest in floodplains of Brahmaputra River and also scattered throughout the state bordering agriculture and shifting cultivation. The Subansiri basin boundary and proposed HEPs have been overlaid on satellite imageries received from IIRS. *The Biological richness map of Subansiri basin given in Figure 10.16 shows that high biological diversity is recorded in Upper Subansiri District. Very high - high and medium biological richness is recorded in Lower Subansiri and Kurung Kumey districts.* The proposed HEPs in Lower Subansiri District, particularly for which information is available, also points towards biological richness. Therefore, the 8 proposed HEPs in Upper Subansiri District (with a total installed capacity of 6467 MW), 4 proposed HEPs (with a total installed capacity of 3958 MW) in Lower Subansiri district and 7 proposed HEPs (with a total installed capacity of 671 MW) in Kurung Kumey district (totaling 19 projects with installed capacity of 11,096 MW) are anticipated to impact on the biological richness of the said districts in Subansiri Basin.

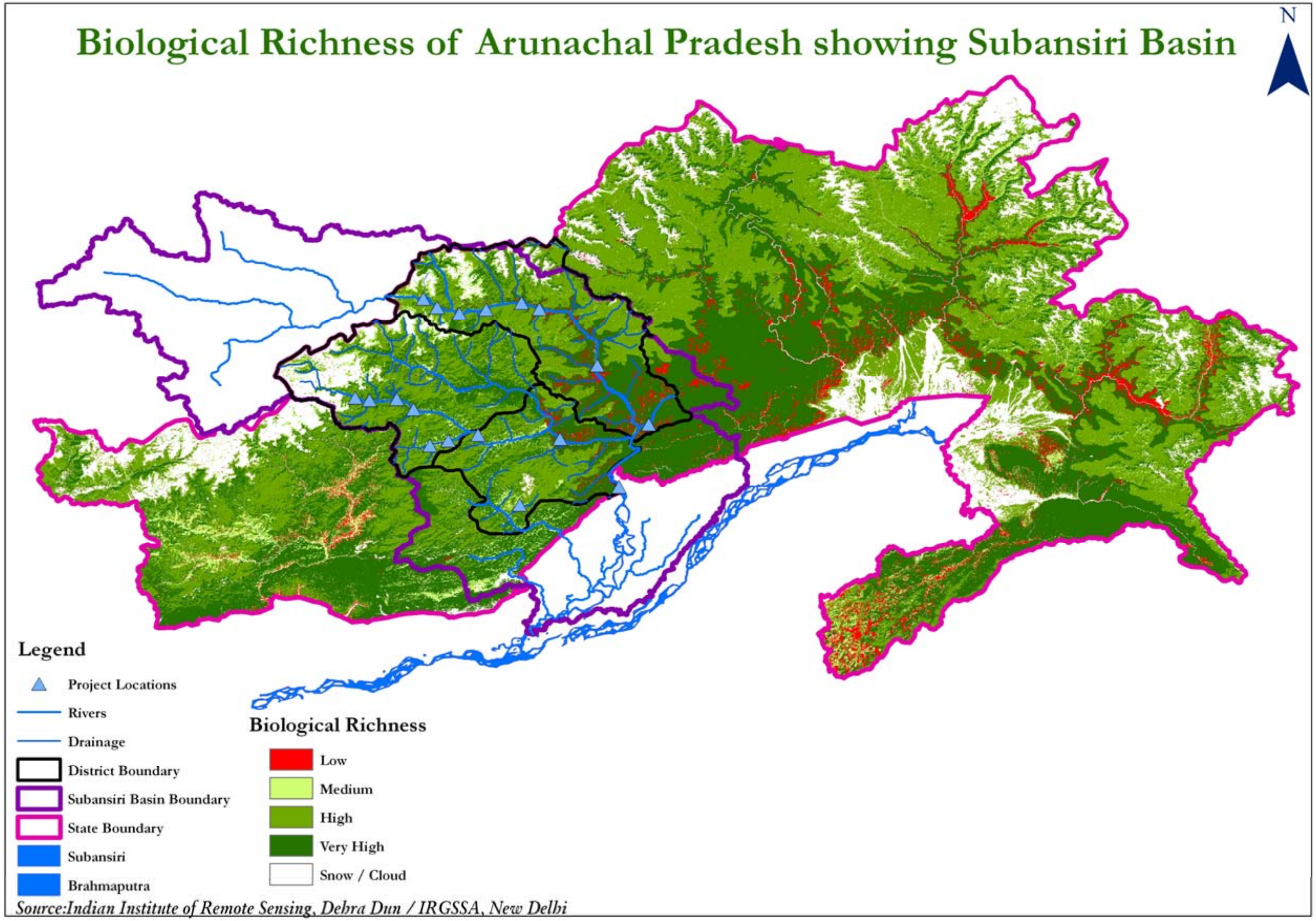

Figure 10.16: Biological Richness

Based on the biodiversity characterisation it can be inferred that that some areas of Tirap, Changlang, and Lohit districts of Arunachal Pradesh show high disturbance undoubtedly due to human developmental activities. *After analysis of required parametres it is deduced that areas of Namdapha, Lower Subansiri etc. are characterised by rich temperate evergreen forest which are biologically rich.*

10.3 Assessment of Forest area in Subansiri Basin

Forest area in Arunachal Pradesh (State of Forest Report, 2013)
The recorded forest area in the State is 51,541 sq.kms. which is 61.55% of State's geographical area. Reserved forests is spread in an area of 10,723 sq.km (20.80% of recorded forest area), protected forests in 9,779 sq.km. area (18.97%) and unclassed forests in 31,039 sq.km. area (60.22%) in Arunachal Pradesh

The Subansiri basin is positioned in three districts namely Lower Subansiri District (3508 sq.kms), Kurung Kumey (6040 sq.kms) and Upper Subansiri District (7032 sq.kms) and thereby covering a total geographical area of 16580 sq.kms. Subansiri basin constitutes 19.79% of the total geographical area of Arunachal Pradesh

Forest Cover
On the basis of interpretation of the satellite data of 2010-2011, total forest and tree cover in the State is 67, 981 sq. kms. which works out as 81.18 of the State's geographical area (83, 743 sq.kms.). In terms of the forest cover within green wash, the area covered by very dense forests is 13,182, sq.kms., moderately dense forests is 20, 674 sq. kms and open forests are 5,381 sq.kms. Forest cover outside green wash comprises very dense forests 7,646, sq.kms., moderately dense forests is 10, 740 sq. kms and open forests are 5,381 sq.kms. Tree cover comprise 660 sq.km. The forest and tree cover totals 67, 981 sq. kms. The density class wise distribution of the forest cover of the state is shown in **Figure 10.17.** The Subansiri basin boundary and proposed HEPs have been overlaid on satellite imageries received from FSI Dehradun.

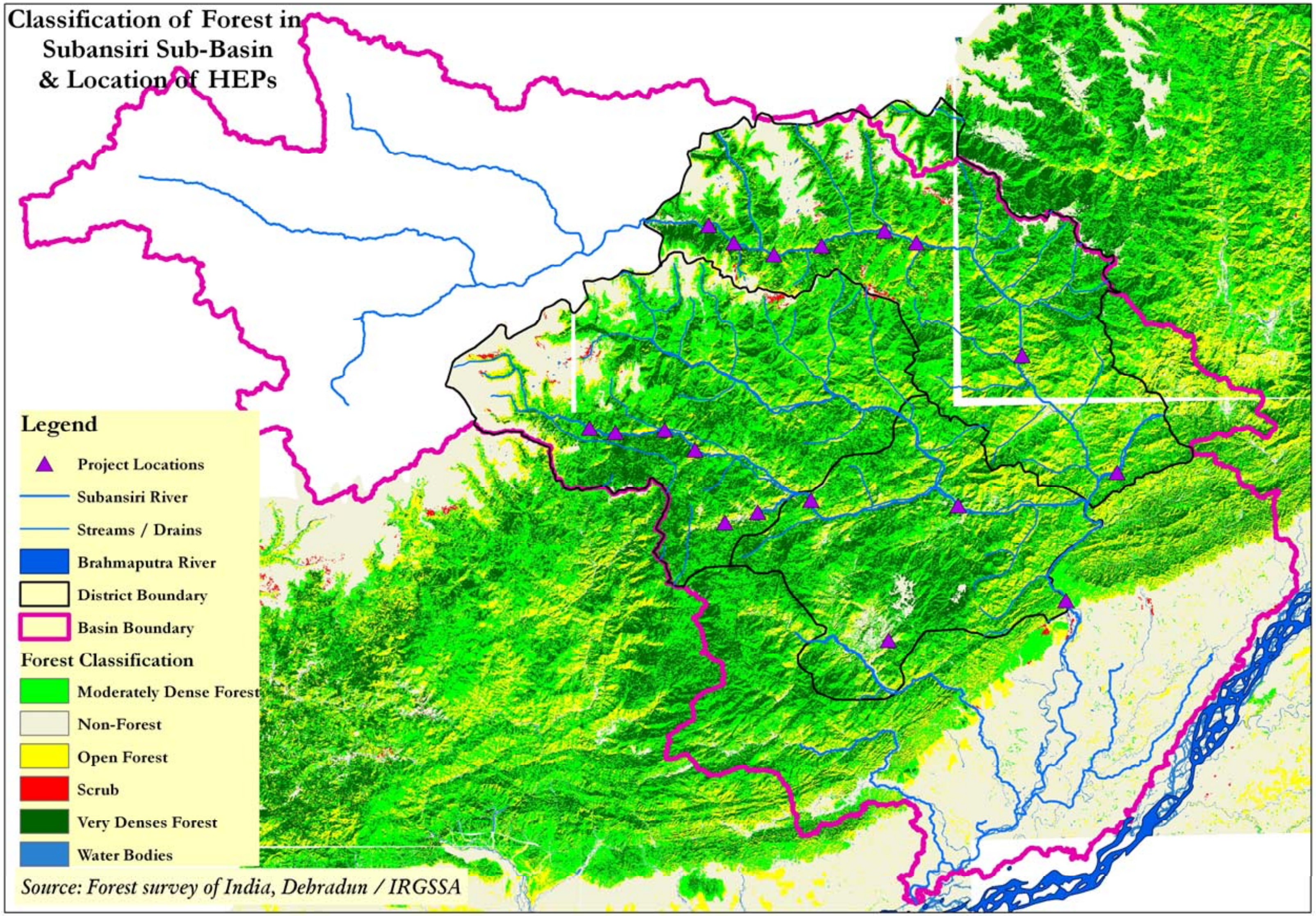

Figure 10.17: Forest Cover of Arunachal Pradesh and Subansiri Basin

Proportion of different forest cover classes in Arunachal Pradesh is depicted in the pie diagram in percentage terms is shown in **Figure 10.18** and proportion of different forest cover classes in Subansiri Basin is shown in **Figure 10.19.**

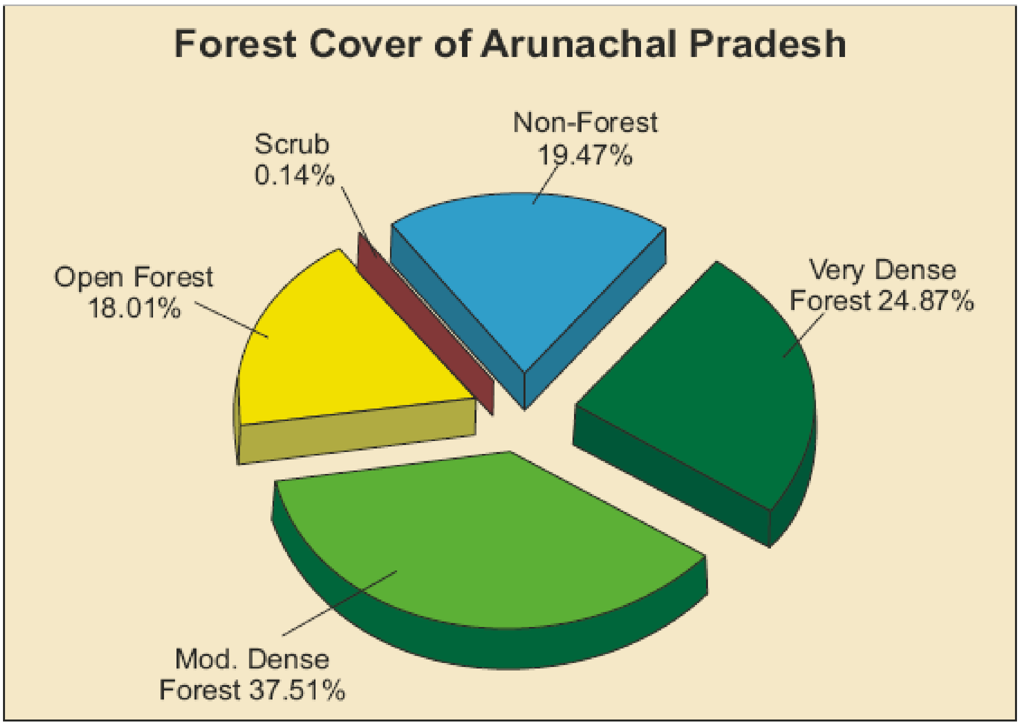

Figure 10.18: Proportion of different forest cover classes in Arunachal Pradesh (as per SFR, 2013)

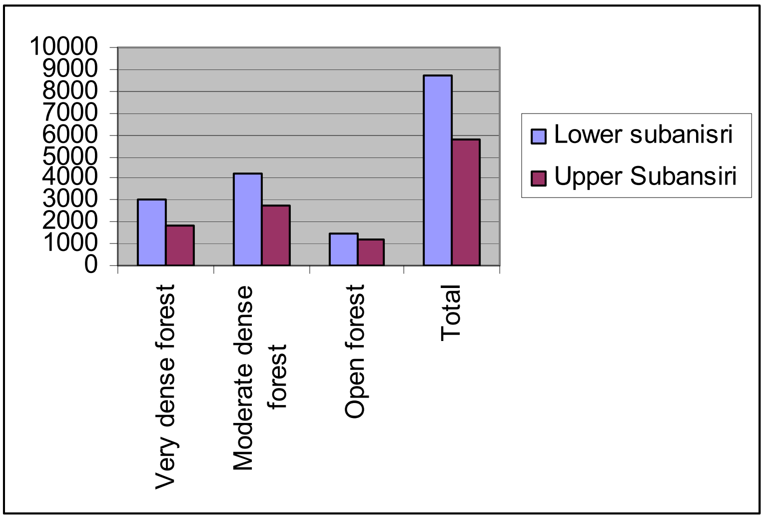

Figure 10.19: Proportion of different forest cover classes in Subansiri Basin

Forest cover in different canopy density classes, scrub and change in forest cover in comparison to 2009 assessment in the Subansiri Basin is given in **Table 10.**1.

Table 10.1: Forest Cover in Subansiri Basin

District	Geographical area in sq.kms	2013 Assessment				% of GA	Change*	Scrub
		Very dense forest	Moderate dense forest	Open forest	Total			
Lower Subansiri*	9548	3004	4245	1427	8676	90.87	3	28

District	Geographical area in sq.kms	2013 Assessment				% of GA	Change*	Scrub
		Very dense forest	Moderate dense forest	Open forest	Total			
Upper Subansiri	7032	1876	2746	1192	5814	82.68	-7	25

*The total geographical area of Lower Subansiri (9548 sq.kms.) used in the assessment of Forest Cover in Subansiri Basin, SFR 2013 is a sum total of geographical area of Lower Subansiri District (3508 sq.kms.) and geographical area of Kurung Kumey district (6040 sq.kms.), as per geographical area given in Census, 2011 for the said two districts.

The change figures are based on comparison of 2008 (SFR, 2011) assessment with that of 2010-11 (SFR 2013) The total forest cover in Lower and Upper Subansiri district is 90.87 and 82.68% of the geographical area of the said districts. The total forest cover of the Subansiri Basin is 14490 sq.kms. which is 21.31% of the total forest cover of the State.

Reasons for change detected in 2013 assessment: Reasons for the negative change in forest cover is due to shifting cultivation practices and biotic pressure.

10.4 Biological and ecological importance of Subansiri basin with respect to locations of proposed HEPs.

Forests of the state are legally classified and notified as reserved forests, protected forests, anchal and village forest reserves, national parks and wildlife sanctuaries under relevant provisions of Assam Forest regulation 1891, Anchal and Village Forest reserve Act 1978, 1981 and Wildlife Protection Act, 1972. Unsurveyed forests where status of right and ownership is not settled are classified as Unclassed State Forests (USF). The USF is a very ambiguous word and there is not much departmental control on it. The Reserved Forests are scientifically managed[79].

Assessment of location of proposed HEPs *vis a vis* presence of Reserved forests, Anchal Reserved Forest (ARF), Wildlife Sanctuary (WLS), Important Bird Area (IBA), Elephant Reserve (ER)/Elephant Corridor (EC) and Unclassed State Forest (USF) in Subansiri Basin has been done. All the proposed HEPs, by virtue of their location in a Biodiversity Hotspot, i.e. Arunachal Pradesh are therefore considered to be important from perspective of biological diversity and ecological importance, as given in Table 10.2.

Table 10.2: Proposed HEPs, their location in Subansiri basin in the context of biological and ecological importance

Proposed/ under construction HEPs	District	Reserved forests	Anchal Reserved Forest (ARF)	Wildlife Sanctuary (WLS)	Important Bird Area	Elephant reserve (ER)/Elephant Corridor (EC)	Unclassed State Forest (USF)	Total forest area
1.Oju I 2.Oju II 3.Niare 4.Naba 5.Nalo 6.Dengser 7.Subansiri Upper 8.Tammu	Upper Subansiri	504	2	-	Nacho-Limeking-Taksing-Majha Site Code: IN-AR-16 (Upper Subansiri District)	-	3076.00	3582.00
	Lower	347.07	-	337	Talley	No ER/EC but	2064.00	2411.73

[79] *State Biodiversity Strategy and Action Plan, Arunachal Pradesh.*

Proposed/ under construction HEPs	District	Reserved forests	Anchal Reserved Forest (ARF)	Wildlife Sanctuary (WLS)	Important Bird Area	Elephant reserve (ER)/Elephant Corridor (EC)	Unclassed State Forest (USF)	Total forest area
9.Middle Subansiri (Kamala HEP) 10.Lower Subansiri (under construction) 11.Tamen 12.Tago I	Subansiri				Valley wildlife Sanctuary Site Code: IN-AR-24 and Subansiri (IN406) (Lower Subansiri District) is in the project impact area	known elephant habitat		
13.Mili 14.Sape 15.Chomu 16.Chela 17.Nyepin 18. Hiya 19. Kurung I&II	Kurung Kumey	-	-	-	Koloriang- Sarli-Damin Areas Site code: IN-AR-10 (Lower Subansiri District) IBA Site Code: IN-AR-24	-	5964.60	5964.60

Note: Area is given in square kilometers.

The analysis of Table 10.2 indicates that 8 proposed HEPs namely Oju I, Oju II, Niare, Naba, Nalo, Dengser, Subansiri Upper and Tammu are located in Upper Subansiri District which has 504.00 sq.kms reserved forest and 2 sq.kms ARFs. 4 proposed HEPs namely Middle Subansiri (Kamala HEP), Lower Subansiri, Tamen and Tago I are located in Lower Subansiri district which has 347.07 sq.kms under Reserved Forest and 337 sq.kms area under Talle Wildlife Sanctuary. Other than this, 7 proposed HEPs namely Mili, Sape, Chomu, Chela, Nyepin, Hiya and Kurung I and II are located in Kurung Kumey district which has unclassed forest area of 5964.60 sq.kms. Besides, 4 Important Bird Areas have been identified in the said districts falling in Subansiri basin. It is anticipated that the proposed HEPs in Subansiri Basin may, therefore, impact on the biological diversity.

10.5 Cumulative Impact assessment on Terrestrial biodiversity at Subansiri Basin level

Biodiversity assessment at the Subansiri Sub Basin level

The results of biodiversity characterization at the landscape level for Arunachal Pradesh has been used for the impact assessment at the Subansiri basin level. The proposed HEPs in the Subansiri Basin have been overlaid on the landscape level map of Arunachal Pradesh to delineate the boundaries of Subansiri basin to show fragmentation, disturbance index and biological richness.

The Subansiri basin boundary and proposed HEPs have been overlaid on satellite imageries received from IIRS. Forest types in Subansiri Sub-Basin is mostly intact as shown in Figure 10.20. The proposed HEPs will directly impact on the forest area. Further, the

Disturbance Index map of Subansiri Basin given in Figure 10.21 shows that the Upper Subansiri District in Subansiri Basin is mostly intact. However, intact to medium level of disturbance is recorded in Lower Subansiri district. The Biological richness map of Subansiri sub basin given in Figure 10.22 shows that high biological diversity is recorded in Upper Subansiri Basin. Very high - high and medium biological richness is recorded in Lower Subansiri district.

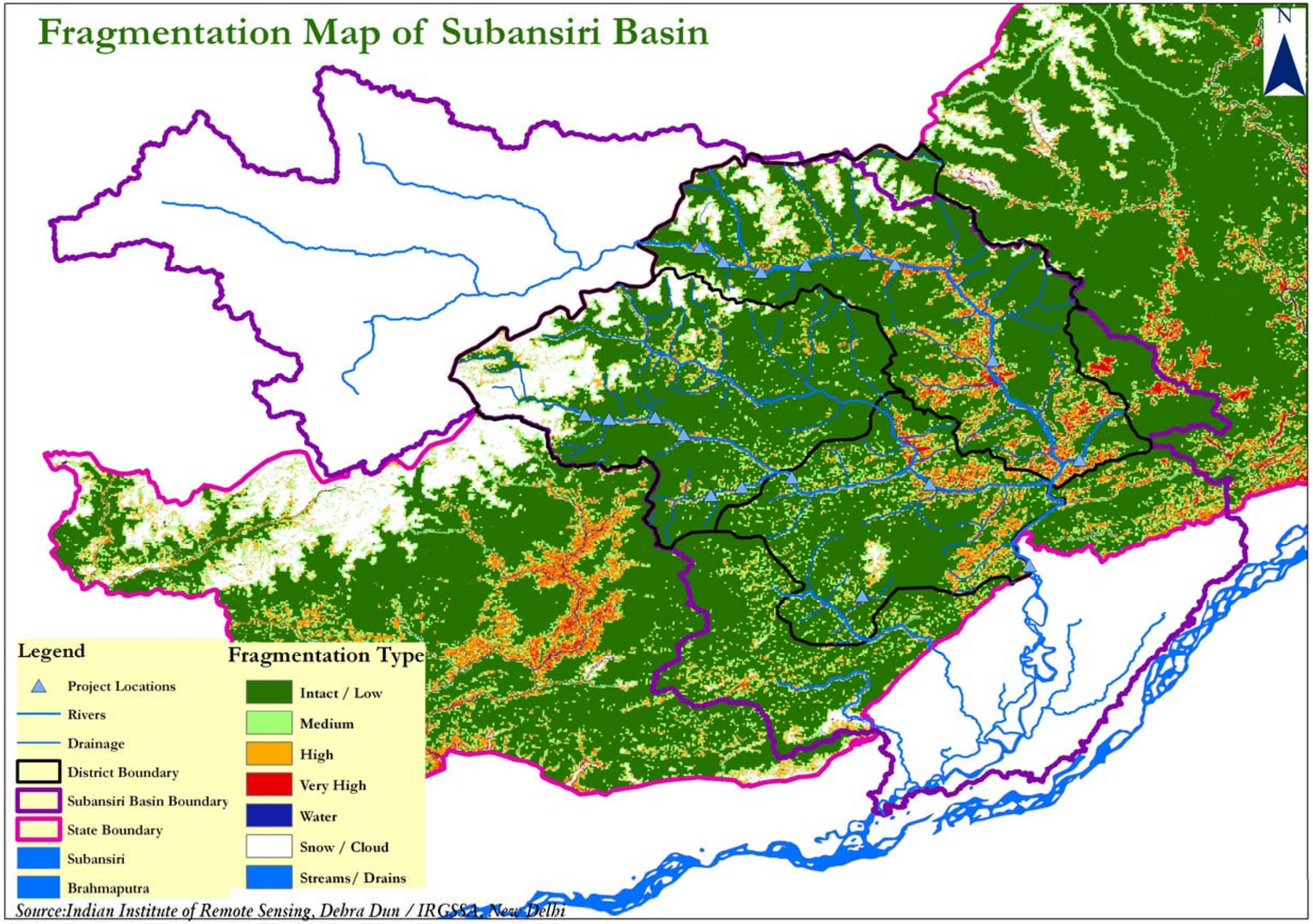

Figure 10.20: Fragmentation map of Subansiri Basin showing HEPs

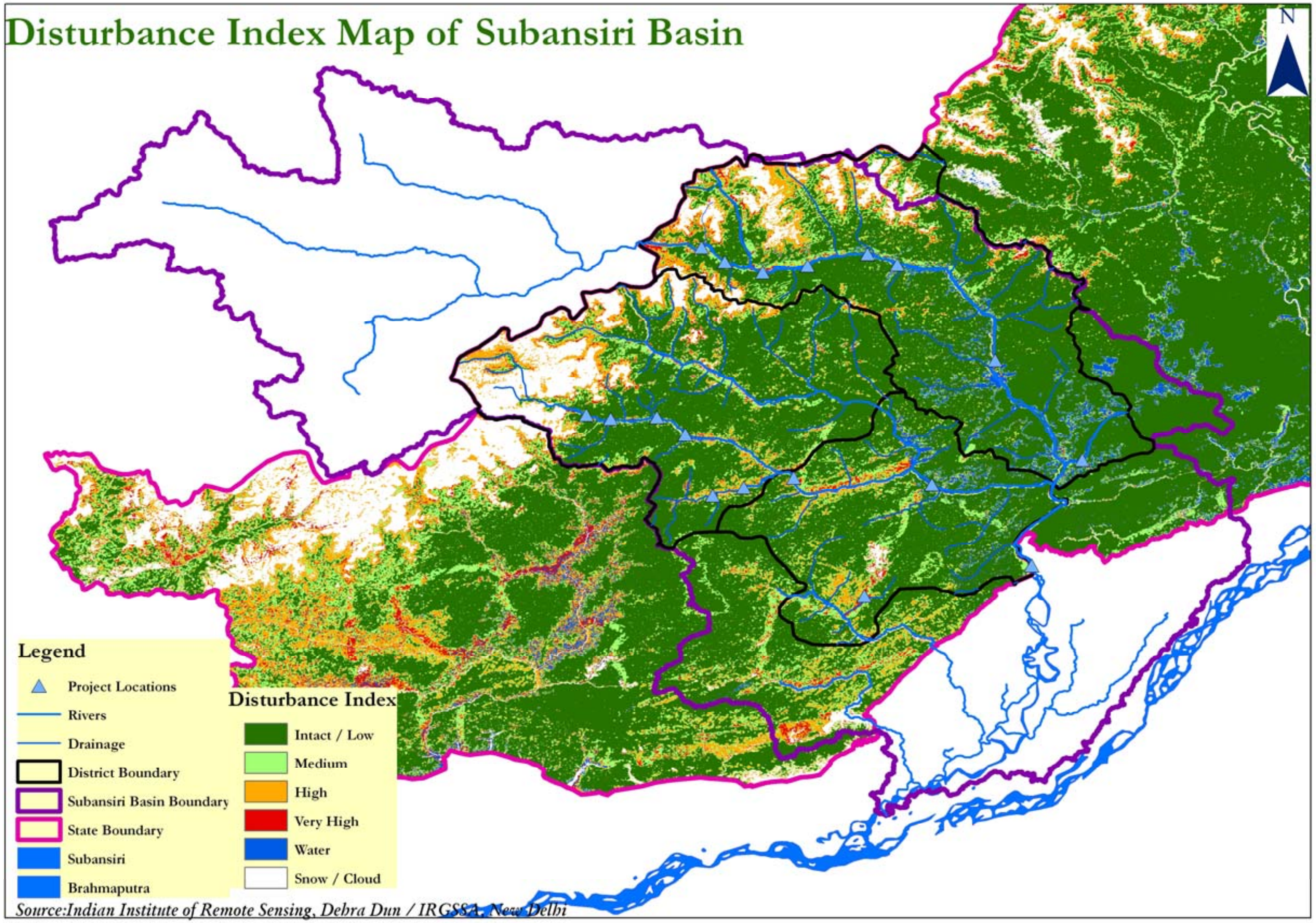

Figure 10.21: Disturbance Index of Subansiri Basin showing HEPs

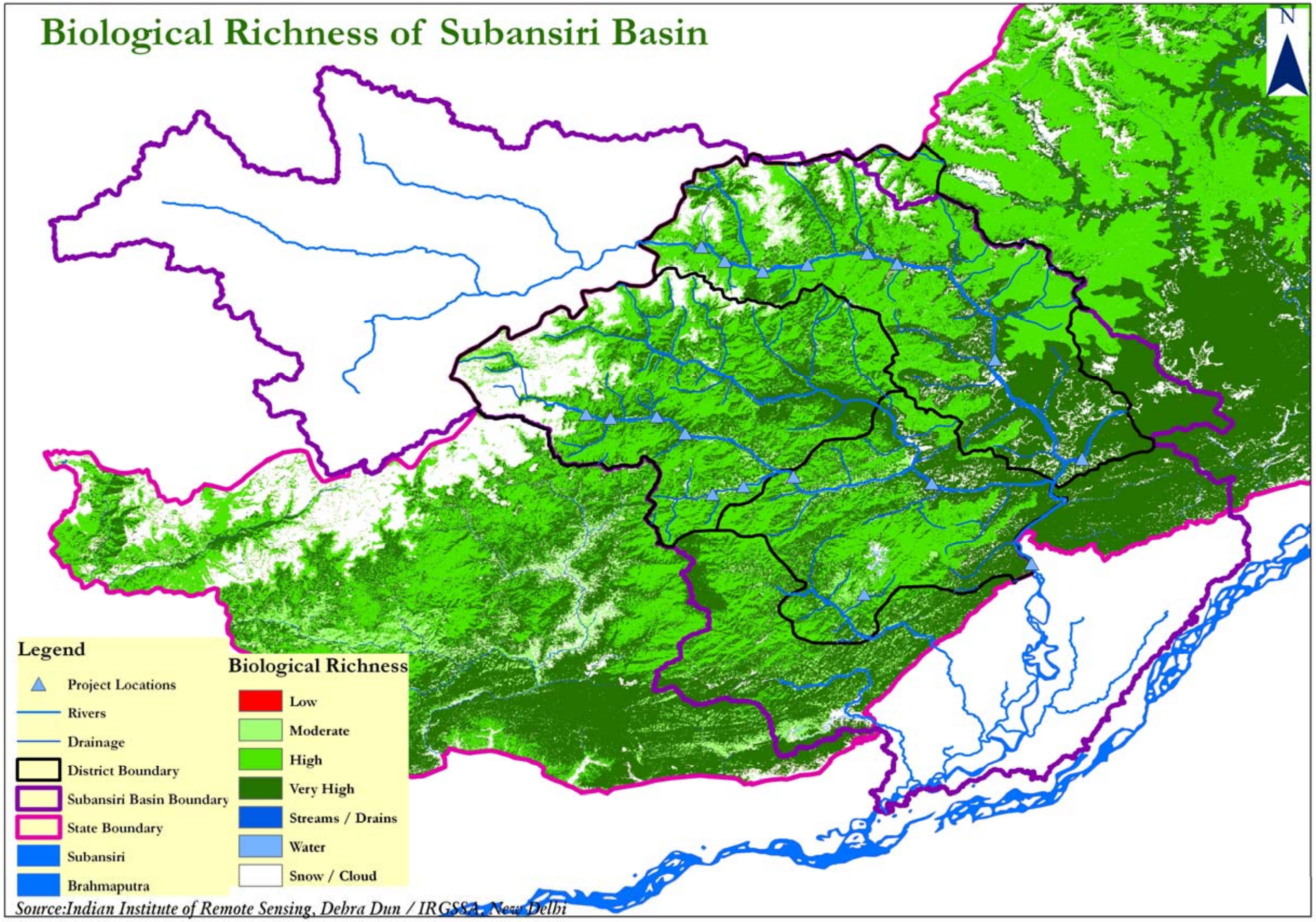

Figure 10.22: Biological richness in Subansiri Basin showing HEPs

The proposed HEPs in Subansiri sub Basin

The Subansiri River is the main river in Subansiri Sub basin. The Subansiri Sub basin has the highest number of 10 HEPs in Subansiri Basin with a total installed capacity of 8522 MW. Eight (8) out of Ten (10) projects are located in Upper Subansiri district and 2 in Lower Subansiri District as given in Table 10.3.

Table 10.3: Proposed HEPs in Subansiri sub basin

Sr. No.	District	Name of the project	Catchment Area (Sq.km)	Present IC (MW)	FRL m	Ht. of the dam (m)	Tail Water Level (m)
1.	Upper Subansiri	Oju – I	9827	700	1950	110	1670
2.	Upper Subansiri	Oju – II	9979	1000	1650	90	1300
3.	Upper Subansiri	Niare	11181	800	1280	100	1055
4.	Upper Subansiri	Naba	14300	1000	1035	110	780
5.	Upper Subansiri	Upper Subansiri	14665	2000	460	214	-
6.	Upper Subansiri	Nalo	12150	360	765	125	645
7.	Upper Subansiri	Dengser	17625	552	630	100	490
8.	Upper Subansiri	Tammu	-	55	310	-	220
9.	Lower Subansiri	Subansiri Lower	34900	2000	205	116	-
10.	Lower Subansiri	Tago – I	-	55	1080	-	790
				Total 8522 MW			

The proposed HEPs in upper reaches of Subansiri sub basin namely Oju, I, Oju II, Niare, Naba, Nalo, Dengser and Upper Subansiri HEP are located in the altitude range in 270-2275 metres in Upper Subansiri District. *Coptis teeta* (mishmee teeta), a vulnerable species and a plant of medicinal value have been reported from upper reaches of Upper Subansiri District at an elevation of 2500-3000 metres. Since the proposed HEPs are not in the altitude range of the recorded distributional range of *Coptis teeta,* the EIA/EMP studies of said HEPs should clearly delineate areas where threatened species are recorded and both *in situ* and *ex situ* species conservation plan prepared and implemented.

Keeping in view the Environmental benefits and other advantages of single scheme, the proposal from developer to merge Oju I and Oju II, has been agreed by the Government of Arunachal Pradesh to develop Oju I and Oju II of single scheme. The proposed environmental benefits of single scheme are:

-In the earlier proposal, Oju-I has been proposed on right bank and Oju-II on left bank as necessitated by the topography. The BRO road alignment runs along the right bank and the left bank is virgin. It is desirable to have both the schemes on right bank only so as not to disturb the virginity of left bank. As the topography is not suitable for having independent Oju-II at right bank, it would be preferable to have both the schemes merged with only one dam (at Oju-I location) and one power house (at Oju-II location) in place of two dams and two power houses.

-The free stretch between the earlier proposed Oju-I and Oju-II works out to less than 1 km which is not desirable from environmental angle.

-In case of single scheme all excavations and construction related activities will be reduced to half except the length of HRT (which may increase by 2-3 km) as compared to two schemes which will result in substantial saving in land requirement.

-There are numerous perennial streams joining the main river between the dam and power house of the single scheme at regular intervals (Table 10.4). This along with the provision of recommended minimum flow shall take care of the intermediate river stretch.

In view of the abovesaid, the proposal to merge Oju I and Oju II will keep the left bank forests intact thus reducing/eliminating the impact arising out of loss of forest area and dependent species. Further, single scheme will lead to substantial savings in land requirement for the project (30 to 40% approx.). Perennial streams joining the main Subansiri River between the dam and power house of the single scheme at regular intervals will augment the flow. This along with the provision of recommended minimum flow shall take care of the intermediate river stretch for aquatic fauna and sustenance of ecological functions.

Table 10. 4: Streams joining Subansiri River between Oju dam & power house of single scheme

Location	Notation	Name of the Stream Nala	Catchment Area (Sq Km)	Max Elevation (m)
Streams joining Left Side to Main Stream Of Subansiri	L 1	Dio Siko - Oyi Siko	73.00	5063
	L 2	Rijugna Siko	10.14	4365
	L 3	Niyonthi Siko	7.40	4264
	L 4		5.86	3802
	L 5		3.87	3509
	L 6		3.41	3527
Streams joining Right Side to Main Stream Of Subansiri	R 1	Chetu Suko	17.51	4391
	R 2	Doju Bung Nalla	16.98	4389
	R 3	Oju Siko	41.77	4870
	R 4	Yang Siko	3.52	3486
Subansiri Catchment Area Between Dam and Power House			222.79	

Streams joining Subansiri River between Oju dam & power house of single scheme (after proposed merger of Oju I and Oju II) is shown in Figure 10.23.

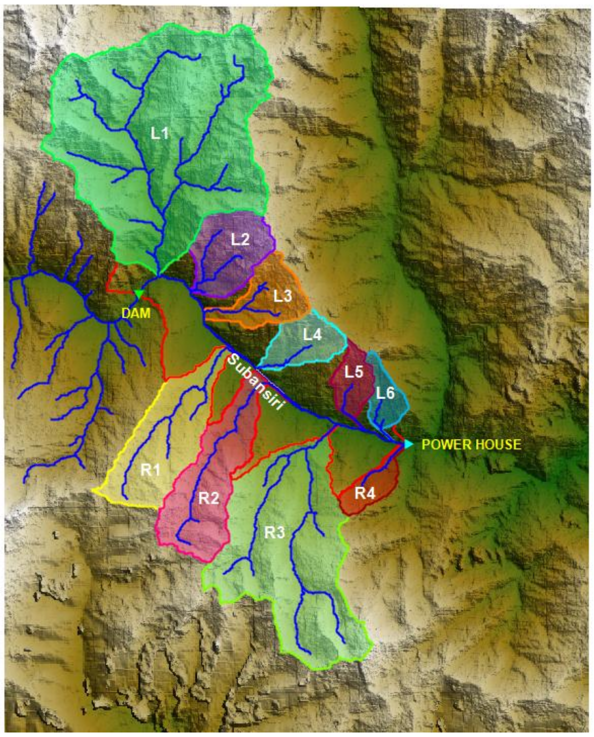

Figure 10.23: Streams joining Subansiri River between Oju dam & power house of single scheme

Lower Subansiri District

Six *threatened* species namely *Begonia aborensis, Begonia scintillans, Begonia tessaricarpa, Pholidota wattii, Livistona jenkinsiana* (all endemic) and *Vanda coerulea* are recorded from submergence areas of Lower Subansiri HEP, Lower Subansiri district. Moreover, three threatened plant species *viz. Heritiera acuminata* (a tree species), *Bambusa mastersii* (a bamboo species) and *Cyathea spinulosa* (a fern species) were found in the submergence area/construction site of the dam. One species of endangered plant, i.e. *Heritiera acuminata* and two rare species, i.e. *Bambusa mastersii* and *Cyathea spinulosa* have been reported in the project area. These species are observed in the nearby forests also, and only a very small proportion of the total forest area in the region is being acquired, hence, no major impacts are anticipated during the construction phase of Lower Subansiri project. It may be noted that these species are not listed in Red Data Book of Indian Plants (Vol 1-3.), BSI. However, these species are listed in EIA/EMP report of Lower Subansiri Project and Preservation plans and project cost was also suggested in the EIA/EMP report. 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. 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. However, as per the study of SFRI, 2009, none of the orchids species found in the submergence area falls under Rare or Endangered species category (as per BSI/IUCN). However, considering the parameters of restricted distribution, rare distribution and frequency in the natural habitat three species were considered rare and endangered namely *Dendrobium vexabile, Pennilabium struthio* and *Pomatocalpa undulatum.* The study concluded that as the above three species are distributed in other districts also, as such there is no threat to them due to dam construction.

Three studies namely, the EIA/EMP study of Lower Subansiri HEP and two studies done in compliance to Environment clearance (EC) conditions namely Survey and Identification of Orchids upto species level in submergence areas of Subansiri Lower Hydroelectric Project and rehabilitation of Rare and Endangered Orchid species in Orchidaria of State Forest Research Institute and NHPC, Gerukamukh, 2009 and Final report on Biodiversity study in the submergence area of Subansiri Lower HE Project-Floral Aspects prepared by Department of Botany, Gauhati University indicate that the area is rich in plant diversity as is indicated by presence of endemic and threatened plant species. It also indicates that such studies should be conducted at the stage of EIA/EMP study itself so that endemic and threatened species are identified and their conservation plan is prepared at the EIA/EMP for implementation during construction and operational phase.

Based on the biodiversity characterization of Arunachal Pradesh at the landscape level, it is deduced that areas of Lower Subansiri district are characterised by rich temperate evergreen forest which are biologically rich. The analysis carried out using landscape parameters in conjunction with field data and literature survey indicates that forests are extremely rich in border areas of Lower Subansiri. Data on plant diversity, endemic and threatened species also indicate that Lower Subansiri HEP is located in the biodiversity rich area.

The analysis of fragmentation, disturbance index and biological richness of Subansiri Sub Basin (Figures 10.20-10.22), indicate that Subansiri Sub Basin is very important in terms of having intact forest types and high -very high biological richness. In particular, border areas of Lower Subansiri are extremely rich. It is to be noted that the Lower Subansiri HEP is located in the border of Lower Subansiri district and Dhemaji District. The biodiversity assessment of Lower Subansiri HEP also indicate biodiversity richness and presence of endemic and threatened species in the submergence areas of the HEP, besides the presence of species listed in Schedules of Wildlife Protection Act and species listed in CITES.

Biodiversity assessment at the Kamla Sub Basin level, Lower Subansiri District

Forest types in Subansiri Sub-Basin is mostly intact as shown in Figure 10.20 The proposed HEPs will directly impact on the forest area. Further, the Disturbance Index map of Subansiri Basin given in Figure 10.21 shows intact to medium level of disturbance in Lower Subansiri district. The Biological richness map of Subansiri sub basin given in Figure 10.22 shows very high - high and medium biological richness in Lower Subansiri district. Two projects are proposed in Kamla Sub basin which will bring 12 sq. kms. of forest area [Subansiri Middle (Kamala HEP)] under submergence (Table 10.5).

Table 10.5.The proposed HEPs in Kamla sub Basin, Lower Subansiri district

Sr. No.	Name of the project	Catchment Area (Sq.km)	Present IC (MW)	FRL m	Ht. of the dam (m)	Tail Water Level (m)
1.	Subansiri Middle (Kamala HEP)	7213	1728	455	203	-
2.	Tamen	-	175	320	-	250
			Total 1903 MW			

Biodiversity assessment at Kurung sub Basin, Kurung Kumey district

Forest types in Subansiri Basin is mostly intact except for a small patch in Kurung Kumey district where intact to medium fragmentation has been recorded as shown in Figure 10.20. The Disturbance Index map of Subansiri Basin given in Figure 10.21 shows intact to medium level of disturbance in Kurung Kumey district. The Biological richness map of Subansiri basin given in Figure 10.22 shows high and medium biological richness in Kurung Kumey district. 7 projects in Kurung Sub basin with total installed capacity of 671 MW are proposed as given in Table 10.6.

Table 10.6: Proposed HEPs in Kurung sub Basin, Kurung Kumey district

Sr. No.	Name of the project	Catchment Area (Sq.km)	Present IC (MW)	FRL m	Ht. of the dam (m)	Tail Water Level (m)
1.	Mili	-	75	1400	-	1200
2.	Sape	-	38	1155	-	1080
3.	Chomi	1194	80	1067	-	920
4.	Chela	1430	75	895	-	805
5.	Kurang I & II	2302	330	745	140	620
6.	Nyepin	-	32	1060	-	920
7.	Hiya	-	41	880	-	745
			Total 671 MW			

Out of seven proposed HEPs in Kurung sub basin, five projects namely Kurang I&II, Chomi, Chela, Nyepin and Hiya have been allotted. As per the Pre feasibility report, Kurung I&II HEP proposes to bring 16.45 sq.kms. of forests under submergence. No information is available for other HEPs. 5964.60 sq.km of Unclassed State Forests has been reported in Kurung Kumey district.

Dalbergia thomsonii and *Derris marginata* which were considered endemic to Khasia and Jaintia hill of Assam and Meghalaya have been reported for the first time from Kurung Kumey district. *Shuteria involucrata* is another species which was collected from the district forms the basis of first report for Arunachal Pradesh. Some of the interesting rare species, viz. *Crotolaria anagyroides* is a native of tropical America reported to be naturalized in Meghalaya and Mizoram is found in this region. Similarly, during the recent floristic survey conducted in the Kurung Kumey District of Arunachal Pradesh, six interesting species were collected which were known only from the type locality. The present collection of these species from areas other than the type localities confirms that they may have a wider distribution in this region. Out of the six species, *Dalbergia thomsonii* Benth. *Larsenianthus assamensis* S. Dey, Mood & S. Choudhury and *Plectocomia himalayana* Griff. are reported for the first time from the state while *Begonia silhetensis* (A.DC.) C.B. Clarke, *Larsenianthus arunachalensis* M. Sabu, Sanoj & T. Rajesh Kumar and *Tricarpelema glanduliferum* (J. Joseph & R.S. Rao) R.S. Rao show extended distribution. It is also interesting to note that many species. viz. *Begonia aborensis, Begonia silhetensis, Glochidion assamicus, Hodgsonia macrocarpa, Hoya parasitica, Illigera khasiana, Maesa nayarii, Modecca cardiophylla, Polygonatum opppositifolium, Pueraria bella, Raphiostema pulchella, Rubus birmanicus, Stauranthera grandiflora, Ventilago madaraspatana* ,which are rare in their natural habitat are also encountered in this region.

In view of the rich biodiversity in the Kurung Sub basin as described above, it is suggested that all the proposed seven projects including Mili, Sape, Nyepin and Hiya (which are not yet allotted and studied) may be studied in detail for assessment of biodiversity and impacts thereon by specialist agencies before considering them for allotment to developers. The figures for forest area under submergence in Kurung sub-basin is not available except for Kurung I&II.

Loss of forest in Subansiri Basin

Cumulative Impact Assessment of loss of forests by proposed HEPs in Subansiri Basin has been done to understand losses on account of proposed HEPs as given in Table 10.7.

Table 10.7: Cumulative Impact Assessment of loss of forests by proposed HEPs in Subansiri Basin

District (area)	Main River	Tributary	Total Catchment Area (Sq. km)	Total Forest cover area (sq. km)	Proposed HEP and its Capacity (MW)	Total Land Affected (sq.km)			Total Forest cover area affected (%)
						Total Land Area	Total Forest Area	Land under Submergence	
Upper Subansiri (7032 sq.km)	Subansiri	Subansiri/Singit	9827	5814	Oju-I: 700	5.1	3.55	0.7	0.06
			9979		Oju-II: 1000	5.25	4.05	0.4	0.07
			11181		Niare: 800	5	5	0.48	0.09
			14300		Naba:1000	5	3.75	0.8128	0.06
			12150		Nalo: 360	7.4	4.55	3	0.08
			17625		Dengser: 552	2.316	1.316	1	0.02
			14665		Upper Subansiri: 2000	31.55	21.7	22.2	0.37
Sub-Total						61.62	43.92	28.59	0.75
L Subansiri 3508 sq.km (9548 sq.km as per SFR 2013)		Subansiri	7213	8676	Subansiri Middle (Kamala HEP): 1728	31.8	13.3	12	0.15
			34900		Lower Subansiri: 2000	41.11	31.87	34.36	0.37
Sub-Total						72.91	45.17	46.36	0.52
Kurung Kumey 6040 Sq.km)	Kamla	Kurung	2302	5620.02 *	Kurung I and II: 330	24.7	16.45	20.25	0.29
Sub-Total						24.7	16.45	20.25	0.29
Grand Total						159.23	105.54	95.2	1.56

Statistics on district and forest area is as per SFR, Arunachal Pradesh, 2013.

* ➔ Figures of Kurung Kumey district has been taken from NRSC, 2005-2006

This assessment is based on data available as per current information on requirement of land for developing HEPs including forest land loss and forest loss which has been computed at the basin level for assessment of forest loss as given in Table 10.7 and summarized below as:

Lower Subansiri district: 0.52% forest area loss
Upper Subansiri district: 0.75% forest area loss
Kurung Kumey district: 0.29% forest area loss
Total loss of forest area in Subansiri Basin: 1.56%

Total estimated loss of forest in Subansiri Basin, Arunachal Pradesh is 1.56% of the total Forest Area of Subansiri Basin, Arunachal Pradesh.

In Assam, Dhemaji district's forest cover as per SFR 2013 is 292 sq. kms and Assam State's forest and tree cover is 29,253 sq.kms (total geographical area of Assam (78,438 sq.kms). Dhemaji district's forest cover of 292 sq. kms amounts to 0.37% of the total geographical area of Assam. The estimated forest loss in Assam's Dhemaji district would be 8.42 sq.kms (on account of Lower Subansiri HEP), which amounts to 2.88% (8.42 sq.kms) forest loss in the district and 0.02% loss to the State's total forest cover.

Being a hilly State, Arunachal Pradesh is required to maintain 66% of forest cover w.r.t total geographical area of the State (83, 743 sq. kms i.e. 55270.3 sq.km). As per SFR 2013, the total forest and tree cover in the State is recorded to be 67, 981 sq. kms. which works out as 81.17% of the State's geographical area (i.e. 83, 743 sq. kms). The total loss of forest area is estimated to be 0.15% (105.54 sq.km) in Arunachal Pradesh and 0.02 % in the Assam's total forest area. The proposed HEPs will, therefore, have impact in terms of loss of current forest area of the Districts/State of Arunachal Pradesh and Assam.

Impacts on Endemic species

220 endemic species have been listed from Arunachal Pradesh, out of which Subansiri Basin has 62 endemic species which accounts for 28% of the State's endemic flora. This is indicative of high endemism in the Subansiri Basin. 7 endemic species of Ericaceae, 3 endemic species of Begoniaceae and 1 species each of Orchidaceae and Arecaceace are threatened as well.

Orchidaceae family has 14 species (1 threatened) , Ericaceae has 8 species (7 threatened), followed by 5 species of Fumariaceae, 4 species each of Ranunculaceae, Magnoliaceae and Rubiaceae, 3 each of Balsaminaceae, Begoniaceae (3 threatened) and Gesneriaceae and 1 species each of family Illiciaceae, Schisandraceae, Vitaceae, Hydrangeaceae, Myrtaceae, Myrsinaceae, Pedaliaceae, Verbenaceae, Euphorbiaceae, Urticaceae, Agavaceae, Araceae, Arecacecae (1 threatened)and Cyperaceae. Further, 5 species namely *Rhododendron falconeri* subsp*. eximium*, *R. santapauii*, *R. subansiriense, Vaccinium dendrocharis* ssp*. talle* and *Livistona jenkinsiana* are assessed as Endangered, 2 species namely *Agapetes atrosanguina* and *Agapetes refracta* are assessed as Vulnerable, 3 species namely *Begonia aborensis, Rhododendron nutalli* and *Pholidota wattii* are assessed as Rare and 2 species namely *Begonia scintillans* and *Begonia tessaricarpa* are assessed as Indeterminate species in Subansiri basin.

Impacts on these species are imminent in view of the loss of forests due to proposed HEPs in the Basin. The presence of endemic species in the project impact area focusing on submergence area of each HEP need to be ascertained in the Environment Impact Assessment report covering three seasons. A detailed conservation plan for endemic species need to be prepared if the presence of endemic species is confirmed. The conservation plan should include both *in situ* and *ex situ* measures considering relocation of the species e.g. Botanic garden, Orchidarium, etc.

Endemic floral species in Arunachal Pradesh, Subansiri Basin and Subansiri Sub basin given in Table 10. 8 shows 8 species as endemic to Subansiri sub basin. 5 of 8 endemic species (in Subansiri sub basin) reported from submergence areas of Lower Subansiri HEP are also threatened.

Table 10.8: Endemic floral species in Arunachal Pradesh, Subansiri Basin and Subansiri Sub basin

Sr no.	Endemic species in Arunachal Pradesh	Endemic species in Subansiri Basin	Endemic species in Subansiri sub Basin
1	220	62	8

Disaggregated data on presence of endemic species in Kamla and Kurung sub basin is not available. However, *Begonia aborensis,* an endemic species is reported from Kurung Kumey district. *Livistona jenkinsiana* (Toko palm), an Endangered and Endemic plant to North East India is reported to occur in different sites in the submergence areas of Lower Subansiri HEP, Lower Subansiri district, Upper Subansiri district and Kurung Kumey district.

Impacts on Threatened floral species

36 threatened species (including 12 endemic species) have been reported from Subansiri basin. Out of 36 threatened species, 6 Endangered, 15 Vulnerable, 13 Rare and 2 Indeterminate) reported to occur in Subansiri Basin. Of 36 threatened species, 20 threatened species are reported in Subansiri Sub Basin as shown in Table 10.9.

Table 10.9: Threatened floral species in Arunachal Pradesh, Subansiri Basin and Subansiri Sub basin

Sr. no.	Threatened species in Arunachal Pradesh	Threatened species in Subansiri Basin	Threatened species in Subansiri sub Basin
1	39	36	20

Disaggregated data on threatened species in Kamla and Kurung sub basin is not available. However, *Begonia aborensis,* a rare and endemic species is reported from Kurung Kumey district. *Livistona jenkinsiana* (Toko palm), an Endangered and Endemic plant to North East India is reported to occur in different sites in the submergence areas of Lower Subansiri HEP, Lower Subansiri district, Upper Subansiri district and Kurung Kumey district.

10.6 Conclusions

Forest types in Subansiri Basin is mostly intact except for a small patch in Kurung Kumey district where intact to medium fragmentation has been recorded. The Disturbance Index map of Subansiri Basin shows that the Upper Subansiri District in Subansiri Basin is mostly intact. However, intact to medium level of disturbance is recorded in Lower Subansiri and Kurung Kumey districts. The Biological richness map of Subansiri basin shows that high biological diversity is recorded in Upper Subansiri District. Very high - high and medium biological richness is recorded in Lower Subansiri and Kurung Kumey districts. The proposed HEPs in Lower Subansiri District, particularly Lower Subansiri HEP for which information is available also points towards biological richness.

Statistics of forest area show a declining trend especially in Upper Subansiri district in Subansiri Basin. The declining trend of loss of forest area in Subansiri basin may further be triggered by the proposed cascade development of HEPs over a period of time as and when the proposed HEPs are approved. The estimated forest loss is summarized below:

Lower Subansiri district: 0.52% forest area loss
Upper Subansiri district: 0.75% forest area loss
Kurung Kumey district: 0.29% forest area loss
Total loss of forest area in Subansiri Basin: 1.56%

Total estimated loss of forest in Subansiri Basin, Arunachal Pradesh is 1.56% of the total Forest Area of Subansiri Basin, Arunachal Pradesh.

In Assam, Dhemaji district's forest cover as per SFR 2013 is 292 sq. kms and Assam State's forest and tree cover is 29,253 sq.kms (total geographical area of Assam (78,438 sq.kms). Dhemaji district's forest cover of 292 sq. kms amounts to 0.37% of the total geographical area of Assam. The estimated forest loss in Assam's Dhemaji district would be 8.42 sq.kms (on account of Lower Subansiri HEP), which amounts to 2.88% (8.42 sq.kms) forest loss in the district and 0.02% loss to the State's total forest cover.

Being a hilly State, Arunachal Pradesh is required to maintain 66% of forest cover w.r.t total geographical area of the State (83, 743 sq. kms i.e. 55270.3 sq.km). As per SFR 2013, the total forest and tree cover in the State is recorded to be 67, 981 sq. kms. which works out as 81.17% of the State's geographical area (i.e. 83, 743 sq. kms). The total loss of forest area is estimated to be 0.15% (105.54 sq.km) in Arunachal Pradesh and 0.02 % in the Assam's total forest area. The proposed HEPs will, therefore, have impact in terms of loss of current forest area of the Districts/State of Arunachal Pradesh and Assam.

However, measures like EMPs, compensatory afforestation, catchment area treatment plan, biodiversity conservation and management plan including *ex situ* conservation measures for endemic and threatened species, green belt development, etc may offset the loss of the forest area and species on account of the proposed HEPs.

Assessment of location of proposed HEPs *vis a vis* presence of Reserved forests, Anchal Reserved Forest (ARF), Wildlife Sanctuary (WLS), Important Bird Area (IBA), Elephant Reserve (ER)/Elephant Corridor (EC) and Unclassed State Forest (USF) in Subansiri Basin shows that the proposed HEPs, by virtue of their location in a Biodiversity Hotspot, i.e. Arunachal Pradesh are therefore considered to be important from perspective of biological diversity and ecological importance. MOEF has specified carrying out cumulative impact assessment in the ToR for Upper Subansiri HEP with respect to Lower Subansiri HEP and Middle Subansiri HEP (Kamala HEP), as part of EIA/EMP of Upper Subansiri HEP.

Therefore, the *8* proposed HEPs in Upper Subansiri District (with a total installed capacity of 6467 MW), 4 proposed HEPs (with a total installed capacity of 3958 MW) in Lower Subansiri district and 7 proposed HEPs (with a total installed capacity of 671 MW) in Kurung Kumey district (totaling 19 projects with installed capacity of 11,096 MW) are anticipated to impact on the biological richness of the said districts in Subansiri Basin.

Based on the data availability on biodiversity on the proposed HEPs, it can be inferred that Subansiri Sub basin is the most important basin from the point of view of having highest number of HEPs with highest installed capacity, the highest estimated loss of forest area and reported presence of endemic and threatened species. The Sub basin also holds possibility of discovery of new species, possible rediscovery of endemic and threatened species or new distributional record for the State.

The Kamla River sub basin has two projects of 1903 MW while Kurung sub basin has 7 HEPs having the total installed capacity of 671 MW. While the proposed 7 projects in Kurung Sub basin are of smaller installed capacity, the proposed HEPs are very important by virtue of their location in Kurung Kumey district, not being fully explored from biodiversity point of view.

10.7 Impacts on Terrestrial Fauna

Worldwide, the most important places for habitat-based conservation of birds are the Endemic Bird Areas (EBAs). Most species are quite widespread and have large ranges. However, over 2,500 are restricted to an area smaller than 50,000 sq.km. and they are said to be endemic to it. BirdLife has identified regions of the world where the distributions of two or more of these restricted-range species overlap to form Endemic Bird Areas. An Endemic Bird Area is defined as an area which encompasses the overlapping breeding ranges of restricted range bird species, such that the complete ranges of two or more restricted species are entirely included within the boundary of the EBA. This does not necessarily mean that the complete ranges of all of an EBA's restricted range species are entirely included within the boundary of that single EBA, as some species may be shared between EBA's (Stattersfield *et. al.* 1998)[80]. There are twelve Endemic Bird Areas (seven EBA and five secondary areas) occur in India. The Eastern Himalaya Endemic Bird Area follows the Himalayan range east from the Arun-Kosi valley of eastern Nepal, through Bhutan, north-east India (Sikkim, northern West Bengal and Arunachal Pradesh), south-east Tibet autonomous region and north-east Myanmar to south-west China (north-west Yunnan province). It also includes the mountain ranges to the south of the Brahmaputra river, which

[80] Stattersfield, A. J., M. J. Crosby, A. J. Long and D. C. Wege, (1998). Endemic bird areas of the world: priorities for biodiversity conservation.

extend through north-east India (Nagaland, Manipur, southern Assam, Meghalaya and Mizoram) to the Chin hills in western Myanmar, and the Chittagong hills in south-east Bangladesh. As they lie further to the south, the mountains of this region have a distinctly different climate (and hence vegetation) from the rest of the Himalayas: they experience warmer mean temperatures and fewer days with frost, and generally have a much higher rainfall. Two evergreen forest types appear to be particularly important breeding habitats for the EBA's restricted-range birds, both of which reach their western limit in eastern Nepal: subtropical wet hill forest is found at altitudes between approximately 1,000 and 2,000.[81]

Subansiri Basin falls in the Eastern Himalayas Endemic Bird Area (EBA) in which 21 species are considered as Restricted Range. The new monal taxon is confined to a narrow altitudinal belt in Arunachal Pradesh so it would also qualify for Restricted Range status. As the habitat is intact in many parts of this IBA, significant populations of many Biome- restricted species are likely to be present.

Important Bird Areas (IBAs) in Subansiri Basin, their status, threats etc are described below:

Upper Subansiri district

IBA Nacho-Limeking-Taksing-Majha (IN353) is a large area in the north of Arunachal Pradesh in Upper Subansiri district, close to Indo-China (Tibet) border. The area is largely mountainous with a number of peaks rising over 4,000 m. The River Subansiri, which originates in Tibet flows through this IBA. Also the area is criss-crossed by number of streams and small rivers that drain into the Subansiri. Most of the forest is inaccessible and still untouched. Road network is limited and the remoteness of the site has left a large extent of habitat intact. Local inhabitants are largely of the Tagin tribe and human settlements are very minimal. In the lower reaches, below 1,500 m, elements of Tropical Wet Evergreen to Subtropical Broadleaf Forests are found. Himalayan Wet Temperate Forest, mixed with Bamboo and Cane, is found in the intermediate elevations from 1,500 to 3,000 m.

Populations of IBA trigger species

Species	Season	Period	Population estimate	Quality of estimate	IBA Criteria	IUCN Category
Sclater's Monal *Lophophorus sclateri*	-	2004	present [units unknown]	-	A1, A2	Vulnerable
Chestnut-breasted Partridge *Arborophila mandellii*	-	2004	present [units unknown]	-	A1, A2	Vulnerable
Ward's Trogon *Harpactes wardi*	-	2004	present [units unknown]	-	A2	Near Threatened
Rufous-necked Hornbill *Aceros nipalensis*	-	2004	present [units unknown]	-	A1	Vulnerable
Yellow-vented Warbler *Phylloscopus cantator*	-	2004	present [units unknown]	-	A2	Least Concern
Broad-billed Warbler *Tickellia hodgsoni*	-	2004	present [units unknown]	-	A2	Least Concern
Blackish-breasted Babbler *Sphenocichla humei*	-	2004	present [units unknown]	-	A2	Near Threatened
Streak-throated Barwing *Actinodura waldeni*	-	2004	present [units unknown]	-	A2	Least Concern
Ludlow's Fulvetta *Alcippe ludlowi*	-	2004	present [units unknown]	-	A2	Least Concern

[81] *http://www.birdlife.org/datazone/eba*

Species	Season	Period	Population estimate	Quality of estimate	IBA Criteria	IUCN Category
Beautiful Sibia *Heterophasia pulchella*	-	2004	present [units unknown]	-	A2	Least Concern
White-naped Yuhina *Yuhina bakeri*	-	2004	present [units unknown]	-	A2	Least Concern
Beautiful Nuthatch *Sitta formosa*	-	2004	present [units unknown]	-	A1	Vulnerable
Rusty-bellied Shortwing *Brachypteryx hyperythra*	-	2004	present [units unknown]	-	A1, A2	Near Threatened

Lower Subansiri district

Subansiri Important Bird Area (IBA-IN406) site includes two reserve forests, Subansiri in Dhemaji district and Dulung in Lakhimpur district in northeastern Assam. The river Subansiri passes through the middle of the IBA, while its tributaries Pavo, Geruka, Dirpai and Dulung drain other parts of the site. It is here that the Subansiri River debouches into the plains, forming a broad braided stretch of aquatic and terrestrial habitats. The terrain of the site is hilly, as it covers foothills of the Eastern Himalayas. Small flat areas occur along the southern portion. The higher parts of Subansiri Reserve Forest are more than 300 m above msl. The site is known for wildlife, especially Asian Elephant *Elephas maximus* and birds. There was an excellent patch of terai grassland in Dirpai area of Subansiri RF, where the Bengal Florican *Houbaropsis bengalensis* and the Swamp Francolin *Francolinus gularis* used to occur. While the call of the francolins is still heard, the florican has become sporadic. This is mainly due to encroachment and settlements in its grassland habitat. There is also a record of the Chestnut-breasted or Red-breasted Hill Partridge *Arborophila mandellii* from the higher areas of Subansiri RF. The entire area is clothed with thick, lush Tropical Evergreen and Semi-evergreen forests, with absolute habitat contiguity with Taley Valley Wildlife Sanctuary (IBA) of Arunachal Pradesh, across the river Subansiri.

Populations of IBA trigger species

Species	Season	Period	Population estimate	Quality of estimate	IBA Criteria	IUCN Category
Swamp Francolin *Francolinus gularis*	-	2004	present [units unknown]	-	A1	Vulnerable
Chestnut-breasted Partridge *Arborophila mandellii*	-	2004	present [units unknown]	-	A1	Vulnerable
White-winged Duck *Cairina scutulata*	-	2004	present [units unknown]	-	A1	Endangered
Lesser Adjutant *Leptoptilos javanicus*	-	2004	present [units unknown]	-	A1	Vulnerable
White-rumped Vulture *Gyps bengalensis*	-	2004	present [units unknown]	-	A1	Critically Endangered
Slender-billed Vulture *Gyps tenuirostris*	-	2004	present [units unknown]	-	A1	Critically Endangered
Pallas's Fish-eagle *Haliaeetus leucoryphus*	-	2004	present [units unknown]	-	A1	Vulnerable
Bengal Florican *Houbaropsis bengalensis*	-	2004	present [units unknown]	-	A1	Critically Endangered
Rufous-necked Hornbill *Aceros nipalensis*	-	2004	present [units unknown]	-	A1	Vulnerable

Taley Valley Wildlife Sanctuary (IBA- IN361)

A portion of the Taley Valley Reserved Forest in Lower Subansiri district of Arunachal Pradesh with an area of 337 sq. km. was declared as a wildlife sanctuary on July 14, 1995. The area of the Reserve Forest is c. 51,587 ha. Whole Reserve Forest and the Wildlife Sanctuary have been considered as an IBA. The Valley proper lies about 30 km away from the district headquarters, Hapoli. The area lies between the Subansiri, Supu and Pange rivers. It is surrounded by gentle sloping hills, clothed densely with thick vegetation. There are two main valleys: the Pange Valley and the Taley Valley. Small rivers, flowing through these valleys, have formed deep gorges and rapid waterfalls. The smaller streams drain into the Subansiri river which ultimately joins the mighty Brahmaputra. The hills are gently sloping, except for a few peaks that are very steep. The following forest types are found in Taley Valley area: East Himalayan Subtropical Forest, East Himalayan Wet Temperate Forest, Lauraceae Forest, Oak Forest, High-level Oak Forest and East Himalayan Mixed Coniferous Forest (Haridasan et al. 1999).

Populations of IBA trigger species

Species	Season	Period	Population estimate	Quality of estimate	IBA Criteria	IUCN Category
Chestnut-breasted Partridge*Arborophila mandellii*	-	2004	present [units unknown]	-	A1, A2	Vulnerable
Blyth's Tragopan *Tragopan blythii*	-	2004	present [units unknown]	-	A1, A2	Vulnerable
Rufous-necked Hornbill *Aceros nipalensis*	-	2004	present [units unknown]	-	A1	Vulnerable
Yellow-vented Warbler*Phylloscopus cantator*	-	2004	present [units unknown]	-	A2	Least Concern
Broad-billed Warbler *Tickellia hodgsoni*	-	2004	present [units unknown]	-	A2	Least Concern
Rufous-throated Wren-babbler*Spelaeornis caudatus*	-	2004	present [units unknown]	-	A2	Near Threatened
Streak-throated Barwing *Actinodura waldeni*	-	2004	present [units unknown]	-	A2	Least Concern
Ludlow's Fulvetta *Alcippe ludlowi*	-	2004	present [units unknown]	-	A2	Least Concern
Beautiful Sibia *Heterophasia pulchella*	-	2004	present [units unknown]	-	A2	Least Concern
White-naped Yuhina *Yuhina bakeri*	-	2004	present [units unknown]	-	A2	Least Concern
Beautiful Nuthatch *Sitta formosa*	-	2004	present [units unknown]	-	A1	Vulnerable
Rusty-bellied Shortwing *Brachypteryx hyperythra*	-	2004	present [units unknown]	-	A1, A2	Near Threatened

Protected areas

Protected area	Designation	Area (ha)	Relationship with IBA	Overlap with IBA (ha)
Tale Valley	Sanctuary	33,700	protected area contained by site	33,700

Important Bird Area in Kurung Sub Basin (Kurung Kumey district)

Important Bird Area is located in Koloriang- Sarli-Damin Areas (Site code: IN-AR-10), IBA Site Code: IN-AR-24. This site is a large area *c.* 2,00,000 ha around Koloriang, Sarli and Damin areas. A significant discovery from this area is a new monal species of *Lophophorus*. The males of the new monal appeared very similar to the male of Sclater's Monal

Lophophorus sclateri, except for the completely white tail in the former. The new monal was sighted on nine occasions (5 males, 13 females and 1 subadult) in the Sarli circle[82]. All sightings were made in the alpine meadows between 3,900 m and 4,200 m. Feathers of this taxon were found in Tali and Damin, indicating a wide distribution in this area. Besides, the new taxon of monal pheasant following pheasants Temminck's Tragopan *Tragopan temminckii*, Blood Pheasant *Ithaginis cruentus* and Black-breasted Kaleej *Lophura leucomelanos lathami* have been also been recorded.

Populations of IBA trigger species

Species	Season	Period	Population estimate	Quality of estimate	IBA Criteria	IUCN Category
Ward's Trogon *Harpactes wardi*	-	2004	present [units unknown]	-	A2	Near Threatened
Rufous-necked Hornbill *Aceros nipalensis*	-	2004	present [units unknown]	-	A1	Vulnerable
Yellow-vented Warbler *Phylloscopus cantator*	-	2004	present [units unknown]	-	A2	Least Concern
Broad-billed Warbler *Tickellia hodgsoni*	-	2004	present [units unknown]	-	A2	Least Concern
Blackish-breasted Babbler *Sphenocichla humei*	-	2004	present [units unknown]	-	A2	Near Threatened
Rufous-throated Wren-babbler *Spelaeornis caudatus*	-	2004	present [units unknown]	-	A2	Near Threatened
Ludlow's Fulvetta *Alcippe ludlowi*	-	2004	present [units unknown]	-	A2	Least Concern
Beautiful Sibia *Heterophasia pulchella*	-	2004	present [units unknown]	-	A2	Least Concern
White-naped Yuhina *Yuhina bakeri*	-	2004	present [units unknown]	-	A2	Least Concern
Rusty-bellied Shortwing *Brachypteryx hyperythra*	-	2004	present [units unknown]	-	A1, A2	Near Threatened

Elephant corridor

The Elephant Range (ER) in Assam- Arunachal Pradesh are namely North Brahmaputra (Arunachal Pradesh-Assam) and South Brahmaputra. Elephant reserve located in North Brahmaputra elephant range is Kameng ER and Sonitpur ER. The details are given in **Table 10.10**.

Table 10.10: Elephant Range and Elephant Reserve in Arunachal Pradesh and Assam

Sr. No.	Elephant Range	Elephant Reserve	Date of Notification	State	Total Area (Sq. Km)	P.A. in ER (Sq. Km)	Population in 2005
1	Kameng-Sonitpur Landscape	1. Kameng ER	19.6.02	Arunachal Pradesh	1892	748	
	(Arunachal - Assam)	2 Sonitpur ER *	6.3.03	Assam	1420	420	612
	Total				3312	1168	612
2	Eastern-South Bank Landscape	1. Dihing-Patkai ER	17.4.03	Assam	937	345	295
	(Assam - Arunachal)	2. South Arunachal ER	29.2.08	Arunachal Pradesh	1957.5	378.13	129
	Total				2894.5	723.13	424

82 http://ibcn.in/wp-content/uploads/2011/12/14-169-230-Arunchal-Pradesh.pdf

* Proposal for extension approved by Government of India, but not yet notified by the State.
Source: *Elephant Task Force Report of MoEF, August 2010*
http://wiienvis.nic.in/Database/elephant_7960.aspx (last updated on 22/06/2012)

The all India enumeration of wild population of elephants in India is carried out at every five year interval. The estimated population trend of wild elephants in Arunachal Pradesh shows that elephant population has decreased from 2102 (1993), 1800 (1997), 1607 (2002) and 1690 in 2007-2008.

Distribution of the Asian elephant in Arunachal Pradesh is shown in Figure 10.24. Number 1 shows High elephant abundance, 2 medium elephant abundance and 3 low elephant abundance. Dot indicates survey points.

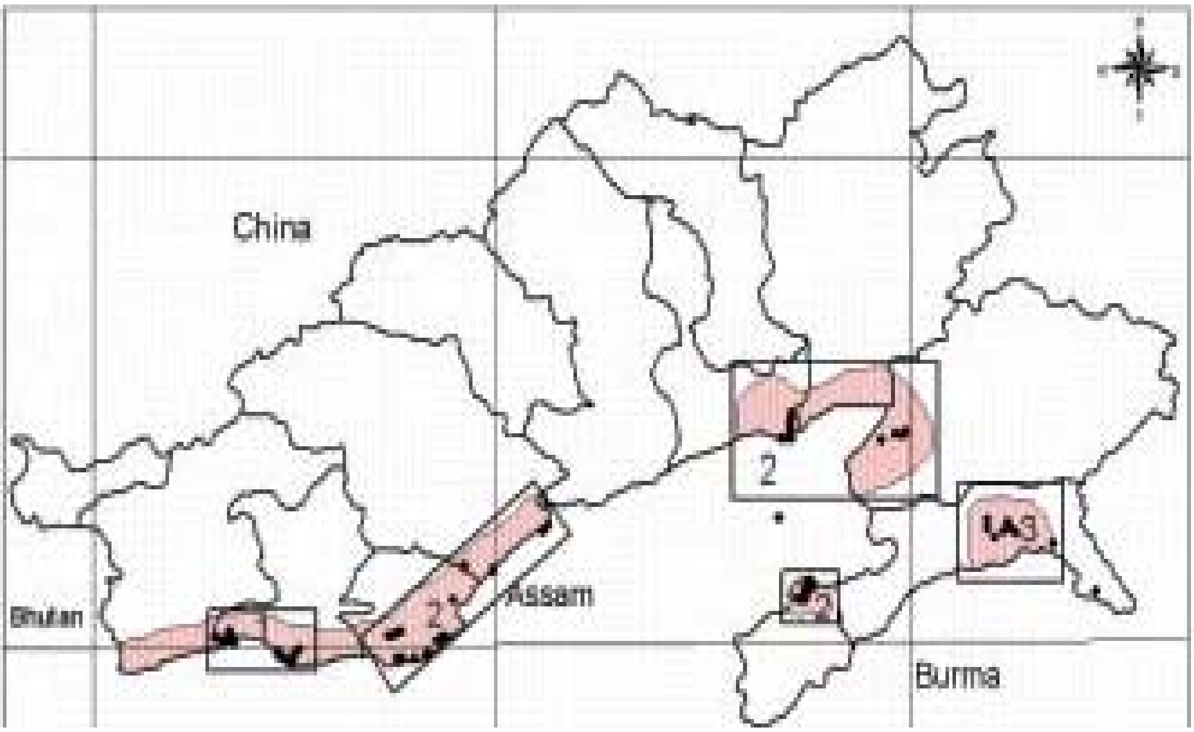

Figure 10.24: Distribution of the Asian elephant in Arunachal Pradesh

The entire elephant range has about 2,700-3,000 elephants out of 10,300-11,300 elephants in Northeast India. The approximate habitat available for elephants in this range is about 11,000 km2, which includes north Bengal – 1,500 km2 (Darjeeling and Jalpaiguri districts), Assam – 3,400 km2 (Kokrajhar, Chirang, Baksa, Udalguri, Darrang, Sonitpur, Lakhimpur, Dhemaji, Dibrugarh and Tinsukia districts), Arunachal Pradesh – 4,500 km2 (West Kameng, East Kameng, Papum Pare, Lower Subansiri, West Siang, East Siang, and Dibang Valley districts) and Bhutan – 1,600 km2 (Paro, Thimpu, Wangdu, Phodrang and Trongsa provinces).

Papum-Pare and Lower Subansiri Districts: The areas surveyed in these two districts included Itanagar WLS and Bandardewa Forest Division. This area has medium elephant abundance, with highly migrant populations. These areas are also highly fragmented and degraded due to increased human encroachment and illegal deforestation. Areas like Poma, Jote, Kimin, Hoj, Tarajuli, Chessa, Hollongi, Changmara, Kokila, Tengabari, and Balijan have a matrix of habitats composed of semi-evergreen and evergreen forest, and cultivation. Unplanned development in the Itanagar area has also destroyed much of the habitat and has been noted as a factor to reckon with as far back as 1984. Setting up of an Elephant Reserve has been planned in Papum-Pare district, but the success of this plan depends entirely on the effective control/removal of encroachments. This area shows very little influx of elephants from Assam because the areas in the Assam side are completely under cultivation. The Subansiri Range of Panir RF (Bandardewa Forest Division) is an interesting situation where repetitive disturbance has been observed to affect elephants. Dolunmukh is a village bordering Panir RF, which has not reported the presence of elephants for the past 10 years due to the presence of a bombing range (an area used for target practice by the Indian Air Force). Even though bombing operations have ceased a few years ago, elephants are yet to return. These areas show the presence of large patches of semi-evergreen and evergreen forests. More interestingly, Dolunmukh was reported to have been an area of high human-elephant conflict.

The people of Arunachal Pradesh have always been living in close conjunction with their forests, but uncontrolled development has already destroyed many prime elephant areas like the foothill forests in Papum-Pare district and Lower Subansiri. The problem of human elephant conflict is compounded by the fact that a large proportion of agriculture in Arunachal Pradesh is subsistence agriculture. Crop depredation hits the subsistence agriculturist very hard, and the existing system is not equipped to deal with this problem at all. The formulation and implementation of a relief scheme will greatly help improving relations between the common man and the government agencies involved[83].

Migration route of elephants in the area

During the course of survey information was gathered through locals in the project area and was informed that elephants do move in the area from Dolungmukh to Lilabali and travel up to Garu and Gansi forest areas. They cross river Subansiri near Dolungmukh to move up to Garu and Gansi forest areas. Dolungmukh is located downstream of the site of the proposed Subansiri Lower project. The project submergence or other appurtenances do not obstruct the migratory route of the elephants, they cross the river Subansiri from Dolungmukh where it is sufficiently wide and the velocity reduces to an extent so that the elephants can cross the river easily. In the upper stretches of river Subansiri, including the stretch in which the project submergence lies, the river flows in a deep gorge, with high velocity with no movement reported of elephants.

The quarries which have been identified for excavation of construction material are Subansiri Shoal bed, Gerukamukh Nallah bed, Gerukamukh Clay quarry, Dirpai-Sapari river bed and Dolung river bed. The Dirpai-Sapari riverbed and Dolung riverbed quarries lie in the elephant migratory route. The Subansiri shoal bed, which does not obstruct the elephant migratory route, has sufficient reserves to meet the entire requirement of construction material for the project. It is quite unlikely, that other quarries especially the Dirpai-Sapari and Dolung quarries would be used. Thus, it can be said that the elephant migratory routes are likely to be affected temporarily during excavation of construction material at Dirpai-Sapari riverbed and Dolung riverbed quarries as a result of the proposed project.

Disturbance to wildlife

A. Construction phase:

The total forest land requirement for the project is 4039.3 ha in Lower Subansiri HEP. In the past, the proposed project site had significant wildlife population. However, at present, in and around the proposed project site, no major wildlife is reported. During construction phase, a large number of machinery and construction workers will have to be mobilized. This activity may create some disturbance to the wildlife population. The operation of various construction equipment is likely to generate significant noise, especially during blasting which might scare the fauna in the region and forcing them to migrate to other areas. Likewise, the siting of construction equipment, godowns, stores, labour camps, etc. may generally disturb whatever fauna is left in the area.

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[83] *Ecology and Conservation of Asian Elephants in Kameng Elephant Reserve, Arunachal Pradesh, Eds Surendra Varma, Prabal Sarkar and Vivek Menon, 2008.*

Since, there is no major wildlife reported in the project area, no adverse impacts are anticipated on this account. However, based on field observations, and interactions with locals, etc, it was mostly avian species, observed in the project area, which may move out to adjoining areas due to disturbances. Hence, no significant impact on major terrestrial fauna is anticipated.

Amongst the various faunal species reported in the area, none of the species are restricted only to the submergence area. During project construction and operation phases, due to noise and human interferences, animals might have a tendency to migrate to the relatively undisturbed areas.

B. Operation phase

During the project operation phase, the accessibility to the area will improve due to construction of roads, which in turn may increase human interferences leading to marginal adverse impacts on the terrestrial ecosystem. The increased accessibility to the area can lead to an increase in human interferences. Since significant wildlife population is not found in the region, the adverse impacts of such interferences are likely to be marginal.

Impacts on Avi-fauna

The whole area supports good vegetation and the birds are well distributed in the region. A small amount of vegetative patch will be required for the project as compared to vast expanse of vegetation in the adjoining areas. Such small amount of acquisition is not likely to cause any significant adverse impact on the avi-faunal population. Moreover, the creation of reservoir will also not cause any adverse impact on the movement of the bird population.

Though the area has a large bird population, water birds are not known in this area as the water flow is swift and water current is high. The damming of the river will pond the river and water flow will reduce significantly in the reservoir. The reservoir will also have fluctuation in the water level which means, that the reservoir banks will have wet environment throughout the year. Due to such reasons grasses may grow along the reservoir banks. Such conditions are generally ideal for various kinds of birds, especially, water birds. Whether this area would serve as a good area for the birds, is a matter of speculation and cannot really be predicted with high levels of certainty. However, because of the presence of a good habitat it is quite likely that water birds may flock in this area in large numbers. This area could also be used for overwintering purposes by birds from colder areas. Thus, the operation of the proposed project may have beneficial impacts on the avi-faunal population.

Impacts on Talle Wildlife Sanctuary

For a small stretch, the Talle Wildlife Sanctuary runs along the river Sipu which is a tributary of river Subansiri. Due to construction of the proposed project, about 42 ha of Talle Wildlife Sanctuary come under the reservoir submergence, which is of the order of 0.12% of the total sanctuary area. The area under submergence runs adjacent to river Sipu where the river passes through a deep gorge and later flattens. There are few smaller animals like deer, civet, monkeys etc in the sanctuary which sometimes come to banks of river Sipu to drink water, whereas there is no report for larger animals like elephants, buffalo etc using the tributary for drinking water. Several perennial springs and small streams in the Talle Wildlife sanctuary meet the drinking water requirements of the animals. Thus, with the construction of the proposed project, no significant impact on Talle Wildlife Sanctuary is anticipated.

Impact on Migration routes of elephants in the Lower Subansiri HEP area

Normally, elephants move from Dolungmukh to Lilabari and travel to Garu and Gansi forest areas by crossing river Subansiri near Dolungmukh, which is located downstream of the site of the proposed Subansiri Lower project. The project submergence or other appurtenances do not significantly obstruct the migratory route of the elephants (Fig 10.25). Hence, the project submergence is not likely to affect the migratory route of elephants in Lower Subansiri HEP area.

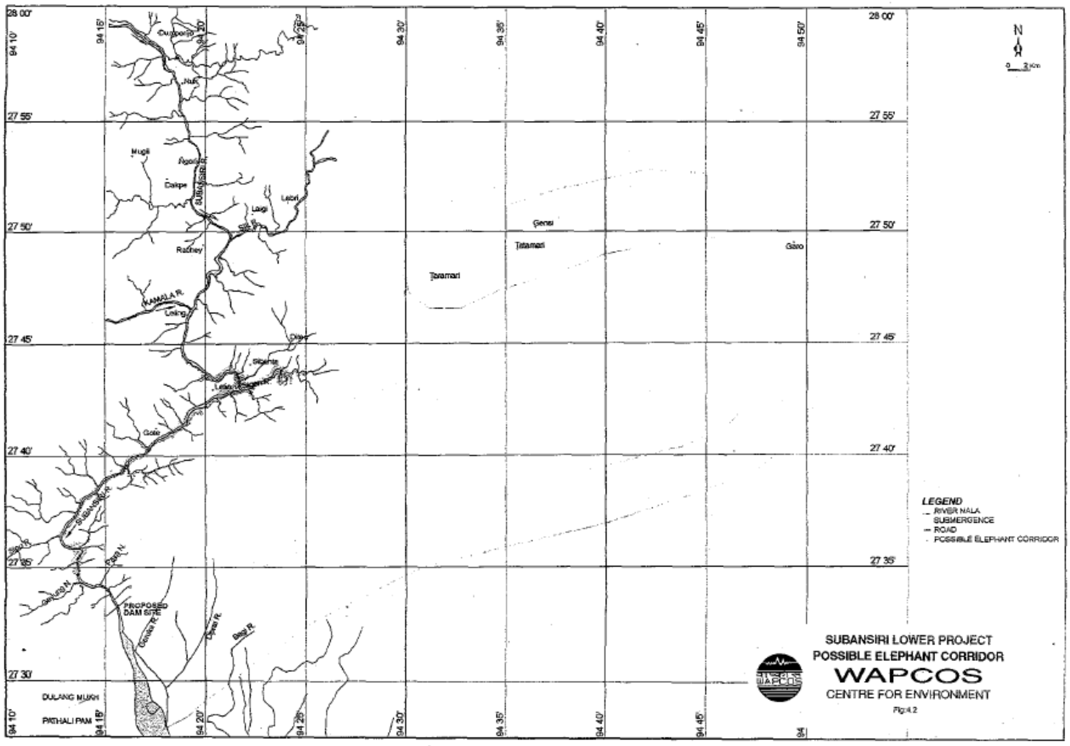

Figure 10.25: Possible Elephant Corridor in Lower Subansiri HEP

As can be inferred from above said, the proposed HEPs in Subansiri basin upstream of Lower Subansiri HEP are located outside the known Elephant Range and Elephant Reserve in Arunachal Pradesh-Assam. Hence, the proposed HEPs in Subansiri Basin are unlikely to impact elephants.

10.8 Overall Biodiversity Impact Assessment

Based on the data availability on biodiversity on the proposed HEPs, it can be inferred that Subansiri Sub basin is the most important basin from the point of view of having highest number of HEPs with highest installed capacity, the highest estimated loss of forest area and reported presence of endemic and threatened species. The Sub basin also holds possibility of discovery of new species, possible rediscovery of endemic and threatened species or new distributional record for the State.

The Kamla River sub basin has two projects of 1903 MW while Kurung sub basin has 7 HEPs having the total installed capacity of 671 MW. While the proposed 7 projects in Kurung Sub basin are of smaller installed capacity, the proposed HEPs are very important by virtue of their location in Kurung Kumey district, not being fully explored from biodiversity point of view.

Namdapha Flying Squirrel *(Biswamoyopterus biswasi* Saha) is the only endemic species of India in Arunachal Pradesh among its 106 species and subspecies of mammals. However, this species is reported from Namdapha National Park, Tirap, which is outside Subansiri Basin[84].

The overall anticipated impacts on fauna will be mainly for Dolphins, although away from the project area in Lower Subansiri HEP, will be impacted only if the required water flow is not maintained downstream, affecting its habitat and survivability in the Subansiri river up to confluence of Brahmaputra. Since, it has been assured that minimum flow of 240 Cumec will be maintained on a continuous basis to keep the aquatic habitat and its biodiversity intact, there is not much impact anticipated for Dolphins. Other commonly occurring wild fauna are widespread in the project area and elsewhere also, thus it may not be impacted much due to the projects in the Subansiri basin.

Threatened species in Subansiri Basin, Arunachal Pradesh

A total of 757 faunal species belonging to 8 faunal groups are reported to occur in Subansiri basin. Pisces is the most diverse faunal group with 213 species, followed by 207 species, aves (175), mammals (106), protozoa (27), reptilia (19), amphibia (6) and trematodes of amphibia (4).

Subansiri Basin has 100 threatened species belonging to Mammals (out of 106 reported species), 57 species belonging to Aves (out of 175 reported species), 1 Reptilian (out of 19 reported species), 2 Amphibians (out of 6 reported species), 25 species belonging to Odonata of Insecta fauna group (out of 28 reported species) are reported to be assessed as per IUCN's threatened categories. No species belonging to faunal groups namely, Protozoa, Trematodes of Amphibian found in Subansiri Basin, Arunachal Pradesh are assessed as per IUCN's threatened category.

63 species belonging to Mammals (out of 106 reported species), 50 Aves (out of 175 reported species) and 2 amphibians (out of 6 reported species) in Subansiri Basin are listed in Schedules of Wildlife Protection Act, 1972 (as amended till date). 60 lepidopteron (butterflies) species are listed in various schedules of WPA.

10.9 Impacts on Aquatic Ecology

Aquatic Ecology

Fishes are an important food resource and good indicators of the ecological health of the waters they inhabit and are invariable living components of water bodies. Running water of Himalaya comprise many torrential rivers and streams providing a wide variety of ecological niche. The distribution of fishes in Arunachal Pradesh can be mainly attributed to altitude and topology. The higher elevations generally support cold water fishes and the foot hills region and mid elevations comprises of fishes which are economically important, but most of the fish resources in the lotic systems of this region had not been completely explored because most of the rivers are located in unapproachable mountainous steep terrain with dense forest cover. The aquatic ecology will be most impacted due to changes in river flow alterations and availability of water for aquatic flora and fauna due to construction and developmental activities due to HEPs. The results from aquatic studies have been analysed for the impact assessment at the basin level for Subansiri basin projects.

During the survey a total of 94 species (comprising of 6 orders, 19 families and 51 genera) were recorded as highest in the post-monsoon season compared to 51 species (6 order, 17 families and 30 genera) during monsoon and 29 species (6 Orders, 12 families and 20 genera) in pre monsoon. Sampling in rivers was conducted using available fishing method

[84] *Fauna of Arunachal Pradesh, Zoological Survey of India (ZSI), 2006 (No. 13 Part 1)*

used for catching fishes mainly from mountainous river and also from secondary sources (Local fisherman, villagers, fishery officers etc). Recent studies by Das et al (2013) also reveals the presence of 87 (Eighty Seven) species of fishes belonging to 9 (Nine) orders, 22 (Twenty) families and 55 (Fifty five) genera in river Subansiri. *Cypriniformes* dominates the whole river and found in higher numbers and *Beloniformes* and *Tetradontiformes* are found in less number. The diversity of fishes from the upstream to downstream of the Subansiri river was earlier described by Sharma *et al.* (2008), where, they found 137 fish species belonging to 7 types of order. *Das et al*., In 2011 reported 48 species of fishes in Subansiri River belonging to 15 families under 7 different orders. There has been studies conducted by various authors in Arunachal Rivers (*Bagra et al, 2009*), which showed varying presence of fish species in Subansiri river.

Endemic species

Out of a total of 2,500 species of fish in India, 930 are fresh water species belonging to 326 genera, 99 families and 20 orders (Talwar and Jhingran 1991). Arunachal Pradesh (AP) state is the largest in geographical area as well as in river drainage area in North-Eastern India and harbours innumerable rivers and rivulets which are home to diverse fish species. Arunachal Pradesh is regarded as the type locality for more than 11 endemic freshwater fish species in the world. These are *Amblyceps arunachalensis, Amblyceps apangi, Pseudecheneis sirenica, Aborichthys kempi, Pareuchiloglanis kamengensis, Schistura tirapensis, Pterocryptis indicus, Garra kempi, Garra rupecula, Nemacheilus tikaderi* and *Lepidocephalichthys arunachalensis.*

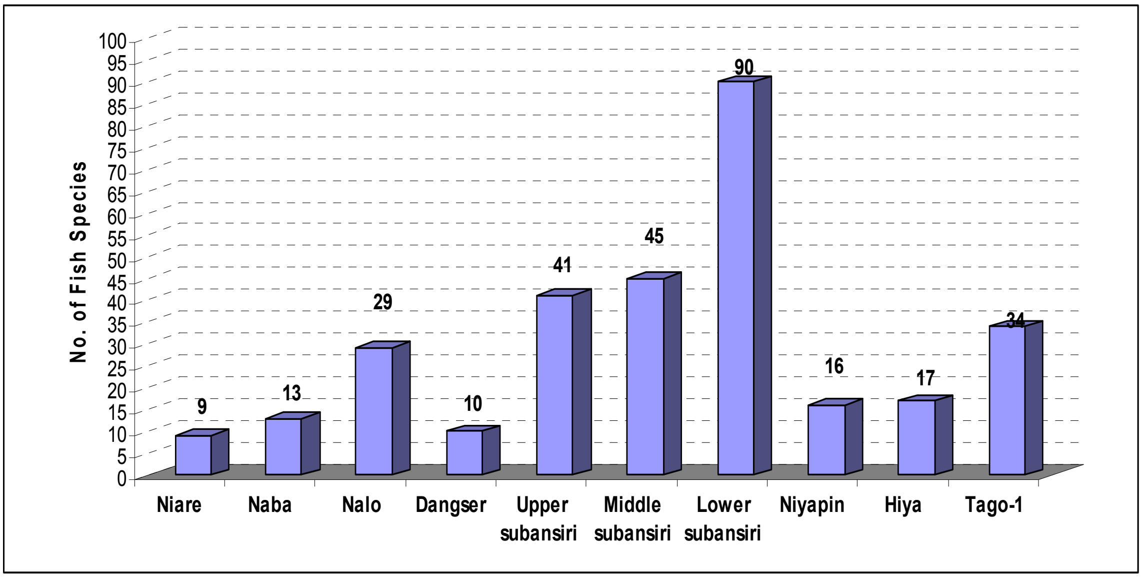

Figure 10.26: Number of Fish Species in Project Area

Overall, Subansiri basin is extremely rich in fishery resources (**Fig. 10.26**), and highest number of fish species were observed at Lower Subansiri (90) followed by Middle Subansiri (Kamala HEP) (45 spp), Upper Subansiri (41 Spp), Tago-1 (34), Nalo (29 spp), Hiya (17), Nyepin (16 spp), Naba (13), Dengser (10) and Niare (9).

Ecologically Important Species

Overall Subansiri river is extremely rich in fishery resources as observed during the study and through various published literature. Fish species of Cypriniformes order was found to be overall dominant in all seasons as compared to that of Beloniformes and Salmoniformes in the Subansiri river. Nyepin had lower Species richness among all sites and was highest in Lower Subansiri HEP. The fishes recorded were present in different ecological niches like hill stream, semi torrential etc. True hill stream fishes recorded were *Garra* species, *Psilorhynchous* species, *Glypthothorax* species. Semi torrential was *Schistura* species, *Botia* species, *Aconthocobitis botia*, *Lepidocephalichthyes* species, *Amblyceps* species, *Aborichthys* species, *Olyra longicaudata*.

Economically Important Species
Among 94 species of fishes found in the project area, more than 26 species are economically important which are consumed locally, prominent among them are *Tor tor, T. putitora, T.progenies, Neolissocheilus hexagonalepis, Schizothorax richardsonii, Schizothorax esonicus* which are also migratory species. Other economically important species are *L.calbasu, L.gonius, L.pangusia, L.rohita, Ompok pabo, O.bimaculatus, Wallago attu, Heteropneustes fossilis, Clarias batrachus* etc.

Impacts on Endemic species
Among 11 endemic species of fishes found in Arunachal Pradesh, 4 species viz. *A.arunachalensis, Amblyceps apangi, A.kempi and G. kempi* are found in the project area. There would be negative impact on all the 4 species, which were found at Middle Subansiri (Kamala HEP) and Lower Subansiri sites. Other species impacted will be *G. Kempi* also found at Upper Subansiri, Dengser, Tago-1, Nalo, Nyepin and Hiya; *A. Kempi* found at Upper Subansiri area; *Amblyceps apangi* and *A. arunachalensis* were present at Upper Subansiri, Tago-1 and Nalo sites. Certainly, these species, which are thriving well in natural water currently, need special attention for sustainable aquatic flow as there is likelihood of reduced water flow due to HEPs.

Impacts on Endangered and Threatened species
According to the IUCN 2011 classification, among 94 fish species sampled, 6 have been categorized as endangered species while 8 under vulnerable category as per the criterion IUCN (2011). 15 species have been categorized under lower risk near threatened, 40 as lower risk least concern and 25 species not evaluated till date (**Fig 10.27**).

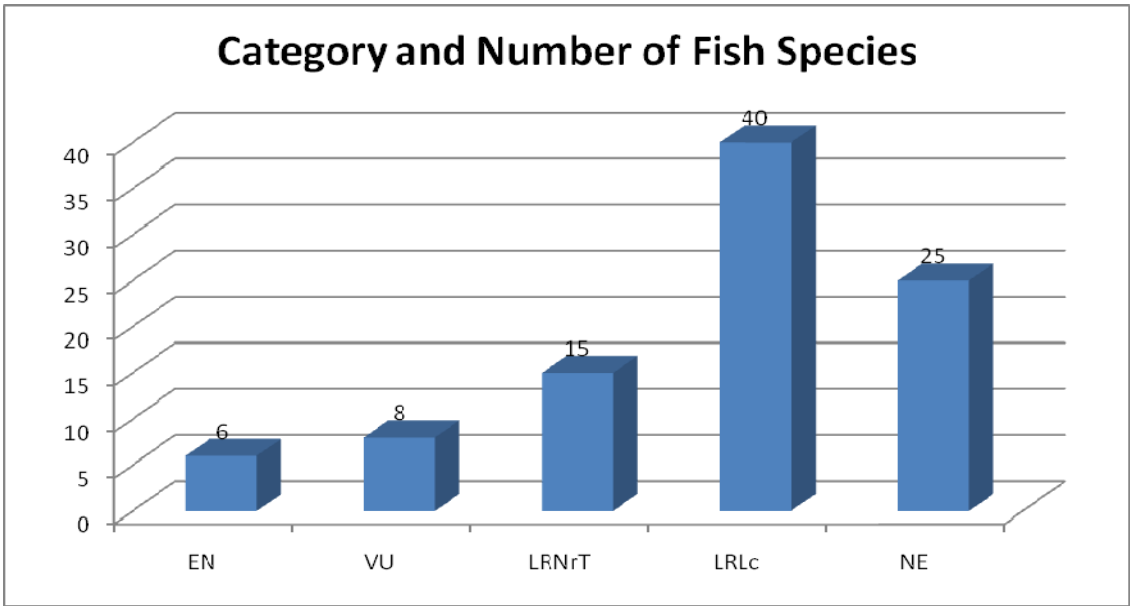

Figure 10.27: Category and Number of Fish Species in Project Area
EN= Endangered; VU=Vulnerable; LRNrT=Lower Risk Near Threatened; LRLc=Lower Risk Least Concern; NE=Not Evaluated

The 6 Endangered (EN) Species are *Tor tor, Tor putitora, Glyptothorax ater, Amblyceps apangi, A. mangois* and *A. arunachalensis*, and 8 Vulnerable (VU) species as identified in the Subansiri basin are *B. vagra, Garra gotyla gotyla, G. kempi, Schizothorax richardsonii, B. rostrata, Pseudecheneis sulcata, Clarias batrachus* and *Channa orientalis* require attention as prone to be impacted by the project.

Impacts on Aquatic ecology downstream Assam

Among the migratory species recorded were Tor species, *Barilius species*, *Labeo dero, Channa sp., Badis sp., Danio sp., Neolissocheilus hexagonalipis. Xenentodon cancila, Macrognathus aral, Aspidoparia species, Puntius sp., etc.* were recorded from the lower reaches of the Subansiri River.

The Lower Subansiri HEP

Since Subansiri Basin is rich in fish resources and other aquatic animals like Dolphin (*Platanista gangetica*), Otter etc, there is need to continuously maintain aquatic flow downstream of all proposed dams upstream of Lower Subansiri HEP, so that there is no shortage of water ultimately at downstream of Lower Subansiri where important fauna like Dolphin, though far away from the project site thrives on continuous source of water flow in the Subansiri river.

As per the project planning (NHPC), it has been assured that at least 240 Cumec water will always be available for aquatic flora and fauna downstream of proposed Lower Subansiri HEP, which would safeguard aquatic habitat from drying and bringing drastic changes in the local biodiversity. Although, regulated flow of water can never replace a natural flow of river, but can provide adequate supply of water to sustain minimum requirement needed for aquatic biodiversity.

Impacts on economic aspects like fishery

The habitation in project area is mostly located away at higher reaches along Subansiri river. People in project area do fishing but in very less number and that also for local consumption not on large scale commercial scale. As per an estimate, the average fish catch per effort by two persons per day using cast net was estimated to be 12.0 kg from Subansiri River near Daporijo. Discussion with local fishermen revealed that the catch percentage during post-monsoon is higher compared to other seasons. They were also of the view that the fish catch is decreasing continuously. Generally most of the fishermen here are very poor and uneducated.

Impacts of HEPs on Aquatic flora and fauna in Subansiri basin

At the basin level
Since, there are 19 HEPs at Basin level, there is challenge of maintaining ample water flow downstream of all projects and then enough water to the tune of 240 Cumec downstream of Lower Subansiri HEP to maintain aquatic biodiversity and sustainability of important aquatic fauna like Dolphin etc., present far away from project site till confluence of Brahmaputra river. The cascading effect of these multiple projects on aquatic life will obviously affect the natural flow of water in the river, which needs to the factored effectively while allocating minimal flow from each of these proposed HEPs especially in terms of water availability during lean period.

At the project level

Impact on Fisheries

There may be disturbances to the aquatic fauna especially fishes due to siltation and turbidity during construction phase. There is likelihood of possible increase in soil erosion due to clearance of vegetation. Project may affect changes in the river ecosystem, as the fast flowing river transforms to slow moving river system and having less water availability compared to natural flow. The aquatic animals which would be affected most may be fishes due to disturbances and alterations to their habitat. The migratory fish species are most likely to be adversely impacted due to obstruction created by the proposed dam.

Management Measures

The management measures are most likely to face following challenges:

- Maintaining minimum ecological flow in the river d/s of dam during all seasons for the sustainability of the aquatic life and fisheries;
- Maintaining adequate water column for facilitating spawning movement of the fishes;
- Effective implementation of supplementary stocking programme;

Lower Subansiri HEP

Impacts on aquatic flora & fauna

Diversion of river water
During project construction phase, river water will be temporarily altered for some time impacting the aquatic environment.

Impacts on Aquatic Fauna

Disturbance to aquatic fauna
There is information from the locals who confirmed, that of late, the clawless otters *(Aonyx cinerea)* have not been seen in the area. Large-scale indiscriminate hunting has led to their virtual extinction from this area. Thus, no impact on otters is anticipated as a result of the proposed project. Although, Otter is sometimes reported from Lower Subansiri HEP area.

b) Operation phase
During the project operation phase, the accessibility to the area will improve due to construction of roads, which in turn may increase human interferences leading to marginal adverse impacts on the aquatic ecosystem. Since significant wildlife population is not found in the region, the adverse impacts of such interferences are likely to be marginal.

Impacts on Talle Wildlife Sanctuary
For a small stretch the Talle Wildlife Sanctuary runs along the river Sipu which is a tributary of river Subansiri. Due to construction of the proposed project, about 42 ha of Talle Wildlife Sanctuary come under the reservoir submergence, which is of the order of 0.12% of the total sanctuary area. The area under submergence runs adjacent to river Sipu where the *river* passes through a deep gorge. Thus, even at present, the animals in the sanctuary are not much dependent on river Sipu and only animals like deer, civet, monkeys etc have been sometimes reported to come down to the banks of river Sipu to drink water. Several perennial springs and small streams in the Talle Wildlife sanctuary meet the drinking water requirements of the animals. Thus, with the construction of the proposed project, no significant impact on Talle Wildlife Sanctuary is anticipated

Impact on Migration routes on Aquatic fauna in the Lower Subsaniri HEP area

There has been a few studies on the Gangetic Dolphin *(Platanista gangetica gangetica)* in Brahmaputra and Subansiri Rivers (Wakid, 2009; Baruah et al, 2012;) which reported presence of Dolphins in Subansiri River mainly confined to 100-110 km upstream of the confluence (Baruah et al, 2012). They attributed absence of dolphins in the first 20 km stretch below proposed Subansiri HEP due to rocky nature of the riverbed and harsh riverine conditions due to transportation of debris from the site, which makes the river water murky and degrades the habitat (Baruah et al, 2012), whereas, they also added that dolphins prefer deeper pools of the Subansiri river as natural habitats. The major issue is to maintain the constant source of water flow for sustainability of dolphin and other aquatic biodiversity downstream, which can be addressed by maintaining minimum average flow discharge to the tune of 240 cumec at least on constant perennial basis. There has been no confirmed reports which suggest presence of Dolphins in upstream of Lower Subansiri

HEP, whereas they are an important species needing attention for conservation in Subansiri river below Lower Subansiri downstream till confluence with Brahmaputra river in Assam.

10.10 Overall Aquatic Impact Assessment

Based on the data availability on biodiversity on the proposed HEPs, it can be inferred that Subansiri Sub basin is the most important basin from the point of view of having highest number of HEPs with highest installed capacity, thus impacting riverine biodiversity to the maximum. The Sub basin has rich fishery resources, which have both important migratory and economically important species. The distribution of fishes in Arunachal Pradesh can be mainly attributed to altitude and topology. The higher elevations generally support cold water fishes and the foot hills region and mid elevations comprises of fishes which are economically important, Arunachal Pradesh is rich in high altitude fish species like *Tor putitora, Tor tor, Schizothorax richardsonii, Barilius barna, B. bendelisis, Labeo dero, Gara gotyla gotyla, Psilorhynchus balitora, Nemacheilus botia botia, Xenentodon cancila, Channa punctatus, Mastacembelus armatus, Badis badis,* etc. Though there are no regular fish landing centres, fishes are caught with the help of long line, cast nets and traps from different streams and nullahs (drains) in the area. Construction of dams may affect habitat of fish fauna and their natural breeding grounds. The movement of some migratory fish species may be obstructed and cause depletion of important sport fish like Mahaseer.

With the completion of proposed dams, the flow in the downstream stretch of the river would be reduced considerably more so during the lean period. The most important changes that can be expected are:

- Reduced flow rate
- Increase in water temperature
- Reduction in availability of stenothermal aquatic animals i.e. animals which can adapt to only small temperature range.
- Increase in population of eurythermal species. i.e. species which can adapt to a large temperature range.
- Unless the desired flow is maintained downstream of the dam, river stretches at places are subjected to near desiccation.

The proposed dams may obstruct the migration route of the Mahseer species, which can be termed as one of the major impacts. The Mahseer species undertake upstream migration in river Subansiri during summer and monsoon months for feeding and breeding. As the winter sets in the upper reaches, the species takes a downstream journey as far as up to its confluence with river Brahmaputra. In addition certain species of *Schizothorax* (Snow trout) also undertake migration from upper reaches during winter months. This fish species breeds in the lower reaches. Amongst the aquatic animals, it is the fish life that would be most affected. The migratory fish species, e.g. Mahseers and snow trouts are likely to be adversely affected due to obstruction created by the proposed dams. The Mahseers (*Tor tor, T. putitora* and *Acrossocheillus hexagonolepis)* migrate from warm water to the upstream sometime in April-May for breeding and feeding purposes. The fish remains upstream much beyond Gerukamukh, Lower Subansiri, till optimal conditions are met for breeding during the months of August-September. The wide stretches of river Subansiri in the project area have deeper pools. A shallower area with gravel substratum is one of the essential requirements for spawning of Mahaseers. This situation is likely to change, once the dam is constructed. As a result of obstruction in the migratory route due to the construction of the dam, the Mahseers are likely to congregate below the wall of the dam. For mature fish, upstream migration would not be feasible. This is certainly going to be the major adverse impact of the project.

The snow trouts namely *Schizothorax richardsonii, Schizopyge progastus* and *S.esocinus* are observed in river Subansiri. They undertake migration downstream as low as near its confluence with the Brahmaputra during prolonged winter months. These species remain in the lower reaches till the onset of summer. Like Mahseers, snow trouts too undertake migration in search of suitable breeding and feeding grounds. The project will bifurcate the population of these migratory species and restrict their upward movement, although various reservoirs which will be created will benefit non-migratory fish species. Local fish population adapt better to the pronounced changes in the abiotic habitat than the biotic. In the latter situation, management measures have to be designed to adjust fish stocks to the changed condition[85]. Fisheries are not well developed in the project area, and there are no fish landing centers in the project area. It is observed that no large-scale fishing activities are being practiced in the area.

Biological and habitat characteristics of migratory fish species reported in Subansiri basin and the data on depth range indicate that *Tor* spp. (Mahseer) is found in the depth range of 0-1 metre. Further, as snow trout is local migratory species, successful migration depends upon adequate water depth and flow velocity. Large fish like mahseer during upstream migration need a water depth of at least 0.51 m and can tolerate a flow velocity of up to 1.4 m/s, whereas snow trout need a water depth of 0.3 – 0.4 m and a maximum water velocity of 1.2 m/s. Spawning habitat is increased when the stream flow is high enough to cover suitable gravels but is decreased when velocity becomes too high for successful spawning activities.

[85] *Environment Impact Assessment and Environment Management Plan for Subansiri Lower Project, Arunachal Pradesh and Assam (2000 MW), NHPC/WAPCOS, Gurgaon*

Chapter 11: Conclusions and Recommendations

The preceding chapter titled Cumulative Impact Assessment describes the cumulative impacts of 19 hydel projects in Subansiri Basin predicated on the baseline data. The baseline data and cumulative impact assessment forms the basis of conclusions and recommendations for sustainable utilization of resources for development of hydropower in Subansiri basin.

The conclusions and recommendations are made with reference to results of the study including impacts on terrestrial and aquatic resources (affected forest area and river reach) as defined in scope of work. Except for the Lower Subansiri HEP (construction initiated) other HEPs are in various stages of appraisal, being allotted, scoping for TOR, survey and investigation and EIA/EMP studies for environment clearance.

Recommendations

11.1 Sustainable Hydropower Development in Subansiri Basin

The total installed capacity of HEPs in Subansiri basin is 11, 096 MW of which Subansiri sub basin has 8522 MW, Kamla sub basin has 1903 MW and 671 MW in Kurung sub basin. Subansiri Sub basin has the highest number of 10 HEPs in Subansiri sub basin with a total installed capacity of 8522 MW, eight out of ten projects are located in Upper Subansiri district and 2 in Lower Subansiri District. 7 projects in Kurung Sub basin with total installed capacity of 671 MW are proposed in Kurung Kumey district while 2 projects of 1903 MW is located in Kamla Sub Basin in Lower Subansiri District.

11.1.1 Project which may be considered for preclusion/reconsideration in Subansiri Basin

In the earlier proposal, Oju-I has been proposed on right bank and Oju-II on left bank as necessitated by the topography. The Border Roads Organisation (BRO) alignment runs along the right bank and the left bank has undisturbed forests. It is desirable to have both the schemes on right bank only so as minimize disturbance and impact on the forests. Further, the free stretch between the earlier proposed Oju-I (with installed capacity of 700 MW) and Oju-II (with installed capacity of 1000 MW) works out to be less than 1 km which is not desirable from environmental angle. **In view of these factors, the earlier proposed Oju I and Oju II have been recommended to be merged as one project namely Oju (with installed capacity of 1878 MW), at the location of earlier proposed Oju I.**

The earlier proposed location of Oju I will be the dam location of the merged Oju project. With this merger, the distance between FRL and TWL of Oju and Niare is 0.88 km and Niare (with proposed installed capacity of 800 MW) and Naba (with proposed installed capacity of 1000 MW) is 0.64 km. **Since the distance between these projects is less than 1 km, it is recommended that detailed surveys and investigations should be carried out to ascertain the distance between FRL and TWL of Niare and Naba. It is recommended that the distance between FRL and TWL should be made in accordance with MoEFCC guideline of maintaining the distance of at least 1 km.**

Based on environment flow computation, release is found to be adequate for all seasons except Tammu HEP which is assessed to meet habitat requirement in lean season with 30% release in 90% dependable year. Tammu HEP will have more than 50 cm of average flow depth under 30% release scenarios for Mahseer. However, **environment flow computation for Tammu indicates 55% flow in pre and post monsoon season and 60% release in monsoon. Therefore, it is recommended that Tammu project may therefore be dropped** (see section 11.2. “Environment Flows in Subansiri Basin” and Table 11.1).

11.1.2 Integrated biodiversity conservation plan

1. Terrestrial biodiversity

The proposed HEPs in Subansiri Basin are located in Eastern Himalaya, Arunachal Pradesh whose biodiversity is underscored by its recognition and designation as Megadiversity Country (India), Biodiversity Hotspot, Ecoregion, Crisis Ecoregion, Endemic Bird Area, Important Bird Area, Centre of Plant Diversity, Important Plant Area, Intact Forest Landscape and the Last of the Wild areas. Assessment of location of proposed HEPs *vis a vis* presence of Reserved forests, Anchal Reserved Forest (ARF), Wildlife Sanctuary (WLS), Important Bird Area (IBA), Elephant Reserve (ER)/Elephant Corridor (EC) and Unclassed State Forest (USF) in Subansiri Basin has been done. All the HEPs, by virtue of their location are therefore considered to be important from perspective of biological diversity and ecological importance.

8 proposed HEPs namely Oju I, Oju II, Niare, Naba, Nalo, Dengser, Subansiri Upper and Tammu are located in Upper Subansiri District which has 504.00 sq.kms reserved forest and 2 sq.kms ARFs. 4 proposed HEPs namely Middle Subansiri (Kamala HEP), Lower Subansiri, Tamen and Tago I are located in Lower Subansiri district which has 347.07 sq.kms under Reserved Forest and 337 sq.kms area under Talle Wildlife Sanctuary. Other than this, 7 proposed HEPs namely Mili, Sape, Chomu, Chela, Nyepin, Hiya and Kurung I and II, are located in Kurung Kumey district which has unclassed forest area of 5964.60 sq.kms. Besides, 4 Important Bird Areas have been identified in the said districts falling in Subansiri basin. It is anticipated that the proposed HEPs in Subansiri Basin may, therefore, impact on the biological diversity.

The results of biodiversity characterization at the landscape level for Arunachal Pradesh for the impact assessment at the Subansiri basin level shows that Forest types in Subansiri Sub-Basin is mostly intact. Further, the Disturbance Index map of Subansiri Basin shows that the Upper Subansiri District in Subansiri Basin is mostly intact. However, intact to medium level of disturbance is recorded in Lower Subansiri district. The Biological richness map of Subansiri sub basin shows that high biological diversity is recorded in Upper Subansiri Basin. Very high - high and medium biological richness is recorded in Lower Subansiri district.

Based on the biodiversity characterization of Arunachal Pradesh at the landscape level, it is deduced that areas of Lower Subansiri district are characterised by rich temperate evergreen forest which are biologically rich. The analysis carried out using landscape parameters in conjunction with field data and literature survey indicates that forests are extremely rich in border areas of Lower Subansiri. Data on plant diversity, endemic and threatened species also indicate that Lower Subansiri HEP is located in the biodiversity rich area. The analysis of fragmentation, disturbance index and biological richness of Subansiri Sub Basin indicate that Subansiri Sub Basin is very important in terms of having intact forest types and high -very high biological richness. In particular, border areas of Lower Subansiri are extremely rich. It is to be noted that the Lower Subansiri HEP is located in the border of Lower Subansiri district and Dhemaji District. The biodiversity assessment of Lower Subansiri HEP also indicate biodiversity richness and presence of endemic and threatened species in the submergence areas of the HEP, besides the presence of species listed in Schedules of Wildlife Protection Act and species listed in CITES.

Biodiversity assessment at Kurung sub Basin, Kurung Kumey district shows that Forest types in Subansiri Basin is mostly intact except for a small patch in Kurung Kumey district where intact to medium fragmentation has been recorded. The Disturbance Index map of Subansiri Basin shows intact to medium level of disturbance in Kurung Kumey district. The Biological richness map of Subansiri basin shows high and medium biological richness in Kurung Kumey district.

Cumulative Impact Assessment of loss of forests by proposed HEPs in Subansiri Basin indicates loss of forests on account of proposed HEPs as given below:.

Lower Subansiri district: 0.52% forest area loss
Upper Subansiri district: 0.75% forest area loss
Kurung Kumey district: 0.29% forest area loss
Total loss of forest area in Subansiri Basin: 1.56%

Total estimated loss of forest in Subansiri Basin, Arunachal Pradesh is 1.56% of the total Forest Area of Subansiri Basin, Arunachal Pradesh.

In Assam, Dhemaji district's forest cover as per SFR 2013 is 292 sq. kms and Assam State's forest and tree cover is 29,253 sq.kms (total geographical area of Assam (78,438 sq.kms). Dhemaji district's forest cover of 292 sq. kms amounts to 0.37% of the total geographical area of Assam. The estimated forest loss in Assam's Dhemaji district would be 8.42 sq.kms (on account of Lower Subansiri HEP), which amounts to 2.88% (8.42 sq.kms) forest loss in the district and 0.02% loss to the State's total forest cover.

Being a hilly State, Arunachal Pradesh is required to maintain 66% of forest cover w.r.t total geographical area of the State (83, 743 sq. kms i.e. 55270.3 sq.km). As per SFR 2013, the total forest and tree cover in the State is recorded to be 67, 981 sq. kms. which works out as 81.17% of the State's geographical area (i.e. 83, 743 sq. kms). The total loss of forest area is estimated to be 0.15% (105.54 sq.km) in Arunachal Pradesh and 0.02 % in the Assam's total forest area. The proposed HEPs will, therefore, have impact in terms of loss of current forest area of the Districts/State of Arunachal Pradesh and Assam.

Endemic species

220 endemic species have been listed from Arunachal Pradesh, out of which Subansiri Basin has 62 endemic species which accounts for 28% of the State's endemic flora. This is indicative of high endemism in the Subansiri Basin. 7 endemic species of Ericaceae, 3 endemic species of Begoniaceae and 1 species each of Orchidaceae and Arecaceace are threatened as well.

Orchidaceae family has 14 species (1 threatened) , Ericaceae has 8 species (7 threatened), followed by 5 species of Fumariaceae, 4 species each of Ranunculaceae, Magnoliaceae and Rubiaceae, 3 each of Balsaminaceae, Begoniaceae (3 threatened) and Gesneriaceae and 1 species each of family Illiciaceae, Schisandraceae, Vitaceae, Hydrangeaceae, Myrtaceae, Myrsinaceae, Pedaliaceae, Verbenaceae, Euphorbiaceae, Urticaceae, Agavaceae, Araceae, Arecacecae (1 threatened)and Cyperaceae. Further, 5 species namely *Rhododendron falconeri* subsp*. eximium*, *R. santapauii, R. subansiriense, Vaccinium dendrocharis* ssp*. talle* and *Livistona jenkinsiana* are assessed as Endangered, 2 species namely *Agapetes atrosanguina* and *Agapetes refracta* are assessed as Vulnerable, 3 species namely *Begonia aborensis, Rhododendron nutalli* and *Pholidota wattii* are assessed as Rare and 2 species namely *Begonia scintillans* and *Begonia tessaricarpa* are assessed as Indeterminate species in Subansiri basin.

Threatened floral species

36 threatened species (including 12 endemic species) have been reported from Subansiri basin. Out of 36 threatened species, 6 Endangered, 15 Vulnerable, 13 Rare and 2 Indeterminate) reported to occur in Subansiri Basin.

It can be inferred that Forest types in Subansiri Basin is mostly intact except for a small patch in Kurung Kumey district where intact to medium fragmentation has been recorded. The Disturbance Index map of Subansiri Basin shows that the Upper Subansiri District in Subansiri Basin is mostly intact. However, intact to medium level of disturbance is recorded in Lower Subansiri and Kurung Kumey districts. The Biological richness map of Subansiri basin shows that high biological diversity is recorded in Upper Subansiri District. Very high - high and medium biological richness is recorded in Lower Subansiri and Kurung Kumey districts. The proposed HEPs in Lower Subansiri District, particularly Lower Subansiri HEP for which information is available also points towards biological richness.

Though the statistics of forest area show a declining trend in Upper Subansiri district in Subansiri Basin. The declining trend of loss of forest area in Subansiri basin may further be triggered by the proposed cascade development of HEPs over a period of time as and when the proposed HEPs are approved. Total estimated loss of forest in Subansiri Basin, Arunachal Pradesh is 1.56% of the total Forest Area of Subansiri Basin, Arunachal Pradesh. The estimated forest loss in Assam's Dhemaji district would be 8.42 sq.kms (on account of Lower Subansiri HEP), which amounts to 2.88% (8.42 sq.kms) forest loss in the district and 0.02% loss to the State's total forest cover. **Therefore, the proposed HEPs will, therefore, impact in terms of percentage loss of current forest area in Subansiri basin.** However, measures like EMPs, compensatory afforestation, catchment area treatment plan, biodiversity conservation and management plan including *ex situ* conservation measures for endemic and threatened species, green belt development, etc may offset the loss of the forest area and species on account of the proposed HEPs.

Assessment of location of proposed HEPs *vis a vis* presence of Reserved forests (RF), Anchal Reserved Forest (ARF), Wildlife Sanctuary (WLS), Important Bird Area (IBA), Elephant Reserve (ER)/Elephant Corridor (EC) and Unclassed State Forest (USF) in Subansiri Basin shows that the proposed HEPs, by virtue of their location in a Biodiversity Hotspot, i.e. Arunachal Pradesh are therefore considered to be important from perspective of biological diversity and ecological importance. MOEF has specified carrying out cumulative impact assessment in the ToR for Upper Subansiri HEP with respect to Lower Subansiri HEP and Middle Subansiri HEP (Kamala HEP), as part of EIA/EMP of Upper Subansiri HEP.

Therefore, the *8* proposed *HEPs* in Upper Subansiri District (with a total installed capacity of 6467 MW), 4 proposed HEPs (with a total installed capacity of 3958 MW) in Lower Subansiri district and 7 proposed HEPs (with a total installed capacity of 671 MW) in Kurung Kumey district (totaling 19 projects with installed capacity of 11,096) are anticipated to impact on the biological richness of the said districts in Subansiri Basin.

Subansiri sub basin has 10 HEPs with a total installed capacity of 8,522 MW, the Kamla River sub basin has two projects of 1903 MW and Kurung sub basin has 7 HEPs having the total installed capacity of 671 MW. While the proposed 7 proposed projects in Kurung Sub basin are of smaller installed capacity, the proposed HEPs are very important by virtue of their location in Kurung Kumey district, not being fully explored from biodiversity point of view.

Based on the data availability of biodiversity on the proposed HEPs, it can be inferred that Subansiri Sub basin is the most important basin from the point of view of having highest number of HEPs with highest installed capacity, the highest estimated loss of forest area and reported presence of endemic and threatened species. The Sub basin also holds possibility of discovery of new species, possible rediscovery of endemic and threatened species or new distributional record for the State.

2 Aquatic biodiversity

The distribution of fishes in Arunachal Pradesh can be mainly attributed to altitude and topology. The higher elevations generally support cold water fishes and the foot hills region and mid elevations comprises of fishes which are economically important. Arunachal Pradesh is rich in high altitude fish species like *Tor putitora, Tor tor, Schizothorax richardsonii, Barilius barna, B. bendelisis, Labeo dero, Gara gotyla gotyla, Psilorhynchus balitora, Nemacheilus botia botia, Xenentodon cancila, Channa punctatus, Mastacembelus armatus, Badis badis,* etc., though there are no regular fish landing centres, fishes are caught with the help of long line, cast nets and traps from different streams and nullahs (drains) in the area by local tribals for their local consumption. Water quality of Subansiri River and all its tributaries was within prescribed limits of CPCB and national drinking water standards. Water Quality Index (WQI) varies from 70 to 81 which indicates that water quality is good. However, it can be degraded during construction phase of projects and best construction practices should be followed as per IS: 15845, 2009. Construction of dams may also affect habitat of fish fauna and their natural breeding grounds. The movement of some migratory fish species may be obstructed and cause depletion of important sport fish like Mahaseer, which move in search of new feeding and breeding grounds.

With the completion of proposed dams, the flow in the downstream stretch of the river would be reduced considerably more so during the lean period. Certainly, the flow in the downstream stretch of the river will be reduced causing reduction in flow rates as compared to natural flow before dam construction. Also, the reduced flow and quantity of water will have increase in water temperature in river, which may cause outward movement of few stenothermal aquatic animals as they would not be able to adapt to changed temperature regime. Similar observations regarding stenothermal species were observed by Singh et al, 1991[86], who recognized the altitudinal range of 600-1200 m as the mahseer zone (Petr and Swar, 2002). The raise in water temperature will encourage inward movement of warm water species as they get favourable habitat. Most important thing is maintenance of desired flow at the down streams of all proposed dams in the river stretch all along for sustainability and conservation of aquatic habitat.

The proposed dams may obstruct the migration route of the Mahaseer species, which can be termed as one of the major impacts. The Mahaseer species undertake upstream migration in river Subansiri during summer and monsoon months in search of new feeding and breeding grounds. As the winter sets in the upper reaches, the species takes a downstream journey as far as up to its confluence with river Brahmaputra. In addition certain species of *Schizothorax* (Snow trout) also undertake migration from upper reaches during winter months basically for feeding and breeding as this fish species breeds in the lower reaches.

Amongst the aquatic animals, it is the fish life that would be most affected. The migratory fish species, e.g. Mahseers and snow trouts are likely to be adversely affected due to obstruction created by the proposed dams. The Mahseers (*Tor tor, T. putitora* and *Acrossocheillus hexagonolepis)* migrate from warm water to the upstream sometime in April-May for breeding and feeding purposes. The fish remains upstream much beyond Gerukamukh, Lower Subansiri, till optimal conditions are met for breeding during the months of August-September. The wide stretches of river Subansiri in the project area have deeper pools. A shallower area with gravel substratum is one of the essential

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[86] *Singh, C.S. and U.P. Singh, 1991. Concepts and strategies of coldwater fisheries with reference to Himalayan lakes. In: Environmental Regeneration in Himalayas - Concepts and Strategies (J.S. Singh, ed.): 349-359.*

requirements for spawning of Mahseers. This situation is likely to change, once the dam is constructed. As a result of obstruction in the migratory route due to the construction of the dam, the Mahaseers are likely to congregate below the wall of the dam. For mature fish, upstream migration would not be feasible, which is certainly going to be the major adverse impact of the project.

The snow trouts, *Schizothorax richardsonii, Schizopyge progastus* and *S.esocinus,* which are autochthonous of cold water, are observed in river Subansiri. They undertake migration downstream as low as near its confluence with the Brahmaputra during prolonged winter months. These species remain in the lower reaches till the onset of summer. Like Mahseers, snow trouts too undertake migration in search of suitable breeding and feeding grounds.

Fisheries are not well developed in the project area, and there are no fish landing centers in the project area. It is observed that no large-scale fishing activities are being practiced in the area as it is done by local tribals for their local consumption. The creation of reservoir is generally beneficial to non-migratory fish species. Local fish population adapt better to the pronounced changes in the abiotic habitat than the biotic. In the latter situation, management measures have to be designed to adjust fish stocks to the changed condition.

Further, aquatic ecosystem is greatly regulated by its physical surroundings; therefore, any changes in the physico-chemical profile of the water affect the biota exist therein. Low values of primary production have been noted when the transparency of water was more and vice versa. The transparency is affected mainly due to phytoplankton population as the phytoplankton count was low in almost all the sampling sites, it resulted in low Primary production. Temperature of the ecosystem also seems to have great influence in regulating the primary production in freshwater ecosystem. During the survey, the Primary production was seen increasing and decreasing with the increase and decrease of surface water temperatures.

During the present investigation the plankton population was found to be low in the river. The population of phytoplankton was found dominating to that of zooplankton. Phytoplankton group consisting of *Chlorophyceae, Myxophyceae* and *Bacillariophyceae* as a whole dominated over zooplankton consisting of Copepod, *Turbellaria Cladocera*, *Rotifera* and *Ostracoda*. The dominant phytoplankton group was *Chlorophyceae*. This may be due to the fact that water temperature range (16-20º) during the pre-monsoon season appears to be optimum for the growth of *Chlorophyceae*. High atmospheric and water temperature along with bright sunshine are important factors influencing periodicity of *Chlorophyceae. Myxophyceae* were found to be the second group dominating the phytoplankton community after *Chlorophyceae*. Only two genera of *Bacillariophyceae* have been recorded during the study period*. Copepods, Turbellaria, Cladocera, Rotifer, Ostracoda* was the groups representing the Zooplankton community. The water temperature was low during the sampling period which resulted in low count of Zooplankton. It may be noted that water temperature is the most important controlling factor in the production of Zooplankton. In fast flowing water (lotic) such as the upland streams, the bed consists of large rocks and stones and the stream is heavily shaded. The influence of vegetation is very high. This provides food supply for largely collectors and shredders. Aquatic plants, particularly rushes and sedges, provide a surface, on which macro-invertebrates can live.

Low values of primary production have been noted in the primary survey. Macro-invertebrates plays a significant role within the food chain, as they are the source of food for large fish. Macro-invertebrates are sensitive to different chemicals and physical conditions, any changes in the water quality, perhaps because of a pollutant entering the water, or a change in the flow downstream of a dam, the macro-invertebrate community also changes. During the survey most of the sampling site was devoid of macrophytes and aquatic vegetation which might have resulted in the poor distribution of macro invertebrates. These factors may have impacts on fisheries resources which could be intensified owing to change in the free flowing regime of water in view of the cascade development of HEPs, more so for migratory species.

Biological and habitat characteristics of migratory fish species reported in Subansiri basin and the data on depth range indicate that *Tor* spp. (Mahaseer) is found in the depth range of 0-1 metre. Further, as snow trout is local migratory species, successful migration depends upon adequate water depth and flow velocity. Large fish like mahaseer during upstream migration need a water depth of at least 0.51 m and can tolerate a flow velocity of up to 1.4 m/s, whereas snow trout need a water depth of 0.3 – 0.4 m and a maximum water velocity of 1.2 m/s. Spawning habitat is increased when the stream flow is high enough to cover suitable gravels but is decreased when velocity becomes too high for successful spawning activities.

In view of the location of Subansiri Basin, in a locally and globally significant biological diverse area of Eastern Himalaya, baseline conditions, anticipated impacts of HEPs and mitigation thereof, **an integrated biodiversity conservation plan for the proposed HEPs should be prepared from the perspective of conservation and management biological diversity at the basin level. Since Department of Environment and Forests, is the concerned department related to conservation and management of biodiversity in the State, it is recommended that the department can develop an integrated biodiversity conservation plan. The said Department may associate other existing institutions in Arunachal Pradesh like State Forest Research Institute, Botanical survey of India, Zoological Survey of India, State Pollution Control Board, research and development organizations, academic institutions, etc in preparing, implementing and monitoring the implementation of the said plan. The Department of Environment and Forests may also consider associating institutions of national repute for the said purposes.** The integrated biodiversity conservation plan may include following aspects for conservation and management of the said plan:

Terrestrial biodiversity

Endemic and Threatened Terrestrial species

Impacts on Endemic and Threatened species are anticipated in view of the loss of forests due to proposed HEPs in the Basin. The presence of endemic species in the project impact area focusing on submergence area of each HEP need to be ascertained in the Environment Impact Assessment reports of individual EIA projects covering three seasons. RET species-voucher specimens should be collected along-with GPS readings to facilitate rehabilitation. RET faunal species to be classified as per IUCN Red Data list and as per different schedule of Indian Wildlife (Protection) Act, 1972. Based on comprehensive listing of endemic and threatened species, specific methodologies should be adopted to ascertain presence of endemic and threatened species in the study area. A detailed conservation plan for endemic species need to be prepared if the presence of endemic species is confirmed. The conservation plan should include both *in situ* and *ex situ* measures considering relocation of the species e.g. Botanic garden, Orchidarium, etc.

For the conservation and preservation of rare, endangered or endemic floral/faunal species or some National Park/Sanctuary/ Biosphere Reserve or other protected area which may be affected directly or indirectly by construction of the project, then suitable conservation measures should be prepared in consultation with the State Forest Department and with the physical and financial details. Suitable conservation techniques (in-situ/ex-situ) will be proposed under the plan and the areas where such conservation is proposed should be marked on a project layout map.

Mitigation plan for flora, fauna, carrying capacity and plan for felling should include the following details:

a) Ex-situ/in-situ conservation of the identified indigenous genetic resources (vulnerable, rare, endangered, threatened species, etc).
b) Creation of a new/enlargement of the existing conservation areas. Source of funding, agency for implementation and responsibility for monitoring should be included.
c) Existence of barriers and corridors, if any, for wild animals should be ascertained. Provision of migratory corridors/escape routes for identified species for re-location of impacted wildlife should be made accordingly.
d) Provision for improving the carrying capacity of the adjoining ecosystem to accommodate the extra wildlife moving out from the submergence area.
e) Plan for felling of the trees from the submergence area in stages to ensure that wildlife is not trapped on hillocks during progressive filling of the reservoir.
f) Plan for social forestry on available lands within the catchment for reducing stress on the existing forest on the fringes of the reservoir.
g) Plan for providing minor forest produce like silk, lac, honey or development of cottage industries in the villages for providing alternate means of sustenance.
h) Coordination of various programmes/schemes of the State and Central Government and institutes for rural developments. Identification of the agencies for co-ordination and source of funding and responsibility for monitoring.

Aquatic biodiversity

Dolphin

Subansiri Basin is rich in fish resources and other aquatic animals like river Dolphin *(Platanista gangetica)*, Otter etc, therefore, there is need to continuously maintain aquatic flow downstream of all proposed dams, so that there is no shortage of water ultimately at downstream of Lower Subansiri, where important fauna like Dolphin, though away from the project site on downstream thrives because of continuous source of water flow in the Subansiri river. **As per the project planning (by NHPC), it has been assured that at least 240 Cumec water will always be available for aquatic flora and fauna downstream of proposed Lower Subansiri HEP, which would safeguard aquatic habitat from drying and bringing drastic changes in the local biodiversity.** Although, regulated flow of water can never replace a natural flow of river, but it can provide adequate supply of water to sustain minimum requirement needed for aquatic biodiversity.

There has been a few studies only on the Gangetic Dolphin *(Platanista gangetica gangetica)* in Brahmaputra and Subansiri Rivers (Wakid, 2009; Baruah et al, 2012;) which reported presence of Dolphins in Subansiri River mainly confined to 100-110 km upstream of the confluence (Baruah et al, 2012) of Brahmaputra river with Subansiri river. They attributed absence of dolphins in the first 20 km stretch below proposed Lower Subansiri HEP due to rocky nature of the riverbed and harsh riverine conditions and also because of transported debris from the site. It makes the river water murky and degrades the habitat (Baruah et al, 2012), whereas, they also added that dolphins usually prefer deeper pools of the Subansiri River as natural habitats. The major issue is to maintain the constant source of water flow for sustainability of dolphin and other aquatic biodiversity downstream which can be addressed by maintaining minimum average flow discharge to the tune of 240 cumec at least on constant perennial basis. There has been no confirmed reports which suggest presence of Dolphins in upstream of Lower Subansiri HEP, whereas they are an important species needing attention for conservation in Subansiri river below Lower Subansiri downstream till confluence with Brahmaputra river in Assam. Following are the major ecological requirements of Gangetic Dolphin in context to Subansiri:

- **A constant source of aquatic flow discharge to maintain the critical water flow to the tune of 240 Cumec at all the time on continuous basis to provide protection**

to its habitat and conservation of aquatic biodiversity. This is crucial as all proposed dams upstream needs to maintain proper aquatic flow discharge to ensure availability of this much of water downstream of Lower Subansiri at all times to accord protection to aquatic ecosystem.

- Availability of water depth/cover of at least minimum of 3 meter (Biswas et al, 1997) during lean season for Gangetic Dolphin habitat especially 10 km downstream of lower Subansiri proposed HEP for maintaining its ecological activities and sustenance of aquatic ecosystem. A few studies showed maximum sightings of Gangetic Dolphins in Brahmaputra in the depth range of 4.1-6.0m (Wakid A., 2009)

- Availability of sufficient water and totally avoid water removal in the river which can bring dramatic changes in flow regime causing harm to its ecosystem.

- Availability of fishes and other biodiversity components in its habitat, on which Gangetic Dolphins forage.

- Ensure protection to the species and its habitat from illegal fishing, human disturbances, population fragmentation etc.

Fisheries management

A specific fisheries management measures should be prepared for river and reservoir. Measures for reservoir fisheries should be proposed. The plan should detail out the number of hatcheries, nurseries, rearing ponds etc. proposed under the plan with proper drawings. If any migratory fish species is getting affected then the migratory routes, time/season of upstream and downstream migration, spawning grounds etc should be discussed in details.

Mitigation plan for Fisheries Conservation should include the following details:

Proper management of the new reservoir fishery for increasing yields and to ensure that fishing rights are allocated first to fishermen previously dependent on the disrupted riverine fishery. It should take into account the following details:

a) Physico – chemical changes in the benthic environment or the water columns and consequent impact on food chain affecting fish species as applicable during and after the trophic burst stage.

- in upstream and downstream.
- in reservoir, rivulets, rivers and streams
- at the confluence of the tributaries with the river.
- Measures for mitigating the loss of breeding/ spawning grounds.
- Managing organic loading of the reservoir from the habitation, industries, etc
- Managing prey-predator relationship.
- Managing carbon-nitrogen ratio.
- Maintaining water quality.
- Propagation of indigenous species.
- Rehabilitation methodologies for the vulnerable, rare, endangered, threatened, etc. species.
- Norms for stocking of the reservoir, lakes or ponds.
- Location of the hatcheries.
- Seasons of ban, if any.
- Technological support for harvesting.
- Mesh type and size, net size and type, boats.
- Training.
- Cold storages, landing sites, transports,
- Marketing, warehousing, etc.
- Source of funding, responsibility for monitoring

Catchment Area Treatment (CAT) plan

In the Catchment Area Treatment (CAT) Plan, both biological as well as engineering measures should be proposed in consultation with State Forest Department for areas requiring treatment. Choice of plants for biological measures should include native, endemic, RET species, if any, particularly in aided natural regeneration, medicinal plant plantation, vegetative fencing, etc.

Following are the key measures for mitigation planning for Catchment Area Treatment (CAT) plan:

a) Area falling in various erosion intensity classes (hectare) as per silt yield index method.
b) Macro watershed plan with maps showing areas already treated under other schemes after the survey work and presently proposed to be treated as well as the treatment measures for each watershed.
c) Micro plan for catchment area treatment with justification for adapting a particular soil conservation measure on consideration of land use slope etc.
d) Engineering measures (check dam, gully control, bench terracing, etc).
e) Biological measures (plantations, closure, pasture development, etc).
f) Phased programme (time table) including maintenance and costs.
g) Agency for implementation.
h) Public participation in implementation.
i) Monitoring mechanism.

Compensatory Afforestation Plan

Compensatory Afforestation Plan should be prepared by the State Forest Department in lieu of the forest land proposed to be diverted for construction of the project as per the Forest (Conservation) Act, 1980. Choice of plants for afforestation should include native, endemic and RET species, if any. This should be a part of the forest clearance proposal.

Following are the key measures for mitigation planning for plantations (including green belt/compensatory afforestation, etc.):

a) Objectives of plantations and ultimate ownership.
b) Methods for reclamation of spoil areas should also be described. This should involve afforestation for areas where the soil types and texture are suitable.
c) Total area of project/township and details of area earmarked (in hectare).
d) Suitability of the land for afforestation.
e) Area (including width of green belt in m), already planted up/proposed to be planted in hectare. In case of afforestation/reforestation, areas should be in patches of not less than 20 hectare in size.
f) List of species/choice of species to be planted with suitability for the land.
g) Density of plantations with rotation period.
h) Index maps and/or map showing the proposed area and adjoining forest boundaries.
i) Year-wise phasing (physical and financial).
j) Note on future management of the forest generated.
k) Details regarding nursery development/ procurement of saplings and water availability.
l) Plantation technique as per the soil type.
m) Support watering (if any).
n) Measures proposed for beautification of the project area (creation of parks, tourist spot, etc).
o) Watch and ward details including fencing, etc
p) Maintenance of plantation including casualty replacement/weeding/hoeing/thinning, etc, (till it is established/transferred to territorial forest division).
q) Responsibility and agency for implementation.

r) Timetable and cost estimate.
s) Monitoring mechanism.

Environmental Monitoring

Environmental Monitoring Programme to monitor the mitigatory measures implemented at the project(s) site is required should be prepared. Provision for Environment Management Cell should be made. The plan should spell out the aspects required to be monitored, monitoring indicators/parameters with respect to each aspect and the agency responsible for the monitoring of that particular aspect throughout the construction and project operation phase.

Further, **it is recommended that Indian Standard IS 15845: 2009 "Environment Management Plan for Hydropower/Irrigation/Flood Control/Multipurpose River Valley Projects" is followed.**

Implementation of Environmental management plans

The Environmental Management Plans should make proposals for agency responsibilities, institutional strengthening and regional/river basin management planning. This agency should include the directorate level personnel from the State Ministries of Health. Forestry, Fisheries. Water Resources. the Department of Environment, the Pollution Control Board and the Water Supply and Sewerage Board, as well as the project liaison officer and the team leader for the project management group. The functions of this group include setting the project budget, environmental screening and determining the components and agency responsibilities for the Environmental Management Plan.

Monitoring and Reporting Procedures

It consists of monitoring and evaluation procedures for physical and socio-economic factors related to environmental benefits and impacts. Sound monitoring programme is needed to provide assurance that problems will be identified early enough to allow remedial measures to be taken and for the following benefits:

a) To ensure early detection of conditions that necessitates particular mitigation measures.
b) To provide information on the progress and the results of mitigation.
c) To integrate into the total project cost tables of the cost estimates and sources of funds for both the initial investment and the recurring expenses for implementing the mitigation plan.
d) To strengthen environmental management capability in the agencies responsible for implementation /monitoring plans to cover one or more of the additionalities such as resource identification for technical assistance/ faculty sensitization/development of equipment and supplies for monitoring needs/organizational setup.
e) Integration of the plan into the projects overall planning, design, budget and implementation- This ensures that the plan receives funding and supervision along with the other investment components and to establish the mitigation plan as a component of the project. Thus, it will help in the following:

    1) Funding - This is necessary to ensure that the proposed actions are adequately financed.
    2) To implement the mitigatory measures the management, technical assistance, staffing and other institutional strengthening and training (strengthening local capabilities), is to be a part of the management plan.
    3) Monitoring - The plan should provide a critical path for implementation to enable the sponsors to evaluate the success of mitigation as a part of project supervision and as a means for improving future projects. It should also include the levels of monitoring and stress on availability of periodic progress reports.

Additional considerations for hydropower projects

a) Multipurpose management needs – Power authority, to provide needed (equal) attention to the other multipurpose needs such as irrigation, flood control, fisheries, and community water supply, through development of in-house multi disciplinary expertise/wings.
b) Local rural community power needs (in addition to transmitting power to urban centres).
c) Transmission lines/access roads routing (if alternative routing is available) should be planned to avoid precious forest/wildlife resources so as no unduly restriction on the movement of wildlife and impairment of environmental aesthetics (scenic views) is caused. Also it should not cause undue soil erosion both during construction and later stage due to inadequate reestablishment of covering vegetation.

11.2. Environment Flows in Subansiri Basin

Environmental flow release recommendations for HEPs have been made in the **Table 11.1** below based on the detailed assessment carried out and discussed in Chapter 8, "Environmental Flow". **Out of 19 projects, Tammu HEP may be recommended to be dropped as it does not meet specific flow release recommendation.**

Table 11.1: Environmental Flow release Recommendation

Sr. number	Name of Project	Capacity (MW)	Lean Season	Monsoon	Pre and Post Monsoon	Remarks
1 - 2	Oju (Oju I* + II*)	1878	20%	20%	20%	Oju I and Oju II have been recommended to be merged as one project namely Oju.
3	Niare	800	20%	20%	20%	
4	Naba	1000	20%	20%	20%	
5	Nalo	360	20%	20%	20%	
6	Dengser	552	20%	20%	20%	
7	Subansiri Upper	2000	20%	20%	20%	
8	Subansiri Middle (Kamala HEP)	1728	20%	20%	20%	
9	Kurung-I & II	330	20%	20%	20%	
10	Mili	75	20%	20%	20%	
11	Sape	38	20%	20%	20%	
12	Chomi	80	20%	20%	20%	
13	Chela	75	20%	20%	20%	
14	Hiya	41	20%	30%	30%	
15	Nyepin	32	20%	40%	30%	
16	Tammu$	55	30%	60%	55%	Not recommended
17	Tamen#	175	20%	30%	25%	
18	Tago -I#	55	20%	30%	25%	
19	Subansiri Lower◊	2000	One unit of turbine should run continuously to ensure at least about 240 cumec release from Subansiri Lower HEP			

* ➔ **Oju and Oju II are recommended to be clubbed together as one project in view of the distance between of FRL and TWL being less than 1 kms. The dam of the merged Oju project location will be at earlier Oju I project**. Therefore, computation of environment flow for earlier proposed Oju II is not applicable and stands null and void.
$ ➔ Environment flow computation for Tammu indicates 55% flow in pre and post monsoon season and 60% release in monsoon. Therefore, it is recommended that Tammu project may therefore be dropped
➔ Environment flow cannot be computed for Tamen and Tago- I as data are not available. These projects are not allotted to any developer. In view of this, **it is recommended that data should be collected during detailed survey and investigation for preparation of DPR and**

EIA/EMP stages for both projects. Nevertheless, as per the prevailing norms, it is recommended that Environmental Flow of 20% in lean season, 25% in other 4 months and 30% in monsoon season should be maintained for both the projects. However, the same need to be verified through environment flow computation during project specific EIA.
◊ ➔ **Subansiri Lower HEP consist of dam toe power house hence one unit of turbine should run continuously to ensure at least about 240 cumec release from Subansiri Lower HEP in Subansiri River downstream for sustenance of aquatic ecosystem.**

Lean Season

Lean Season flow release is found to be adequate for all except Tammu HEP which is assessed to meet habitat requirement in lean season with 30% release in 90% dependable year. However, **environment flow computation for Tammu indicates 55% flow in pre and post monsoon season and 60% release in monsoon. Therefore, it is recommended that Tammu project may therefore be dropped** (see Table 11.1. "Environment Flows in Subansiri Basin").

Monsoon Season

20% of release is recommended for Oju-I, Oju-II, Niare, Naba, Nalo, Dengser, Upper Subansiri, Subansiri Lower, Subansiri Middle (Kamala HEP), Kurung-I & II, Mili, Sape, Chomi and Chela. River Modelling results show that these projects meet habitat requirement for base flow at 15% release; however, in the absence of flood peak analysis, higher recommendation i.e. 20% release is made.

For Hiya, environmental release of 30% is required to meet the 50% pre-project depth and 120 cm depth criteria while 35% of environmental release is required to meet the 50% pre-project depth and 120 cm depth criteria for Nyepin HE project.

For Tammu, 60% environmental release is needed to meet the of 120 cm depth requirement and therefore, may be dropped.

Pre and Post Monsoon Season

Oju-I, Oju-II, Niare, Nalo, Dengser, Subansiri upper, Subansiri Middle (Kamala HEP), Kurung-I&II and Chomi HEPs were meeting the base depth requirement for 10% release scenario, however the depth was reduced to less than 50% of the pre-project level. Further in the absence of daily measured data the minor flood peaks could not be captured. Hence, **in order to ensure the natural flow regime with minor flood peaks environmental release of 20% is recommended for Oju-I, Oju-II, Niare, Nalo, Dengser, Subansiri upper, Kurung-I&II, Mili, Sape, Chomi and Chela HE Projects.**

For Hiya and Nyepin environmental release of 30% is required to meet the 50% pre-project depth and 90 cm depth criteria. For Tammu, 55% environmental release is needed to meet the of 90 cm depth requirement. Therefore, Tammu project may be dropped.

11.3 Impacts on downstream Assam

From the detailed hydrodynamic simulations of natural condition flow of pre-project scenario and peaking releases from the hydroelectric projects in post project scenario the following conclusions have been drawn:

- **The peaking will have insignificant impact in the downstream river reach during the non-monsoon period when the average natural condition discharge in Subansiri river is of the order of about 500-600 cumec**

- The non-monsoon peaking release from the projects in Subansiri basin will cause the fluctuations in discharge and water level up to first 40 km downstream of Subansiri lower HE Project. In this reach of river the daily fluctuation in water level may be about 1.5 m to 2 m.

- For the Subansiri river from 40 km downstream of Subansiri lower HE project and up to the Subansiri Brahmaputra confluence the daily fluctuation in water level will progressively decrease to 1 or 2 cm near the Subansiri Brahmaputra confluence.

- The Subansiri-Brahmaputra confluence is about 90 km downstream of Subansiri lower HE project. Guwahati is about 328 km downstream of Subansiri lower HE Project. For the river reach of Brahmaputra from Subansiri-Brahmaputra confluence and up to the Guwahati, due to very wide reach of Brahmaputra River, the impact of peaking release will be damped. The fluctuations in daily discharge will be less than 15 cumec, while the fluctuation in daily water level will be hardly 1-2 cm.

- The natural condition average non-monsoon discharge in Brahmaputra at Kaziranga, Tezpur and Guwahati is about 4117, 4475 and 5377 cumec respectively. Due to 3 hours peaking releases the average non-monsoon discharge at these locations will be about 4180, 4550 and 5440 cumec respectively. The same for 4 hours peaking releases will be about 4275, 4635 and 5540 cumec respectively. From these simulated discharge patterns it has been concluded that increase in flow at these locations will be less than 200 cumec only. The consequent increase in water level in comparison to natural condition will be about 5 to 12 cm at these locations.

Compliance to CWC comment no.1 vide letter 2/18(A)/2014-EIA/646 dated September 09, 2014

Comment no.1 An index to be provided by the consultant in support of compliance of ToR by referencing the page numbers.

Scope of Work (SoW)

A. OBJECTIVE OF THE STUDY:

1. The basin study envisages providing optimum support for various natural processes and allowing sustainable activities undertaken by its inhabitants. The same is determined in terms of the following:
   - Inventorisation and analysis of the existing resource base and its production, consumption and conservation levels.
   - Determination of regional ecological fragility / sensitivity based on geo-physical, biological, socio-economic and cultural attributes.
   - Review of existing and planned developments as per various developmental plans.
   - Evaluation of impacts on various facets of environment due to existing and planned development.

The study should involve assessment of stress load due to varied activities covering e.g. exploitation of natural resources, industrial development, population growth which lead to varying degree of impacts on various facets of environment. The basin study should also envisage a broad framework of environmental action plan to mitigate the adverse impacts on environment which should be in the form of:

- Preclusion of an activity
- Infrastructure development
- Modification in the planned activity
- Implementation of set of measures for amelioration of adverse impacts.

The basin study is a step beyond the EIA, as it incorporates an integrated approach to assess the impacts due to various developmental projects.

2. STUDY AREA

The study area to be covered as a part of the Basin Study is for entire Subansiri Basin. The study should be based on secondary as well as primary data collection.

3. PROJECTS ENVISAGED IN SUBANSIRI BASIN

Nineteen (19) projects are envisaged in the study area to be covered in the Subansiri basin. The details of the same are given below in Table.

Table: Projects on Subansiri River (Cascade development)

Sl. No.	Name of the project	Catchment Area (Sq.km)	Present IC (MW)	FRL m	Ht. of the dam (m)	Tail Water Level (m)
1.	Oju – I	13350	700	1950	110	1670
2.	Oju – II	13760	1000	1650	90	1300
3.	Niare	14400	800	1280	100	1055

Sl. No.	Name of the project	Catchment Area (Sq.km)	Present IC (MW)	FRL m	Ht. of the dam (m)	Tail Water Level (m)
4.	Naba	14300	1000	1035	110	780
5.	Mili	-	75	1400	-	1200
6.	Sape	-	38	1155	-	1080
7.	Chomi	-	80	1040	-	920
8.	Chela	-	75	900	-	805
9.	Kurang I & II	2302	330	745	140	620
10.	Tamen	-	175	320	-	250
11.	Tago – I	-	55	1080	-	790
12.	Subansiri Lower	34900	2000	205	116	-
13.	Subansiri Middle	8100	1600	460	203	-
14.	Subansiri Upper	20250	2000	460	214	-
15.	Nalo	14500	360	765	125	645
16.	Dengser	17625	552	630	100	490
17.	Tammu	-	55	310	-	220
18.	Nyepin	-	32	1060	-	920
19.	Hiya	-	41	880	-	745

Compliance to CWC comment no.1 vide letter 2/18(A)/2014-EIA/646 dated September 09, 2014

Sr. No. as per scope of work	Scope of Work	Particulars	Compliance
4. **Data Collection** In the present study emphasis should be laid on terrestrial and aquatic ecology. The estimation of supportive capacity of the basin should involve the preparation of the existing scenario i.e., the preparation of detailed data base of the basins. This should be accomplished through the steps outlined in following sections.			
4.1	**Meteorology**	The information on various meteorological aspects is to be collected from India Meteorological Department (IMD) for meteorological stations located within the basin area on in vicinity to the basin boundary. The information on various aspects such as rainfall, temperature wind, humidity etc. will be collected.	Chapter 4 – Page 66 to 72
4.2	**Water Resources**	The information on following aspects should be collected: • Review of drainage characteristics of the basin, including various surface water bodies like rivers and lakes. • Data collection and review of past studies/reports/data, etc. • Review of existing water sharing agreements for meeting various need-based existing and future demands viz. municipal, irrigation, power generation and industrial. • Analysis of all, past assessment of the water availability and assessing the water availability, as per updated data for the system as a whole and at existing ongoing / proposed project locations on annual / monsoon / non – monsoon and monthly basis. • Estimation of sediment load at various points in the basin based on available secondary data. • Identification of perennial sources of water and their designated usages.	Chapter 2 – Page no. 20 Chapter 2-Page 17-18 Chapter 3 – Page 43 Chapter 4 – Page 72 to 76 Chapter 2 – Page 32 to 39 Chapter 7 – Page 236 to 244
4.3	**Water Quality**	As a part of the Studies, secondary data is to be collected for water quality in the study area. In addition to above,	

Sr. No. as per scope of work	Scope of Work	Particulars	Compliance
		information on human settlement, sewage generated and mode of collection, conveyance treatment and disposal of sewage should also be collected. The water quality monitoring should be conducted at 32+2 locations in the study area. The frequency of sampling should be once per month for 9 months including one rainy season. The various parameters include pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Alkalinity, Total Hardness, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrates, Chlorides, Sulphates, Phosphates, Sodium, Calcium, Magnesium, Potassium, Iron, Manganese, Zinc, Cadmium, Lead, Copper, Mercury, Total Chromium, Total Coliform.	Chapter 7 – Page 222 to 235
4.4	**Flora**	The following data should be collected from various secondary sources for river Subansiri and its tributaries in the basin area: • Characterization of forest types in the study area and extent of each forest type. • Information on general vegetation pattern and floral diversity. • Presence of economically important species in the basin area. • Presence of endemic floral species found in the basin area, if any should be assessed as a part of the basin study. • Location of wild life sanctuaries, national parks, biosphere reserves if any, in the study area The field studies should be conducted for sampling at 32 locations to collect primary data on terrestrial ecology in the study area. The monitoring should be conducted for 3 seasons (one should be rainy season). The following should be covered as a part of the EIA study. • Identification of forest type and density, bio-diversity in the	Chapter 6 – Page 93-97 Chapter 6 – Page 99 to 116 Chapter 6 – Page 116 to 122 Chapter 6 – Page 187 to 191 Chapter 6 – Page 216 to 221 Chapter 6 – Page 150 to 180

Sr. No. as per scope of work	Scope of Work	Particulars	Compliance
		study area. • Preparation of comprehensive checklist of flora (Angiosperms, Gymnosperms, Lichens, Pteridophytes, Bryophytes, Fungi, Algae etc.) with Botanical and local name. • Importance Value Index of the dominant vegetation at various sampling locations. • Frequency, Abundance and density of each species of Trees, Shrubs and Herbs at representative sampling sites should be estimated. • Identification and listing of plants genetically, biologically, economical and medicinal importance. • Major forest product, if any, and dependence of locals on the same in the forests observed in the study area. In addition, based on the published literature including various research papers, the information on forest types, presence of various species, biological diversity etc. should be collected for the study area.	Published literature referred to and mentioned in the foot note in Chapter 6.
4.5	**Fauna**	The following data be collected from various secondary sources for the study area: • Inventory of Birds (resident, migratory), land animals including mammals, reptiles, amphibians, fishes etc reported & surveyed in the basin area should be prepared. • Presence of RET faunal species as per the categorization of IUCN Red Data list as per different schedules of Indian. Wildlife Protection Act, 1972 in the basin area. • Presence of endemic faunal species found in the basin area, if any should be assessed as a part of the Basin Study.	Chapter 6 – Page 205 to 216 Annexure 6.12 (Volume II) Chapter 6 – Page 208 RET species given in Annexure 6.14 (Volume II) IWPA species given in Annexure 6.14 (Volume II) Chapter 6 – Page 209

Sr. No. as per scope of work	Scope of Work	Particulars	Compliance
		• Existence of barriers and corridors for wild animals, if any in the basin area should be covered as a part of the study. • Identification of threats to wildlife in the region. • Presence of National Park, Sanctuary, Biosphere, Reserve Forest etc. in the basin area should be assessed. During ecological survey, identification of faunal species should be carried out simultaneously. Indirect observations of mammals should be carried out by identification of tracks, droppings (scat), claw marks and calls, etc. The listing of faunal species by direct observation techniques should be carried out. The detailed list of faunal species should be formulated based on forest record and published literature.	Chapter 10-page 385 to 389 Chapter 10-page 381-385 Chapter 6 – Page 216 to 221 Published literature referred to and mentioned in the foot note in Chapter 6.
4.6	**Aquatic Flora And Fauna**	The following data should be collected from various secondary sources or river Subansiri and its tributaries in the basin area: ➢ Presence of major fish species ➢ Inventory of migratory fish species & migratory routes of various fish species ➢ Presence of major breeding and spawning sites. The field studies should be conducted for sampling at 32 locations to collect primary data on aquatic ecology & fisheries in the study area. The density and diversity of phytoplankton, zooplankton should be estimated. In addition, primary productivity should be monitored at various location to be covered as a part of the study. The diversion of water for hydropower generation leads to reduction in flow downstream to the dam site upto disposal of tail race outfall. This leads to diverse impacts on riverine ecology. The dam could also act as a barrier for migration of fishes. The data on prevailing fish species should be collected from the Fisheries Department. To augment the existing data, a fisheries survey should be conducted at 32 locations in the study area. The survey should be conducted once per month for Nine months. The	Chapter 7- Page 257 to 260 Chapter 7- Page 269 to 273 Chapter 7- Page 260 to 261

Sr. No. as per scope of work	Scope of Work	Particulars	Compliance
		details of the monitoring work should be carried out as per the following; • Assessment of biotic resources with special reference to primary productivity, zooplanktons, phytoplanktons, benthos, macrophtes, macro-invertebrates and fishes in the study area. • Population densities and diversities of phytoplanktons, zooplanktons, benthos, macrophytes, macro-invertebrates and fish shall be estimated. Diversity indices of these ecological groups should also be calculated separately. • Fish composition • Migratory route of migratory fishes • Spawning & breeding grounds of fish species, if any, should be identified.	Chapter 7- Page 244 to 257 Ditto Chapter 7- Page 257 to 260 Chapter 7- Page 269 to 273 Chapter 7- Page 260 to 261
5.	**Impacts Due To Hydro Power Development**	The impacts on terrestrial and aquatic ecology should be studied. The scenario to be considered for assessment in the present study should be based on the hydropower projects presented in Table. The key aspects to be covered are listed as below: • Modification in hydrologic regime due to diversion of water for hydropower generation. • Depth of water available in river stretches during lean season and its assessment of its adequacy vis-à-vis various fish species. • Length of river stretches with	Chapter 3-Page 62 to 65 Chapter 7-Page 271 to 277

Sr. No. as per scope of work	Scope of Work	Particulars	Compliance
		normal flow due to commissioning of various hydroelectric projects due to diversion of flow for hydropower generation. • Impacts on discharge in river stretches during monsoon and lean seasons due to diversion of flow for hydropower generation. • Impacts on water users in terms of water availability and quality. • Impacts on aquatic ecology including riverine fisheries as a result of diversion of flow for hydropower generation. • Assessment of maintaining minimum releases of water during lean season to sustain riverine ecology, maintain water quality and meet water requirement of downstream users. • Impact due to loss of forests. • Impact on RET species & impacts on economically important plant species. • Impacts due to increased human interferences • Impacts due to agricultural practices. • Downstream impact on Assam due to hydropower development in Subansiri basin and release from Lower Subansiri Dam.	Chapter 11- Page 397 to-398 Chapter 9- Page 319 to 344 Chapter 7- Page 233 to 236 Chapter 7- Page 273 to 277 Chapter 11- Page 408 to 409 Chapter 10- Page 354 to 379 Chapter 10- Page 379 to 380 Chapter 10- Page 358 to 360 Chapter 10- Page 358 Chapter 9 - Page 319 to 344
6.	**Outcome of the Study**	The key outcomes of the study should be to: • Provide sustainable and optimal ways of hydropower development of Subansiri river, keeping in view of the environmental setting of the basin. • Assess requirement of environmental flow during lean season with actual flow, depth and velocity at different levels. Downstream impacts on Assam due to hydropower development in Subansiri basin in Arunachal Pradesh.	Chapter 11- Page 397 to 398 Chapter 11- Page 408 to 409 Chapter 11 - Page 409 to 410

Sr. No. as per scope of work	Scope of Work	Particulars	Compliance


28.02.2013


Subansiri Upper dam site
0
-100
-200
-300
-500
-600
-800
-900
Subansiri Upper
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-1900
-2000
-2100
2.1 km