

Review Paper

The Spatial Analysis of Satluj Basin, Himachal Pradesh, India

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Abstract

Satluj River is the longest river of the Himachal Pradesh. It is one of the richest basins among all four river basins (Beas, Ravi, Chenab and Yamuna Basins) in reference to hydropower potential. The development of hydropower projects is rapidly increasing due to the suitability of present topography. With the help of this research, it tries to find out what are the characteristics that promote hydropower development activities in Satluj Basin with compare to the other basin in Himachal Pradesh, India.

Keywords: Satluj River, Beas, Ravi, Chenab, Yamuna, Hydropower and Tributaries.

Introduction

The study area falls within Himachal Pradesh. The name of Himachal constitutes with "Hima" which means snow in Sanskrit. Himachal Pradesh is situated between 30°22'40" and 33° 12'20" North latitudes and 75° 45'55" and 79° 04'20" East longitudes and covers a geographical area of 55,673 km². It is verge by the state of Jammu and Kashmir in the north, Punjab and Haryana in the south and southwest, Uttaranchal in the southeast and in the northeast it shared India's border with China (Tibet). Himachal has an enormous treasure of natural resources and a mosaic socio-cultural diversity^{1,2}.

History of Study Area: According to the Chand³ in the Himalayan region the presence of a human being was two million years ago. It is believed that the first civilizations of Satluj valley were in Ancient Western Tibet. The Zhangzhung civilization used to call this valley as a Garuda valley. This civilization built a center place in the upper Satluj valley that is known as a Kyunglung.

This place still exists near the Moincer village, southwest of Mount Kailash. The Zhangzhung civilization was captured and taken up to become the Tibetan Empire. The Garuda Valley (Satluj valley) was the main mode of transportation of deodar woods along the Satluj's banks.

The geological evidence proved that the river was present before 1700 BC as tributaries of the legendary River Ghaggar-Hakra or the Saraswati. About 4000 years ago, due to tectonic activities and the change of plates, which forwarded River Satluj towards the southwest and it, became the reason for Saraswati drying up. There is also evidence that Satluj has been responsible for the

local faulting along Rampur area which is similar activity in the Nanga Parbat region by River Indus.

Methodology

The present study is based on primary (field survey) as well as secondary data (published material, literature and newspaper). The secondary data were obtained from the report of Indian Meteorological Department, National Hydropower Corporation (NHPC), Himachal Pradesh State Electricity Board (HPSEB), Revenue Department, State Census Department, State Government Reports and Economic and Statistics Department. The tributaries of River Satluj were mapped based on the GPS survey and local people perceptions. The elevation of the study area is calculated with the ASTER data and Land use and land cover are calculated from LISS III data under the environment of ArcGIS 10.

Study Area: The present study deals with environmental impacts of the hydroelectric power projects in the River Satluj basin within the Himachal Pradesh. It is the third largest river of a trans-Himalayan that originates beyond the Indian Territory from the Tibetan Plateau near Mansarover Lake⁴. It enters into Indian Territory at Shipkila (Himachal Pradesh) at an altitude of 6,608 meters and flows in the southwesterly direction through Kinnaur, Shimla, Kullu, Solan, Mandi and Bilaspur districts⁵. It is called River Tibet before joining the River Spiti and after the confluence with River Spiti at Khab it is known as a River Satluj (Figure-1).

The River Satluj has very low flow in the Tibetan Plateau due to winter climate until it joins River Spiti⁶. The Spiti catchment (10 071 km²) has experienced heavy snowfall (westerly

disturbances) during the months from December to March and contribute to the Satluj flow in the months of July, August, and September⁷⁻⁹. The peak values of total discharge are noticed during the months of July and August due to snowmelt and monsoon rainfall especially in the lower elevations.

It is estimated that during the winter season round about 65% Satluj Basin is covered with snow and 12% of the basin is covered with permanent snow¹⁰. According to the Singh and Jain the round about 50% of the annual flow to Satluj is contributed by the snow and ice melt¹¹.

River Satluj traverses a course of 320 km area within Himachal Pradesh and considered as a largest river among the four rivers (Beas, Ravi, Yamuna and Chenab)¹². It left the Himachal Boundary at Bhakhra Dam, which is the second highest dam 225.55 m in compare with 261 Tehri Dam in Indias⁵. The River Satluj finally drains into the Indus in Pakistan.

The total catchment area of River Satluj is highest exists around 38 % area (20,398 km²) among the five major rivers of Himachal Pradesh². The catchment area of about 50,140 km of the River Satluj is located above the permanent snow line at an altitude of 4,500 meters¹³. As is apparent from the Figure-2, more than 63% of the State's area is drained by Satluj and Beas river systems.

On account of varying geographical features, the Satluj basin topographically divided into two parts, i.e.; the Upper Satluj basin and lower Satluj basin. Beyond the Nathpa village in Kinnaur district, Satluj is considered to be the upper Satluj basin, while southwestern part of the Nathpa village to Bilaspur, it is known as the lower Satluj basin⁴. Since the Upper Satluj part has favorable slope conditions for a development of hydropower projects, here these projects are going to be developed in a series giving least value to environmental considerations¹².

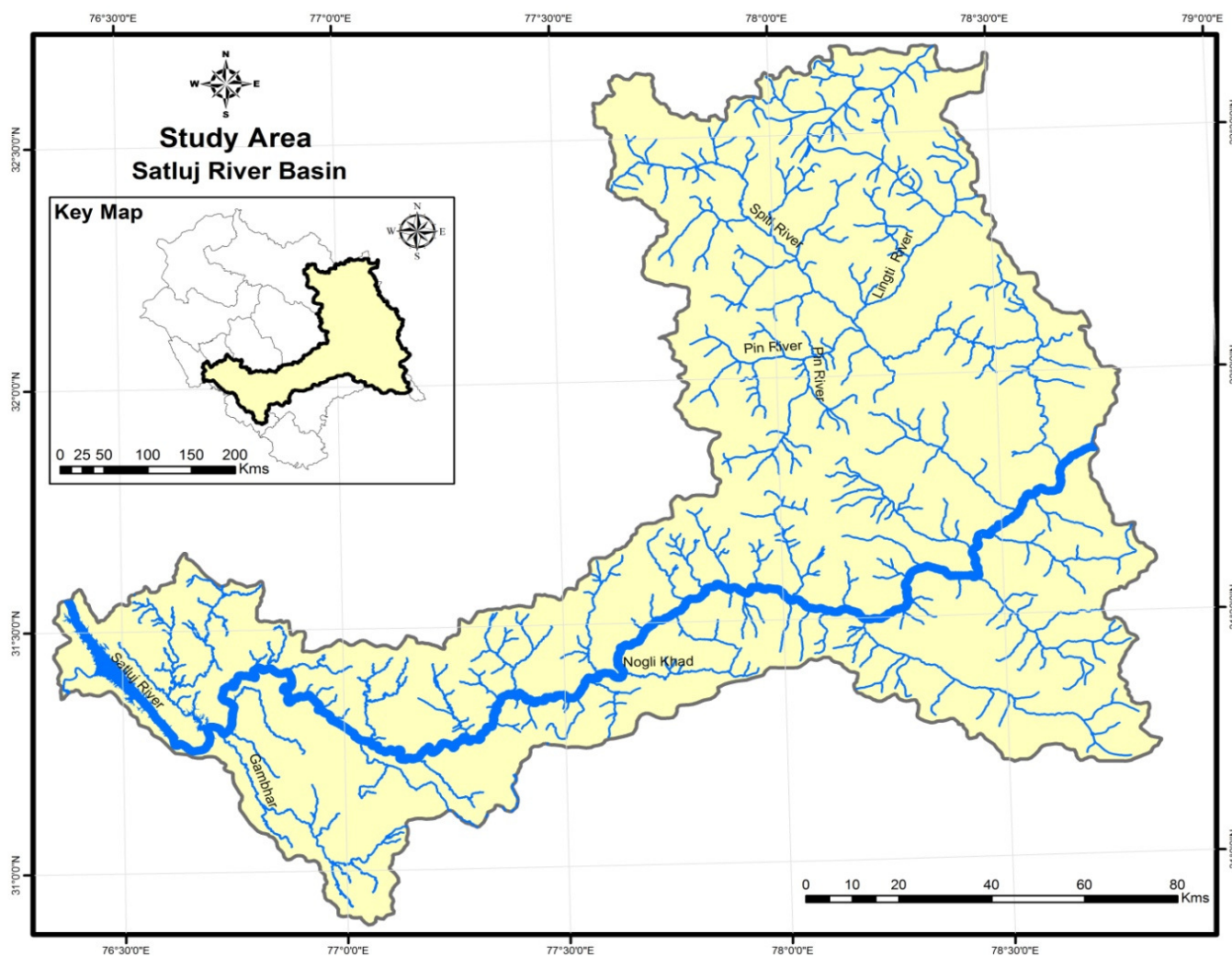


Figure-1
Study Area

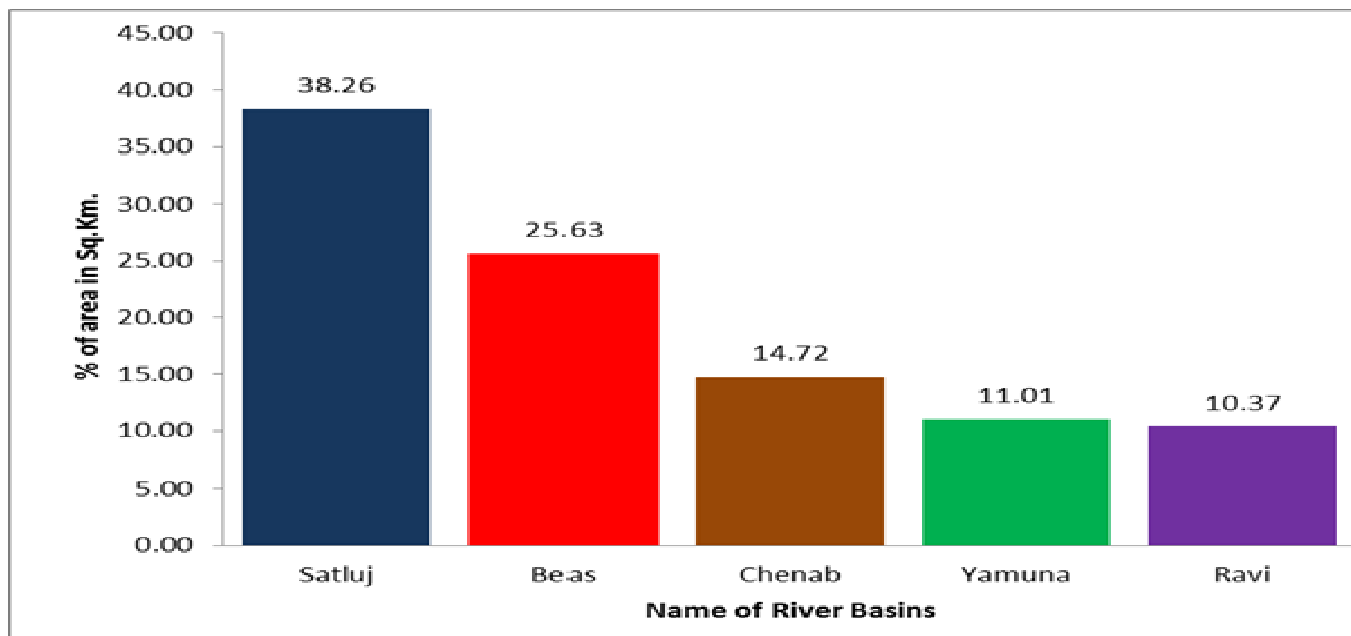


Figure-2
Catchment Areas of Major Rivers

Climate: According to Sharma¹⁴ due to the variation in elevation, the Satluj basin has great variation in its climate. The climate of basin varies from hot and sub-humid tropical in the southern part and while the glacier and alpine are seen in the eastern and northern part of the basin. The cold desert i.e. Spiti has two seasons, summer from March to September and winter thereafter. Downstream of upper Kinnaur, the catchment experienced the three seasons (summer, rainy, and winter season). In the basin the summer season starts from April to June with an average temperature varies from 20°C to 38°C. The rainy season starts from July to September, followed by a relatively warm October. The winter season starts from November to February with the average temperature varies from 0°C to 15°C. Snowfall is common in alpine tracts (generally above 2200 m i.e. in the higher and Trans Himalayan region).

The bulk of annual precipitation in monsoon falls due to movement of the southeast monsoon from the Bay of Bengal. The western disturbances occur during the winter season and larger parts of the upper reaches of the Satluj valley remain under snow cover due to the western disturbances.

Precipitation: Satluj basin receives precipitation from western disturbances. The western disturbance passes over the northwestern part during the winter. Satluj valley faced the heavy monsoon of the outer Himalayas and heavy snowfall of the arid Tibetan. The monsoons from the Indo-Gangetic plain of India, first hits the outer ranges of the Indian Himalayas, become the reason of heavy monsoon rains. When monsoon crosses the outer Himalayas and enter into the inner Himalayas, it receives some clouds, with low precipitation. At the higher altitudes due to the western disturbances, the valley experiences

the snowfall (above 1600 meters but sometimes goes down to 900 meters) during the months from January to March. The precipitation continues to decline in the Spiti valley and beyond the Tibetan border. The total annual rainfall is observed 766 mm in Kinnaur and 800 mm at Rampur. The average humidity observed during winter in the project area is about 50%. Overall, humidity ranges during winter from 35 to 54.2%, which is very low. While in monsoon months, humidity is observed more than 90% especially in the lower part of Satluj basin.

The drainage network of the Satluj basin depends upon spring and snowmelt and the South Asian Monsoon. Some incidents of heavy monsoon often produce extensive flooding at downstream. The maximum flood discharge was recorded about 600,000 cubic feet per second during 1955. The water flow decreased during the winter. The Figure-3 showing precipitation detail in Satluj basin.

River and Tributaries: The numbers of important rivers flow through the Northern Plains. The three main rivers of the Northern plains are the Satluj, Ganga and Brahmaputra. These Himalayas River has plenty of water throughout the year due to snow-fed.

River Satluj is the largest river among the five rivers basing of Himachal Pradesh. The River Satluj basin divided into 11 sub basins. It is joined by various right bank tributaries such as Spiti, Ropa, Rupi, Kashang, Taiti (Kiran), Mulgaon, Yul, Kerang, Wanger and Throng in Kinnaur. The Tirung, Gayanthing, Duling, Baspa, Solding, Manglad and Nogli streams belong from the left bank tributaries. The Major Tributaries of Satluj River are River Baspa, River Spiti, Nogli Khad and River Soan (Figure-4).

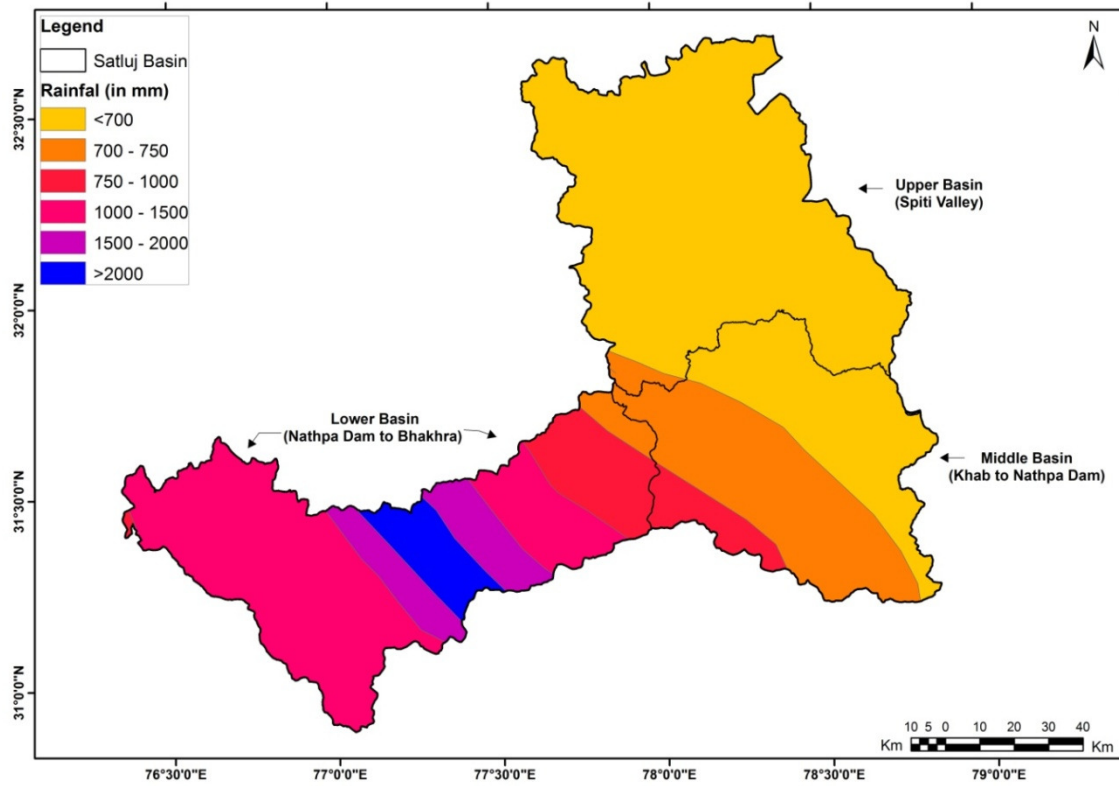


Figure-3
 Precipitation in Satluj basin

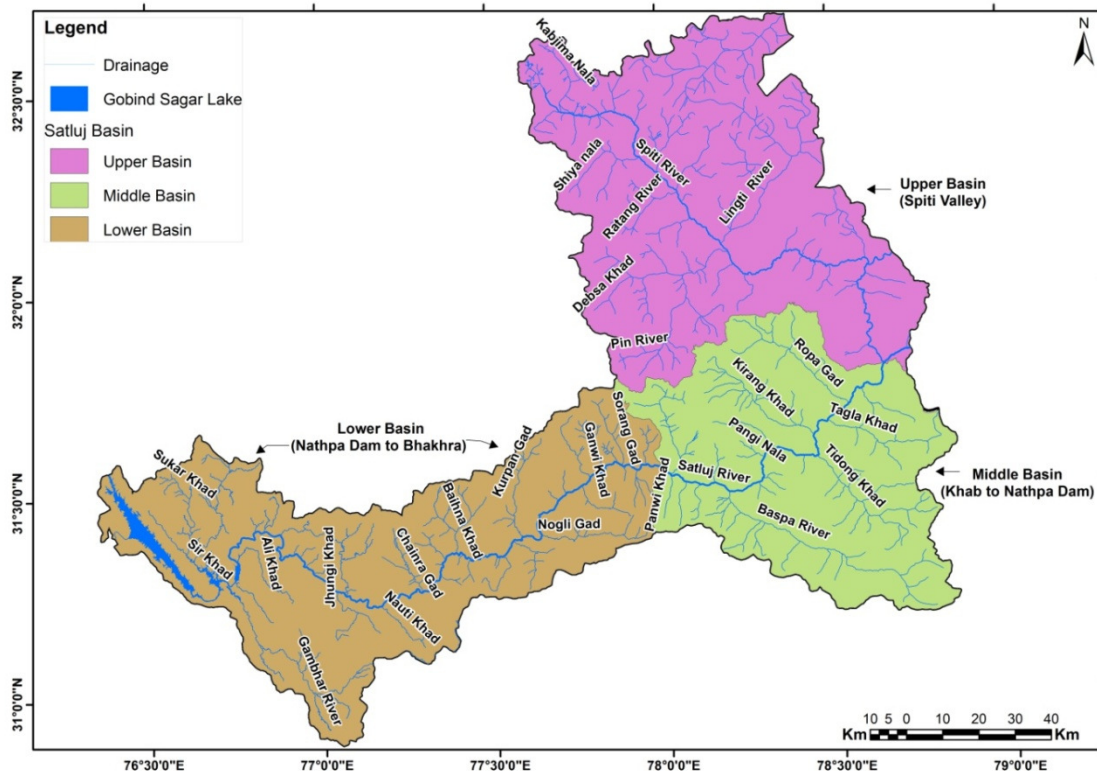


Figure-4
 Tributaries of Satluj River

Right Bank Tributaries

Tributaries of River Satluj in Spiti block, Lahul and Spiti:

River Spiti: The River Spiti rises from Kunzum range on the northern slopes of main Himalaya. The River Spiti also drains from the famous Pin valley that is known as a National Park. The River Spiti joins the River Satluj at Khab in Kinnaur district after traveling a distance of about 150 km. River Spiti and its major tributaries (Tegpo and Kabzian) pass through huge mountain on either side. Its other tributaries are Lingti on the left bank and River Pin on the right bank. The main settlements along the river are Hansi and Dhankar Gompa.

Right Bank Tributaries of River Spiti

Gyundi Nala: It joins the River Spiti near to Hal and Morang village. The main source of this Nala is Sumto Kona glacier. The tributaries of Gyundi Nala are Shiya Nala (joins on the left bank) and Kuligo Nala (joins on the right bank).

River Ratang: It originated from the Shigri Parvat near to Khamengar range in Spiti block. The main source of water for this river are Sumto Yoma and other glaciers. The major tributaries of this river are Sanugba Nala, Chhachhumi Nala and Tarakh Nala on left bank.

River Parahio: The main source of this river is the permanent glaciers. It is the major tributary of the River Spiti in the Spiti block. The Debsa Khad and Killing Khad are the left bank tributaries and Maro Nala, River Pin is the right bank tributaries. River Pin is the major tributary of River Parahio that originated near the boundary of the Kullu block of Kullu district and Nichar block of Shimla district.

Stream from Yang Cho Lake: Yang Cho stream is a small stream that flows northward from the Yang Cho Lake and joins with River Spiti near Mane.

Left Bank Tributaries of River Spiti

Kabjima Nala: It joins the River Spiti at an initial stage near to Losar in Spiti. It originates at the intersection of Lahul and Spiti's block boundary. The main source of this Nala is permanent glaciers bodies.

Takling Nala: It is a tributary of River Spiti in Spiti block. It joins the Spiti on left bank near Latarse village. Major tributaries of Tackling Nala are Kigar Nala and Tokro Nala that joins it on the left bank.

Puri Lungpa Nala: It joins the river near to Sumling Gompa in Spiti block. Its tributary is Dumla Nala that joins it on the right bank.

River Lingti: It is the major tributary of the River Spiti. The major glaciers on the catchment of this river are Lagma glacier. The River Sheru Tokpo originated from this glacier that joins the River Lingti on the left bank. Other left bank tributaries are

Kebri Tokpo Nala, Zingiu Tokpo Nala and Tuti Tokpo Nala. The other major tributaries that join on the right bank are the Sharma Lungpa Nala, Aksinma Tokpo Nala and Tiphu Tokpo Nala and Korse Tokpo Nala.

River Parechu: The main source of water for River Parechu is permanent glaciers. It originates in India and flows in the Tibetan part before once again enter into the India border. It joins River Spiti at Samdoh. In 2005, the flash flood incident was occurred due to bleach of artificial lake that results the lot of property and life loss

Tributaries of River Satluj in Pooh block, Kinnaur

Ropa Khad: It is originated at the boundary of Pooh and Spiti block. Where chhuktayanjan Nala and Sanand Nala meets, onwards that it is known as Ropa Khad. The major left bank tributaries of this Khad are Barasumdo Nala, Sumdo Nala Shakar Sumdo Nala and right bank tributaries are Ghunsa Nala, Phophlan Nala and Ranam Khad. The major settlements on the bank of Ropa Khad are Thangsari and Ropa.

Kiran / Tati Garang Khad: It is originated from the Rongphuway dhar at the boundary of pooh and Spiti block. When this Khad entered in Kiran Dogri, it is also known as Kiran Khad instead of Tati Garang Khad. It joins the River Satluj just above the Jangi village. The left bank tributaries of Kiran Khad are Thoti Nala that meets the Kiran Khad at Porang village. Pejar and Waling Nala meet the river at Lippa village. The major settlements of this river are Porang Dogri, Asrang, Lipa and Kiran Dogri.

Tributaries of River Satluj in Kalpa block, Kinnaur

Kashang Khad: It originates at the foothill of Chikim and Mukim dhar that divided the Kalpa and Nichar block. The Rogle Khad on the left bank tributary drains the water from the Sankarishul glacier. It joins the River Satluj on left bank just below the Rarang village. The major settlements on the bank of Kashang Khad are Shangidor, Dunang, and Grama Dogri

Pangi Nala: It is originated from Sankarishul glacier. Where the two tributaries Mebar Khad and Kojang Khad meet, downward that point it is called as Pangi Nala. It joins the River Satluj just above the Pawari village. The major settlements along the bank are Thuti and Pangi.

Tributaries of River Satluj in Nichar block, Kinnaur

Bhaba/ Wanger Khad: The Wanger Khad originated from Shrikhand Parvat and its catchment is within the Nichar block. It has a larger catchment with an eastern tributary even adjoining the far away Taiti valley. The Surcho Khad joins the Wanger

Khad at Shango on the left bank. The Kangrang Khad is also the left bank tributary of the river. It joins the River Satluj near to Rarang and above Wangtoo village. The major settlements on the bank of Wanger Khad are Homte, Huri, Surchu and Rarnq.

Sorang Khad: The Zangasu glacier is the main source of the water for Sorang Khad. The main left bank tributaries of this Khad are Tal Nala and Kumrang Nala. It joins the River Satluj just below the Nigulsari rope bridge. The major settlement on the bank of this Khad is Sorang.

Rupi Khad: It is originated just above the Rupi village. Some of the local Nalas feed this Khad. It joins the River Satluj just below the Sornag Khad. The major settlements on the bank of Rupi Khad are Rupi and Lingri Dogri.

Tributaries of River Satluj in Rampur block, Shimla

Kut Khad: It originates just above the Kot Dogri near to the Nichar block boundary. The Kut Khad joins the River Satluj at the bottom of Suru village. The major settlements on the bank of Kut Khad are Kut and Suru.

Ganwi Khad: Ganwi Khad originated from the Sirikhand Mhadev. At its origin place, it is known as Nanti Khad on the name of Nanti village and downward to Ganwi village; it is called as Ganwi Khad. Its left bank tributaries are Daduwa Khad, Ghartr Khad and right bank tributaries are Sagori, Kapni and Saran Khad. The major settlements on the bank of this khad are Nanti, Phancha, Badain, Dhar and Ganwi Khad.

Tributary of River Satluj in Nirmand block, Kullu

Kurpan Khad: It is known as Umli Gad on its origin the southern slopes of 5048 m high peak near to the boundary of Banjar and Rampur blocks. After the confluence with Dewar Gad, Umli Gad is known as Kurpan Gad. Its tributary is Nager Khad that joins it on the left bank near to the Nager village. The major settlements on the bank are Badar, Bagipul and Bhadu Khad.

Tributaries of River Satluj in Karsog and Ani blocks, Mandi and Kullu: **Baihna Khad:** The Khudhi Khad and Kunir Khad confluence in Shawad village from that point it is known as Baihna Khad. It joins the River Satluj in Phirnu village. One of the major tributaries of this river is Ani Khad that joins the Baina Khad at Rorha village. The Baihna Khad also demarks the natural boundary between Kullu (Ani block) and Mandi districts (Karsog Block). The major settlements on the bank are Shawad, Nagan, Bari, Haripur and Phirnu.

Left Bank Tributaries: Tributaries of River Satluj in Poo block, Kinnaur: **Tagla Khad or Gymthing Khad:** Gymthing Khad originated on the Zaskar and offers the route to Tibbetthis. It joins the River Satluj at the left bank near Nesang village. The

major settlements on the bank of this river are Nisang and Giyuri Dogri.

Tidong/ Tirung Khad: Tidong Khad originated at an elevation of 6000 m in the Zaskar range where it offers the route to Tibbetthis. It joins the River Satluj above the Rispa village. The major tributaries on right bank of this Khad are Lamber Khad, Gara Khad and Dua Khad. The Lamber Khad is snowfed tributary that joins the Tidong Khad after about 260 m. Another tributary of Tidong Khad is Gara Khad. It is a snowfed perennial tributary of Tidong and originates from Gara glacier. It joins Tidong Khad near Thangi village. The Dua Khad is also a snow fed perennial tributary that joins Tidong Khad after traveling 8.7 km from its origin. It is also fed by many small nallas.

The left bank tributaries are Shankvi Khad and Rovang Khad. The Shankvi Khad is a perennial tributary that joins Tidong Khad on right bank near Thangi village after traveling 7.74 km from its origin. The Rovang Khad is perennial Khad and joins Tidong Khad its right bank near Roving Dogri village at an elevation of about 2400 m.

Tributaries of River Satluj in Kalpa block, Kinnaur

Tangling Khad: It originates at the boundary of Pooh and Kalpa block of Kinnaur district. The main source of water for this Khad is glaciers. It joins by the Kangrang Khad on right bank at the Kangrang Dogri. It joins the River Satluj at Tangling village. The major settlements on the bank are Kangrang Dogri and Tangling.

Shyang / Shongtong Khad: It is left bank tributaries of the River Satluj that join the River Satluj at Shongtong. The major settlements on the bank are Tathpa and Shongtong.

River Baspa: River Baspa is an important tributary of the River Satluj in its upper course. It is 70 km long and second largest tributaries of Satluj. This river rises in Indo Tibetan border and it also demarking the catchment of the Satluj and the Bhagirathi. The river starts in the Baspa hills and joins River Satluj near the left bank of Karcham at the lower end of Kinner Kailash.

The Singan Khad and Hurba Khad join River Baspa at Batseri village, Rokti Khad join Baspa at the Sangla and Baturi Khad join the Baspa at Chunang village.

On the right bank Nagasti Khad meet the Baspa at Nagasti village and Shailpya Khad meet the Baspa at Chitkul village and Mangsa Garang Khad join the River Baspa at Mastarang village. The major settlements on the bank of Baspa are Chitkul, Nagasti, Mastarang, Rakchham, Batseri, Sangla and Chunang.

Tributaries of River Satluj in Nichar block, Kinnaur: **Shatul/ Panwi Khad:** It is also known as Shatul Khad. Near to the Panwi village, it is called as Panwi Khad on the name of

village Panwi. It has joined River Satluj just above the Wangtoo village. The major settlements on the bank are Panwi and Joktarang.

Tributaries of River Satluj in Rampur block, Shimla

Nogli Khad: It has joined River Satluj just south to the Rampur Bushahar at Nogli. It is known as a Sageti Gad on its origin place. The Nogli Khad come to exist where the Suket Khad and Devpani Khad meets. The Sharnal, Sari, Nogli are the major settlements on the bank of this Khad

Tributaries of River Satluj in Basantpur block, Shimla

Sainj Khad: The catchment of the Sainj Khad is on the Basantpur block. It joins the River Satluj just below the Anu. The major settlements on the bank are Sainj.

Tributaries of River Satluj in Kunihar and Bilaspur blocks, Solan & Bilaspur

Ali Khad: The catchment of this Khad is in the Kunihar and Bilaspur blocks. The Ali Khad comes to an exit where the Badar Khad and Jor Khad meet. The Ali Khad joins the Gobind Sagar Lake at Korwarni. The Ghagas is the main settlement on the bank of this Khad.

Tributaries of River Satluj, Solan and Bilaspur

River Gambhar: Its catchment falls within the five blocks (Kandaghat, Solon, Dharampur, Kunihar, Nalagarh of Solan district and Bilaspur of Bilaspur district). The River Dabar and River Kuthar on the left bank are the main tributaries of this river. The Kuni Khad joins the river on the right bank at Shiti. The major settlements on the bank are Jayalng Padog and Neri.

Topography: Soil: The Satluj valley has relatively poor sandy loam constituting exposed bedrock, and gravel soil. The soils in the study area as grouped under Udalts – Ochrepts soils are shallow, veneer and brown in color with high base in Lahul and Spiti and Kinnaur region; Othents – Ochrepts soil are combination of shallow red loamy and sandy ideally suitable for horticulture in Kullu and Kinnaur district; Udoll soil characterization of cold desert and found in Lahual and Spiti and Kinnaur district; Glaciers and snow cap soils are found where the glaciers and snow cover is present throughout the year in Lahual and Spiti, and Kullu district. Medium deep, well-drained soil with loamy surface was observed in the lower reach of the Sutlej with limited area.

The soil depth is considered most suitable criteria for the site selection of reservoirs. The very deep soil is considered less suitable and the shallow soil considered a suitable site for the dam sites. The more deep soil has more vulnerability to the

landslides According to the soil depth in upper basin 2118 sq km has been identified. In the middle basin, the suitable area has been increased with the area of 1772 sq km whereas in lower basin it was estimate 1724 sq km

Elevation: The elevation in Satluj valley varies from 300 meters to 7000 meters (Figure-5). The Satluj basin divided into four parts such as Tibet plateau, Spiti valley and Khab to Nathpa that include many V-shaped valleys cirques, glaciers, U-shaped and hanging valley moraines and Nathpa dam site to Bhakhra. They are further divided into two parts, namely gorges and canyons. Gorges represent very deep and narrow valleys having very steep valley side slopes. Canyons are the extended form of gorges. Topographically Satluj catchment has been divided into four parts, (Figure-6). i. The Tibetan Plateau, ii. The Spiti Valley, iii. Catchment from Khab to Nathpa dam site and, iv. The catchment from Nathpa dam site to Bhakhra.

Tibetan Plateau: The River Satluj originates from beyond the Indian Territory that is known as Tibetan plateau. The geographically the Tibetan plateau has the similar characteristics that have the Spiti region. River Satluj travels round about the 320 km within the in the Tibetan province.

Spiti valley: One of the largest tributary of the River Satluj is River Spiti that flows in the Spiti block and joins river Satluj at Namgia (Khab), about 14 kilometers upstream of Pooh. During its course, it flows from moderate to hilly terrain.

The entire Spiti valley is known as a cold desert. The vegetation is very less and with loose strata. The elevation of the valley varies from 1525 meters to 3048 meters and experiences the heavy snowfall during winters.

Khab to Nathpa dam site: The topography of the area is moderate high hills to small hills with an elevation 1525 meters to 3048 meters. The snowline of the area lies above the 3048 meters.

The Kinnaur district varies from 2,550 meters to 6,791 meters. The Sangla village is situated at an altitude of 2,680 meters and Chitkul the last and highest village on the right bank of Baspa River is located at an altitude of 3,450 meters. At the altitude of 2,670 meters Kalpa village is situated which is connected by link road of 14 kilometers from Powari to Rekong Peo. Rekong Peo and Pooh are situated at the altitude of 2,760 meters and 2,830 meters respectively. Ribba (Rirang) is situated at an altitude of 2,745 meters on the right bank of River Spiti. Village Karchham, which is the most affected villages by the flash floods, is situated at an altitude of 1,900 meters. The settlements of this area are Nichar (2,150 meters) is situated between Taranda and Wangtu on the left bank of the Satluj. Morang village (2,591 meters) is situated about 39 kilometers away from Kalpa on left bank of River Satluj. Due to such variations in the altitudes, Satluj River flows with high speed in district Kinnaur.

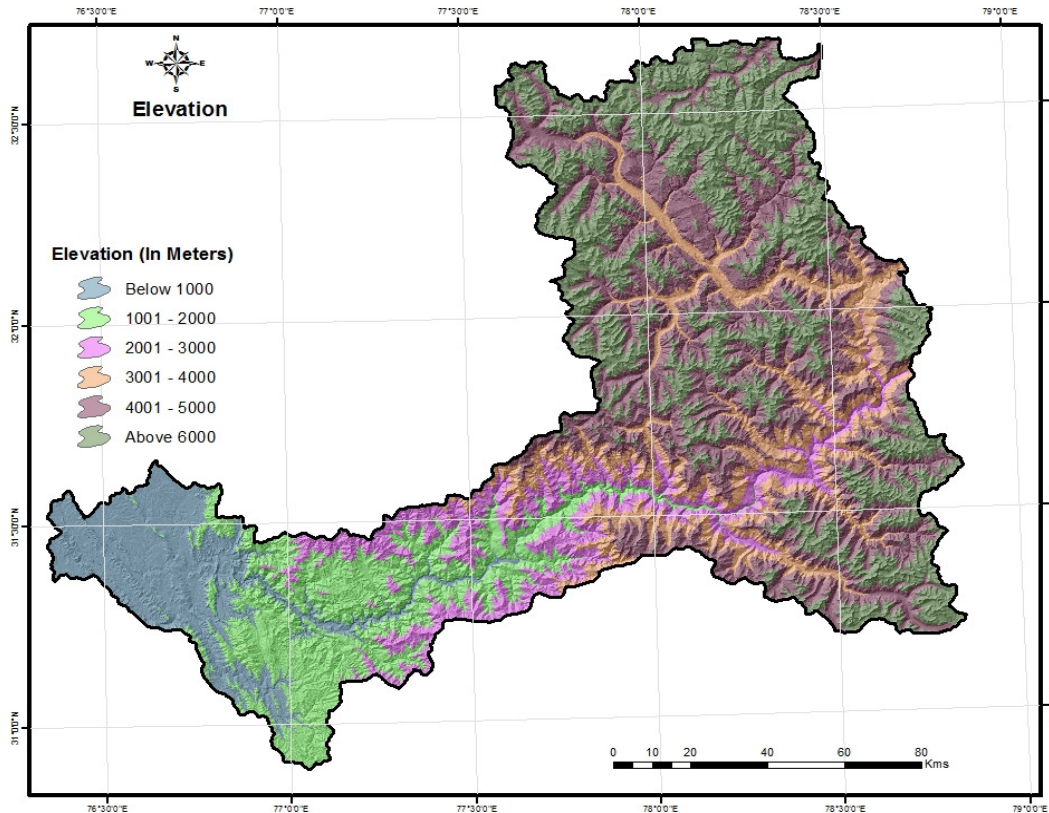


Figure-5
Elevation in Satluj valley

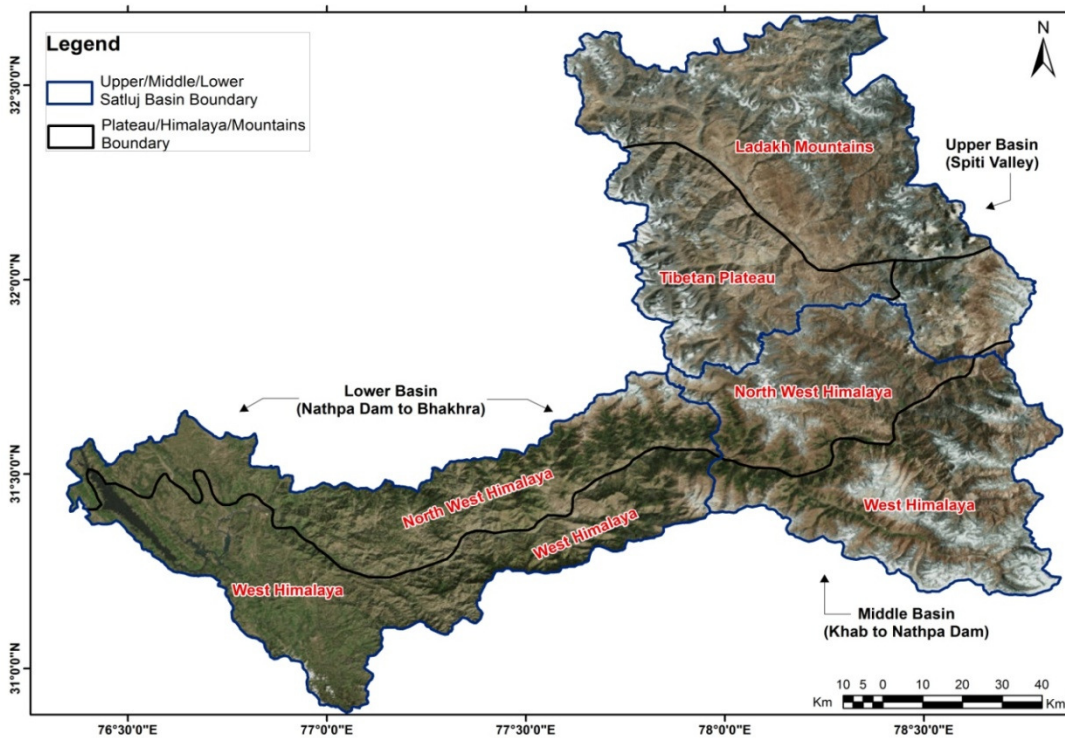


Figure-6
Topography of Satluj Basin

Nathpa dam site to Bhakhra dam: The catchment area has high surrounding hills, such as Narkanda and Shimla (3050 meters). In this course the valley slopes become gentle. The course is marked by a decrease in valley deepening as the velocity of the river flow is decreased and there is a decrease in transporting capacity of the river. Just after Kinnaur, River Satluj has entered into Shimla district. The altitude of district varies from 300 meters to 6,000 meters. Rampur is situated on the banks of River Satluj with an altitude of 924 meters along the Hindustan-Tibet road. Mandi district extends upto 754 meters of heights. Tattapani is located on the right bank of river Satluj at an altitude of 656 meters. Bilaspur varies between altitudes of 290 meters to 1,980 meters. From Kinnaur to Mandi River Satluj flows from an altitude of 6000 meters to 656 meters. This makes a very steep slope and caused massive destruction in Kinnaur, Shimla and Mandi districts. After Mandi district, the variation in altitude of Satluj catchment area is not high as much as in Kinnaur, Kullu, Shimla, and Mandi districts. It flows from moderate slope at an altitude of 656 meters to 290 meters.

Geology and rock structures of Satluj basin

Competent rocks offer a stable foundation for the construction of HEPs. The all plutonic rocks or hypabyssal rocks like

Granites, Syenites, Diorites, Gabbros, and volcanic rocks are most desirable for the foundation of dam due to strong and durable character, interlocking texture, hard silicate mineral composition, absence of any inherent weak planes, resistance to weathering. The well cemented siliceous sandstones have good compressive strength and suitable for the dam foundation. The Quartzites are very hard and highly resistant to weathering and suitable for foundation of dam sites. Among the metamorphic rocks, Gneisses (granites) are most competent rocks, unless they possess a very high degree of foliation¹⁵ (Figure-7).

In case of sedimentary rocks, it is considered as an undesirable to serve as a foundation. The undesirable sedimentary rocks are laterites and conglomerates because of their porosity and permeability. The shales are the most undesirable due to slippery bases and slates due to typical slaty cleavage and soft nature become undesirable. The khondalites that are feldspar rich contain soft graphite, and are usually weathered area also unsuitable. The volcanic rocks, that are generally vesicular or amygdaloidal, are not suitable due to permeable and contribute to porosity and hollowness. In upper basin most suitable area was estimated 108 km² and in the middle basin it was estimated 973 km² whereas in lower basin this was only 212 km².

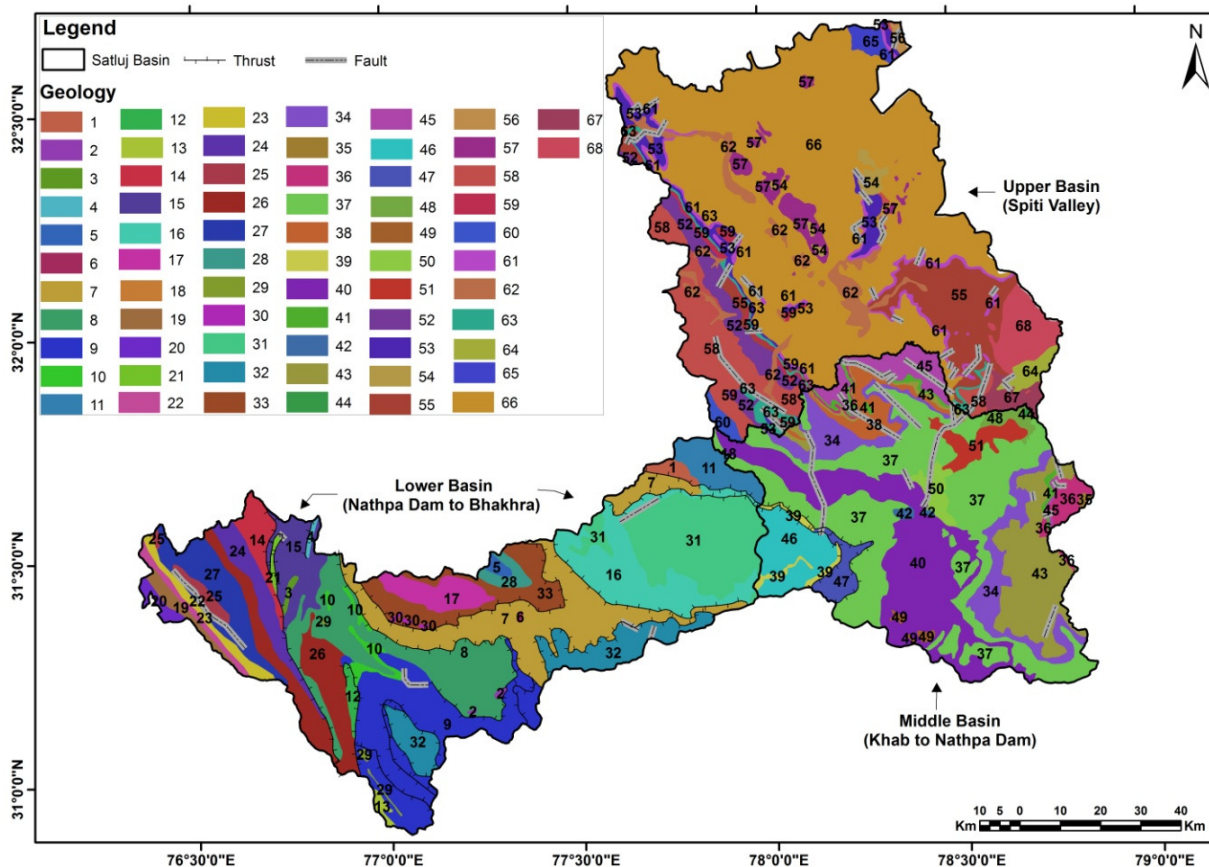


Figure-7
 Geological Map of Study Area

Natural Vegetation

Flora and Fauna: The Satluj basin is known for variation in its biodiversity due to the extreme elevation variation. In the upper reaches (Spiti and Kinnaur) of Satluj basin have the less vegetation. The major forest type of cold desert area has the Dry Alpine Scrubs especially in the elevation from 3600 to 5500 m (Figure-7). This region is famous for the high medicine shrubs.

The Moist Alpine Forests: Above the 3600 m elevation, these types of forest found. In this region, the dominant forest herbs are Berberies, Corydalis, Geranium, Astragalus and Cotoneaster.

The Himalayan dry Temperate Forests: The Himalayan dry Temperate Forest found in the Kinnaur district. The dominant

tree species are *Picea smithiana*, *Juniperus*, *Populus ciliata*, *Salix viminalis* and *Alnus India*.

The Sub-tropical broad Forests: In middle basin, sub tropical broad forest is found. The major forest is Deodar Mixed Coniferous Forest (1800 to 2400 m), *Cedrus Deodara* and mixed Coniferous Forests include pure Spruce and Kail.

The Sub-tropical Pine Forests: This type of forest is found in Solan, Shimla and Bilaspur district, especially between 600 to 1700 m. the major forest types are *pinus Roxburghii*, *Lyonia ovalifolia*, *Acacia catechu* and *Emblica officinalis*, dominant shrubs as *Carissa opaca*, *Carissa spinarum*, *Dodonea viscosa*, *Indigofera heterantha*, and *Rhamnus virgata*.

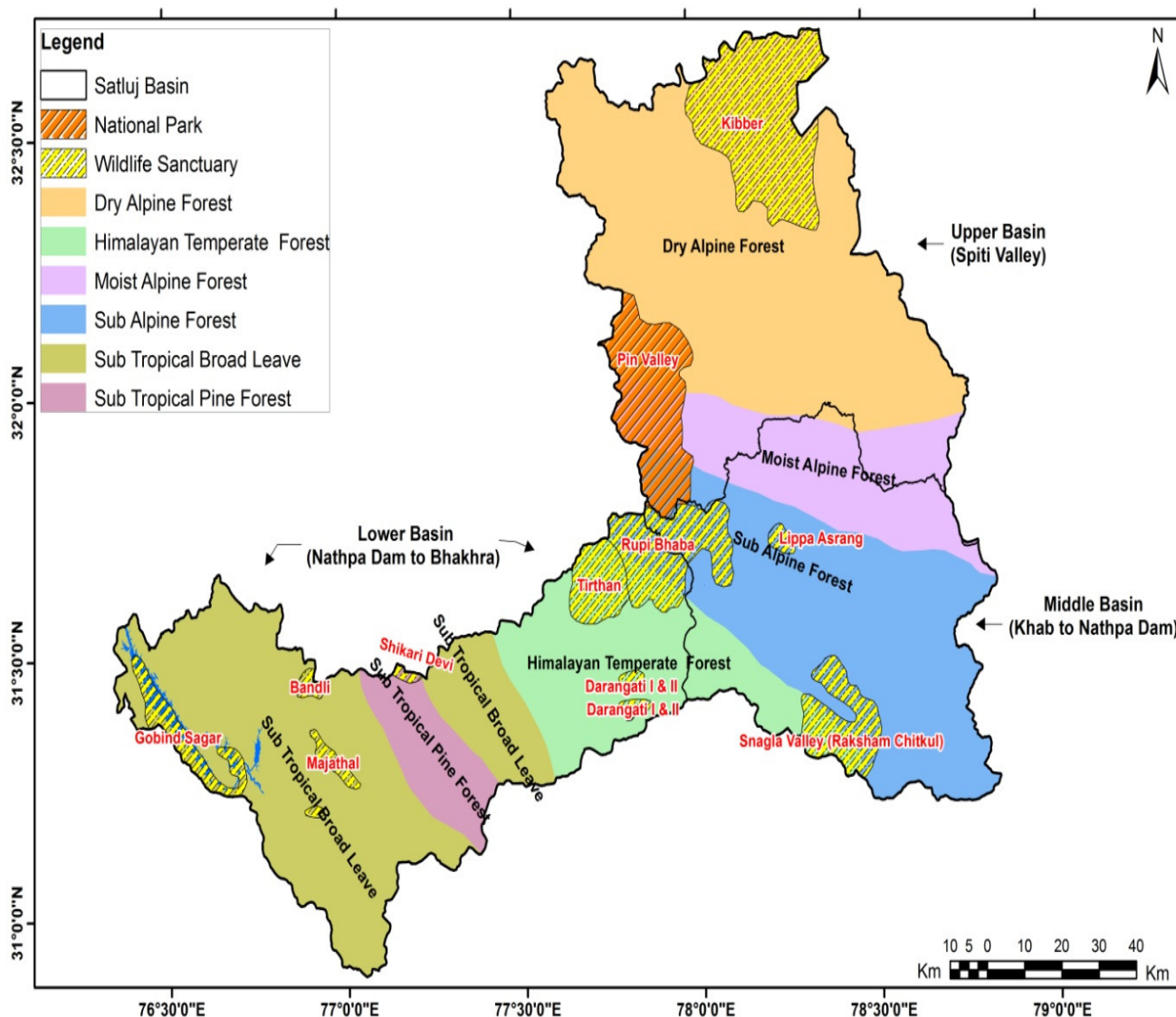


Figure-7
 Forest Map of Study Area¹⁶

Fauna: There are also the variations in fauna in the Satluj basin. The fauna of the upper basin of cold desert is of special concern; as most of them wildlife is reported in this part of the region. In Satluj Basin, the large variation in carnivores of endangered species such as Snow Leopard, Black Bear, Woolly Hair Wolf, Brown and Black Bear.

The major herbivores in the region are Ibex, Blue Sheep, Yaak, Ghoral, and Yak. In the lower basin Jungle Cat, Wild Boar, Bengal Fox, and Indian Porcupine are the major fauna. This river basin has 2 National Parks and 32 wildlife sanctuaries.

Demographic Characteristics: On the basis of geography of study area, it is divided into two parts. One is Tribal area and the second one is the Non-tribal area. The tribal area such as Spiti and Kinnaur are mainly engaged in agriculture and horticulture sector. The roofs of houses are slanting. For the higher education, maximum people prefer the Shimla and Kullu district. Downstream of Kinnaur to Bhakra non-tribal area is considered. The people mainly involved in the agriculture activities. The houses are constructed with cement and flat roof.

Landuse and Cropping: The land use of the study area is varying according to the altitude. People mainly engaged in agriculture and horticulture sector. The maximum area falls under the snow cover and forest class. The detail land use is in figure 8. The agricultural crops which are sown and harvested mainly include wheat, seed-potato, paddy, maize, barley, pulses,

vegetables, etc. The main horticulture fruits are in the study region is apple, pear, almond, apricot, and dry fruits.

The Kinnaur district is known as for the production of nuts and dry fruits. The potato production is very high in Spiti (adjoining Lahul area)¹⁷. A Seed Multiplication Centre are continually promoting the agriculture and horticulture sector which are situated at Leo later converted into Millet Research Station, Vegetable Seed Farms at Ribba, Barang and Kalpa, Dry Fruit Research Station at Bokta, Keylong, the Grapes Research Station at Sharboo and Thiro, Progeny Orchards at Ribba, Kilba and Nichar and Fruit Plant Nurseries at Bhaba and Spillo, Bee Keeping Farms at Urni, Bhaba and Kalpa, Sheep breeding Farm at Karcham, a Yak Breeding Farm at Sangla, a Goat breeding Farm at Sangla, Kuth Research Station at Keylong, etc. in the early 1960s and 1970s¹⁷. The agro-climatic conditions though hard, are conducive to the production of off-season vegetables, hops, saffron, black zeera, kuth, pulses, sunflower etc. Chilgoza, medicinal and brewing herbs, and other minor forest produce support the tribal economy¹⁷. The Purbani and Rispa villages which are known for grapes, orchards and the alcohol; distilled from grapes (Angoori). Pooh is famous for vineyards, apricot, almond and grape orchards. The Kalpa, Ribba, Peo, Akpa and Rampur are known for the horticulture producing areas. The Solan is famous for tomato production. Bilaspur area under Satluj catchment is related to the production in the agriculture sector.

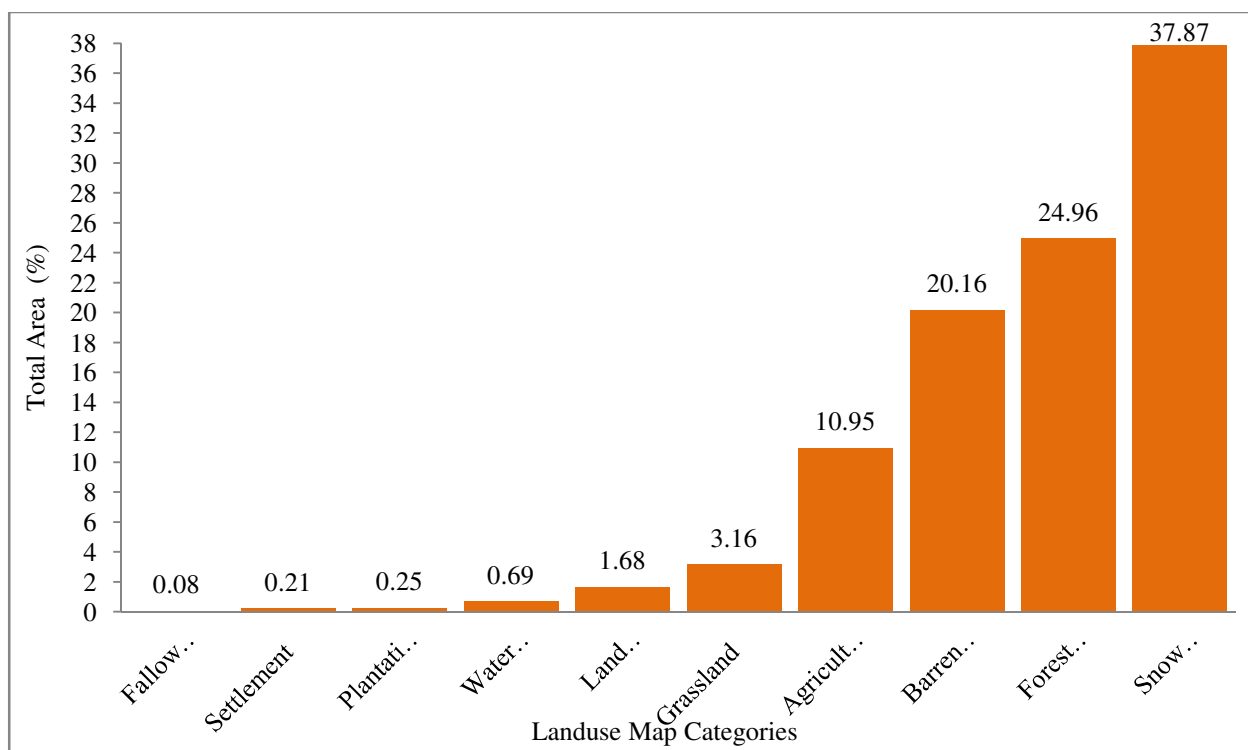


Figure-8
 Landuse type in the study area

Conclusion

River Satluj is the largest river of Himachal Pradesh and 3rd largest of the Himalaya. It has a great variation in the physical characteristics. The availability of a perennial river due to permanent glacier makes this river basin unique from the other basin. The topography of upper Satluj basin is very favorable for the Hydropower Development. This basin is also rich in the herbal plant and rare chilgoza plants. This river basin has maximum glacial which covers the 37.87 area follow by Forest areas 24.96, Barren areas 20.16 and Agricultural land 10.95. Upper basin has more than above 4000 m elevations that increases the velocity of the river and sometime become the reason of flash flood. The lower basin has 1000 to 3000 m elevation and surrounding Gobindsagar Lake has 600m elevation. The overall Satluj basin is rich in the developmental activities of hydropower development.

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