HYDROLOGICAL DYNAMICS AND HYDROELECTRIC PROJECTS IN INDIAN HIMALAYAS: A CASE STUDY OF EAST HIMACHAL PRADESH

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Abstract

Hydrological dynamics in upslope and downslope region of HEPs describes the attributes related with water flow in an area. It is known fact that these linkages are complex in nature because of extremely high altitude nature of young and dynamic geology of Himalayas, extreme seasonal and spatial change in the rainfall pattern and diverse anthropogenic activities. As the Himalayan water output is in the form of one of the major running surface water source of the land, the River Sutlej along with its other tributaries is affecting the hydrological balance in Indian Himalayan region. The upstream portion of the river comprises all traits of Youth River equipped with high surface runoff due to high slope and high gradient in the river basin where with the dam placement, river flow density subsequently tends towards low and another form of water impacts can be seen in the downstream portion as well. Being the most important river of the region it carries most of the water which flows through the respective ecosystem. The findings and observations during the ground zero visit and secondary data analysis has underlined some of the responsible factors which have drawn last unit impact on the regional hydrological balance and well-being of the region.

Keywords: Hydrological dynamics, hydroelectric projects, surface runoff, river flow density and downstream flow dynamics.

Introduction

The process of understanding the Upstream-downstream linkages is an important base for integrated land and water management and planning in the upper Satluj river basin. It is especially in critical form due to high

altitudinal differences, where climatic conditions depends on geological setup very much which further differentiate the upstream and downstream in the river basin. However, understanding these linkages is a challenge and this is especially true in the Himalayan region, where a large region and widely glaciated in the upstream region (Erikson et al, 2009). Assessments of upstream-downstream relationship in Satluj River's hydrological sphere are very important in the field of water resource planning as per the regional energy requirements. Although there have been some investigative studies on this relationship of the Himalayan region rivers but still there is requirement of much specific explanations. Mazari and Sah (2005) drew attention towards a need of defined policy for site selection of hydropower projects and creation of its related infrastructures.

The hydrological setup in the region is been categorized in the terms of river system and available major and minor surface water sources such as dams and reservoirs, which constitutes as well as bifurcates the long and intense river systems into two major parts, one in the form of upstream and another in the form of downstream hydrological tract, simultaneously. The hydro power projects have been constructed with intention to harness energy for meeting energy demand by expanding industries and to reduce risks associated with frequent floods but still there are many negative implications with their construction. These huge structures alter river ecosystems to a great extent. HEPs stand as a barrier to the upstream-downstream movement of nutrients and organisms which affects physical and biological exchange scenario.

Study Area

Kinnaur district is one of the administrative districts situated in the eastern most part of Himachal Pradesh, an entirely mountainous district. The district extends between 31° 06' N and 32° 06' N latitudes and 77° 45' E and 79° 00' E longitudes, according to Survey of India degree-sheet nos. 53I, 53E and 52L. Total geographical area of the district is about 6401 sq. km covering 11.5 per cent of geographical area of Himachal Pradesh. It is bounded by Lahaul and Spiti district in the north, Kullu district in the northwest, Shimla district in the southwest, Uttarakhand in the south and shares international border with China (Tibet) in the east. Nichar, Kapla, Sangla, Pooh and Moorang are the five tehsils along with one sub-tehsil namely Hangrang.

The districts headquarter; Rekong-Peo town comes under administrative jurisdiction of Kalpa tehsil. Kinnaur is accessible through treacherous motor able road from district Shimla via Rampur. The lifeline of the district is NH-22, which was once called as Hidostan-Tibat Border road. Lofty snow laden mountain peaks with scenic beauty of mighty Himalayas are some specific characteristics of the district.

In past few years Kinnaur has emerged as prominent tourist destination. Leisure time can be well spent in popular tourist hotspots such as Kalpa, Sangla valley, Hangrang valley and others. Perennial and fast flowing Satluj can be considered as lifeline of Kinnaur.

Database and Methodology

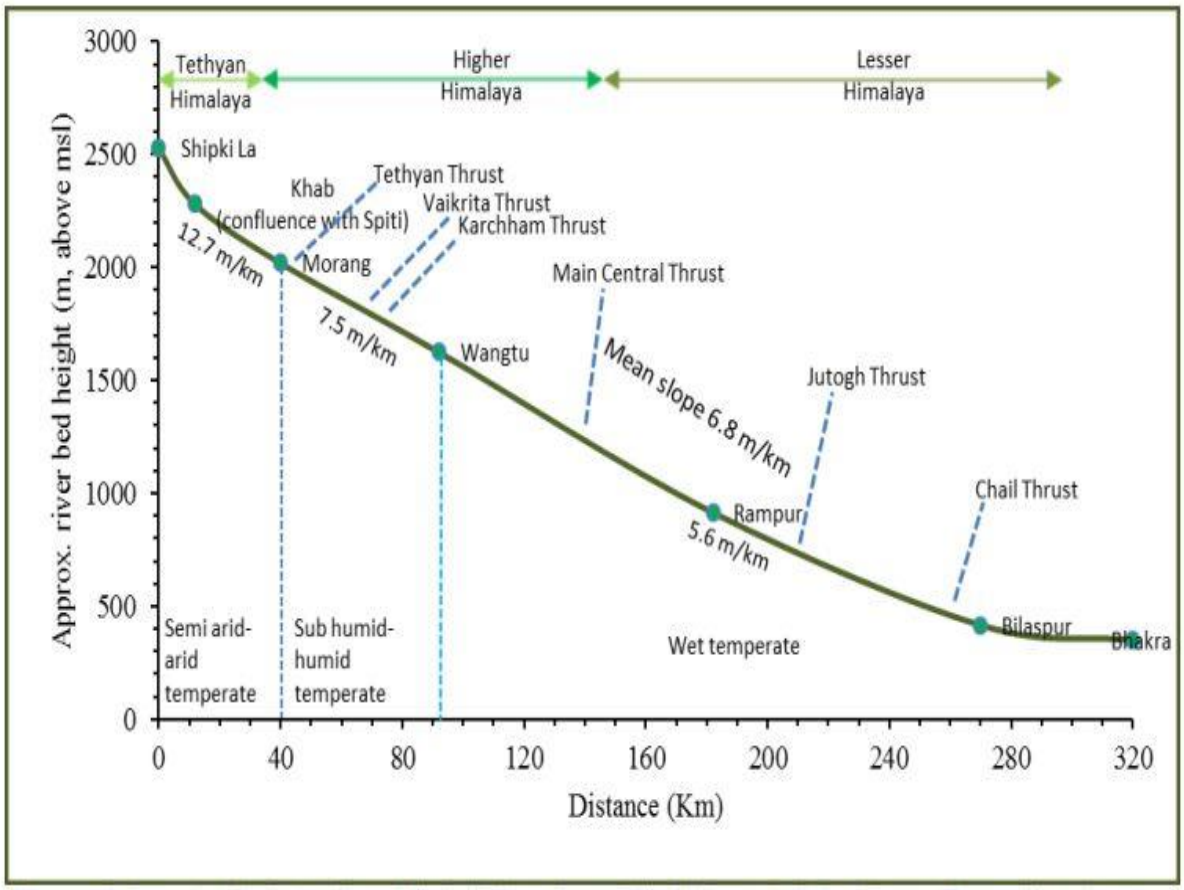
The study comprises of several data sources which include Survey of India topographical sheets, various maps from Geological Survey of India, datasets from Census of India, pertinent articles and reports published from temporal basis by both government and non-government agencies. Indian Remote Sensing (IRS) satellites under National Remote Sensing Agency (NRSA), Hyderabad and Landsat TM and ETM imageries through Global Land Cover Facility (GLCF) along with GLOVIS (USGS) were utilized for analyzing and understanding the slope dynamics context of hydroelectric projects.

Database regarding status of ongoing and proposed hydro power projects was assessed from MOP (Ministry of Power) and NHPC (National hydro power corporation) websites and published reports. Detail Project Report (DPR) and Project Design Document (PDD) from the private hydro developers were further used as a data source for cross verification. The database related to major rivers and tributaries such as water flow, total water discharge, net flow was collected from Central Water Commission (CWC) and other concern departments whereas the Public Health and Engineering Department provided the data related to river discharge and water quality. Indian Meteorological Department (IMD) was concerned for providing database related to climatic parameters.

Result and Discussion

The river Satluj surfaces on southern slopes of Mansarovar Lake near mount Kailash from Rakas Lake as Longcchen Khabab River in Tibet which lies in China, thereafter it crosses the Indian mainland from Himachal Pradesh at Shipki La at the altitude of 6608 meters and flow in the south-western direction through the district Kinnaur. After leaving Kinnaur district it crosses through Shimla, Kullu, Solan, Mandi and Bilaspur district. River Sutlej flows approx. 320 km in Himachal Pradesh. The important tributaries are Spiti, Ropa, Taiti, Kasang, Mulgaon, Yula, Wanger, Throng and Rupi as right bank Tributaries, whereas, Tirung, Gayathing, Baspa, Duling and Soldang are left bank tributaries. Satluj leaves Himachal Pradesh at Bhakhra and enters into the plains of Punjab state, and whole south-eastern part of Pakistan and finally falls in Arabian Sea. Sutlej is the largest among all major rivers of Indus River system (Fig. 1).

Figure 1: Distance and Slope Relationship



Source: Wulf,et.al., 2010

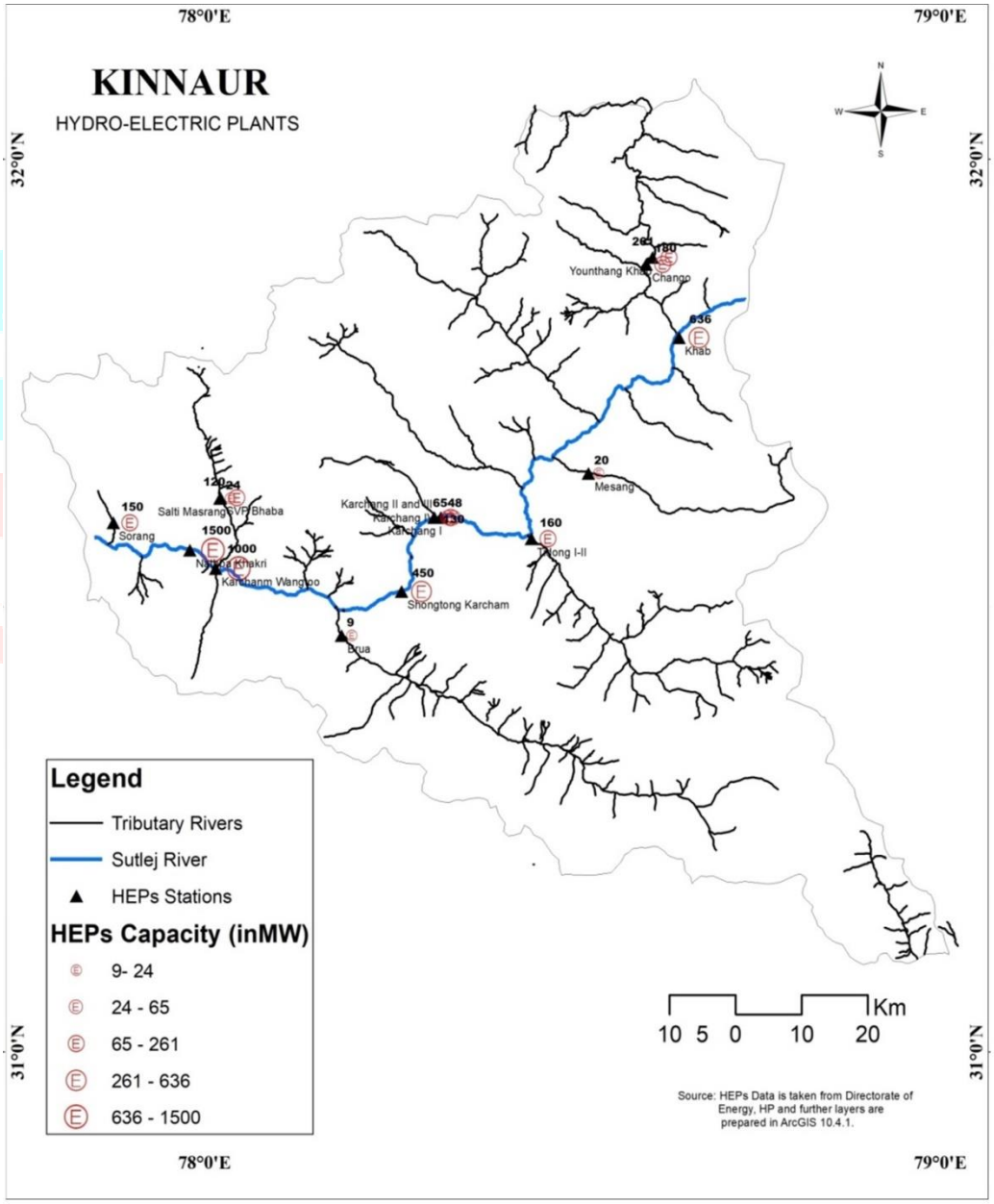
Hydrological Dynamics

Hydro dynamics in the Himalayan region is complex, fast and low in terms of bifurcation ratio. Spatial dynamics of regular flowing streams are calculated based on climatic and morphological features of the respective catchment, integrating a physically based approach that accounts for the record of rainfall with a water balance framework and a geomorphic recession flow analysis.

Ecologically meaningful minimum stage threshold capacity are used to evaluate the connectivity of individual stream which reaches to meeting point and other relevant network-scale connectivity metrics of the river basin. A quantitative description has been provided along with cartographic techniques, especially for hydrological and ecological unfolding and their consequences in terms of water dynamics experienced by the main river and their network in the region.

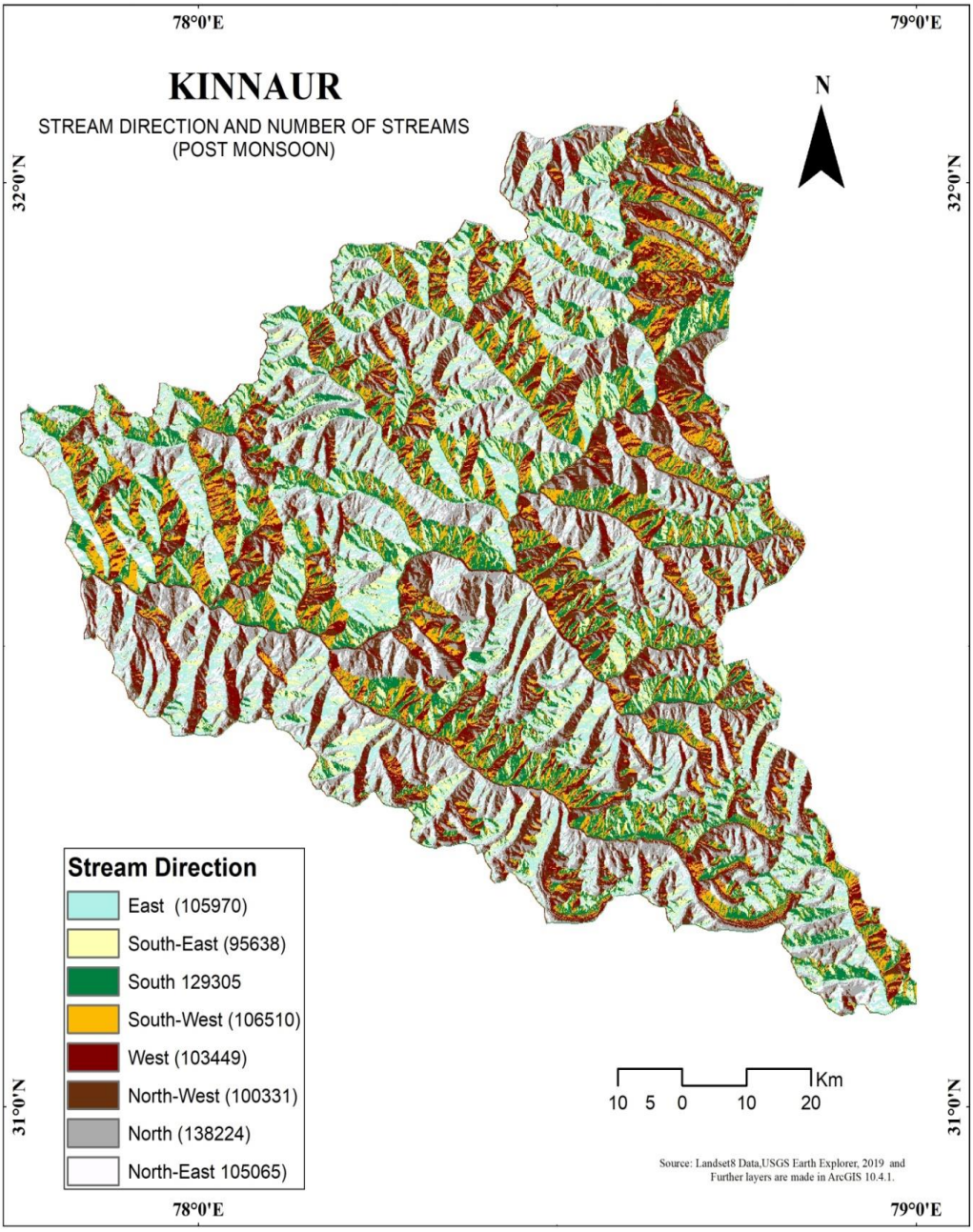
The further assessment and analysis unfold the variation in hydrological connectivity and dependency which get affected by the spatial-temporal distribution of climatic variables depending upon the underlying climatic setting and the critical threshold stage, which results in the loss of connectivity throughout the year and can be observed in the headwaters or along the main river channel, which results in a fragmented river network.

Figure 2: Upstream and Downstream Power projects



Source: Authors

Figure: 3: Post monsoon Flow scenario



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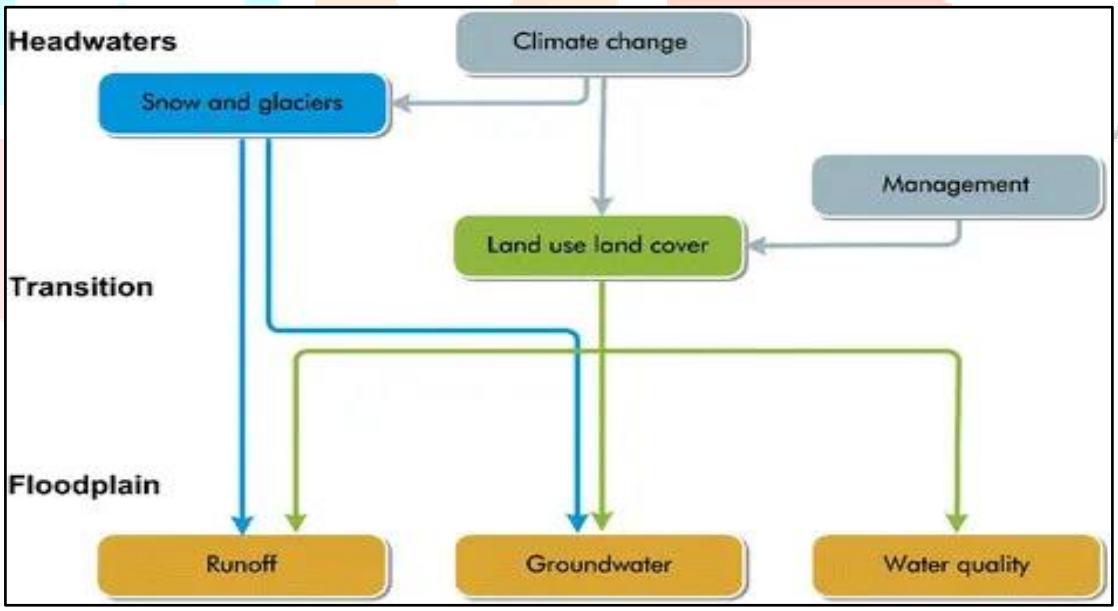
The number of streams flowing in the direction of north is maximum whereas minimum in the south-east, which clearly pictures the availability of water in the region of upstream and downstream where water would be harvested through artificial construction and efforts (Fig. 2). The difference in the number of stream directly affects the regional water resource potential of the flow areas which further affects the total hydroelectric power potential.

Upstream- Downstream Linkages

The term "Upstream" refers to the region or part of the distinct river basin in which river collects its most of the water from its contributing streams and tributaries. The upstream region of some districts in Himachal receives most of the water resources from melting ice sheets situated in the higher Himalaya region and rest of the water requirements are fulfilled from the south eastern monsoon in the rainy season. Upstream also gets its importance from the region of headwater where a river takes off to its early phases and delivers water and sediment output to comparatively lower regions and plains where possibilities of hydroelectric harvesting are present. The river flow area after the HEP is known as "Downstream" which receives comparatively unnatural and controlled flow of water with excess load of waterlogged area which further affects plant, animal and human ecology at different level as altitude changes.

Figure: 4 Components of Upstream-Downstream Linkages- A Schematic Diagram



The concept of isostasy gets into the play and starts affecting the environmental settings of the region with highest degree of threat. The upstream and downstream occurs at different places under different scales and magnitude, which gives birth to various natural and anthropogenic problems which further makes changes in the catchment area at micro scale as well as macro regional river basin level. The physical linkage encircles various activities such as change in land use pattern, fluctuation in run-off generation. But the impact section in the region of downstream is mainly related to environment, where many process takes

place at single point of time at changing spatial and temporal levels. For example Figure 4 shows the inter-relevancy of upstream and downstream dynamics in a river basin like Satluj in the Kinnaur district of Himachal Pradesh.

Plate 1: Confluence of Spiti and Satluj River at Khab, Himachal Pradesh

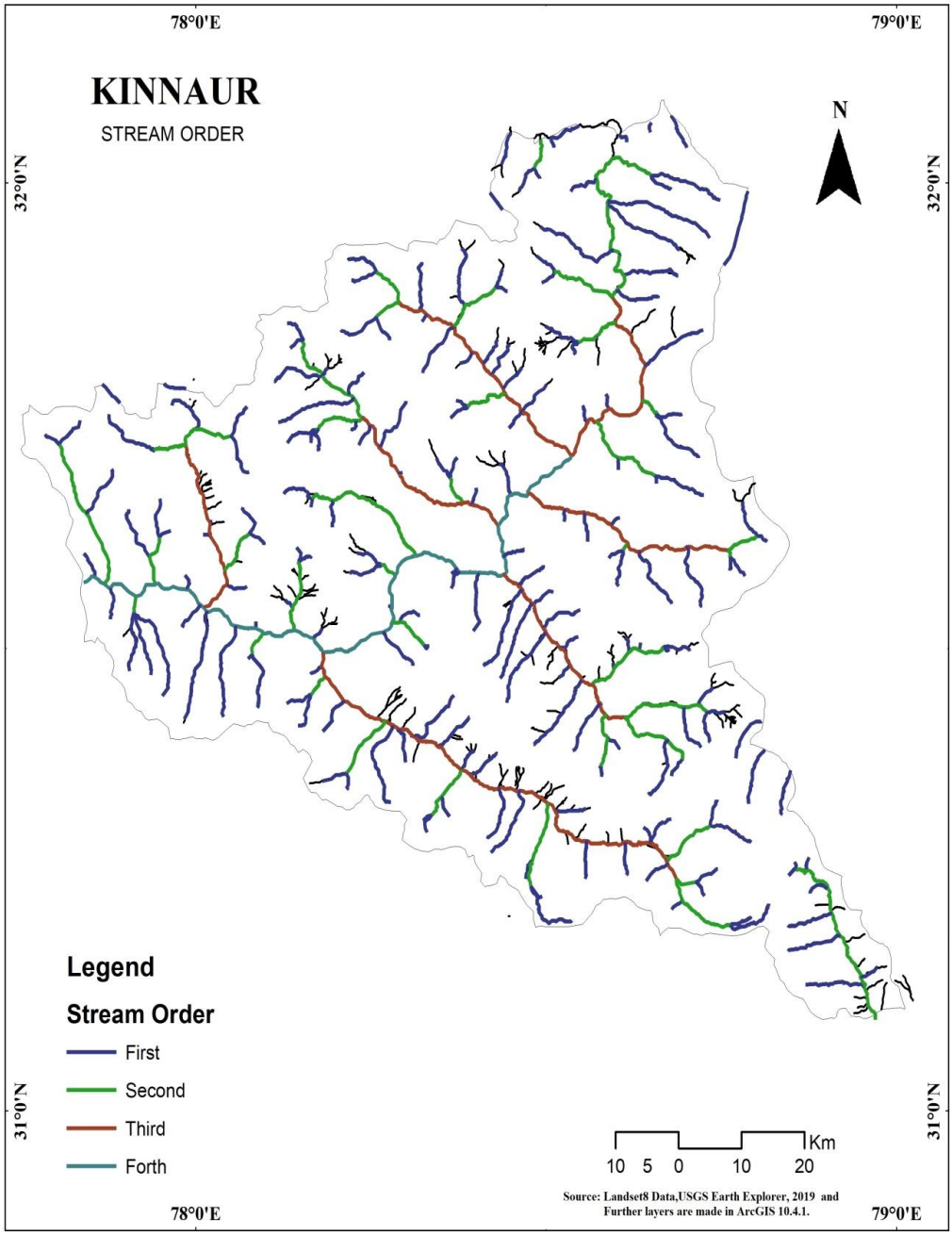
Upstream Flow Dynamics

Upstream-downstream linkages include socio economic, cultural, institutional, environmental factors. Upstream impacts on hydrological processes can be classified into two types, (i) Human-Influenced activities related to land use and agro-activities and (ii) Natural impacts related to climate (Nepal, 2012). Many research studies have underlined the impacts of land use change and indicated towards the potential impacts of further climate effects on hydrological scenario (Chang and Franczyk, 2008). Further when river flows in the upper part of the slope topography till it comes in contact with surface obstacles such as concrete infrastructure establishment it shows high run off and high water density (Plate 1).

River velocity is fast as compared to lower region of river profile. In the Upstream dynamics, river remains to be shallow but with high runoff, the stream order and Bifurcation ratio remains to be high and low respectively which further makes impact on the landscape and ecosystem at large. Being the most important part of Indus river system, river Sutlej plays very vital and important role in defining the upper river basin ecosystem which ends up with the artificial water storage such as Dams.

The river followed by less meandering features allows high river bottom erosion and makes the river deeper as compared to downstream region of river. Upstream also provides base for the dam construction based conditions where access rainfall and high melting processes complexes the water condition and Hydro power generation capacity.

Figure 5: Stream order in Kinnaur



Source: Authors

Downstream Flow Dynamics

River in its downstream matrix, is different in terms of water resource availability where the catchment area revolves around the region where people and the natural cover comprises of mountain ecosystem along with river bank ecosystem where the vegetation cover and agricultural practices depends upon water saturation which further influences in terms of ground water availability and surface water presence. The aerial extension of river also covers different social and cultural backgrounds which are influenced from the different population set which is following excessive carbon alongside the river region. River ecosystem in the downstream direction where the water is being influenced from the local slope, smaller, large dam construction. The downstream direction also gets influenced from the water need and consumption pattern of the respective population base. The stream order scenario can be seen in fig. 5.

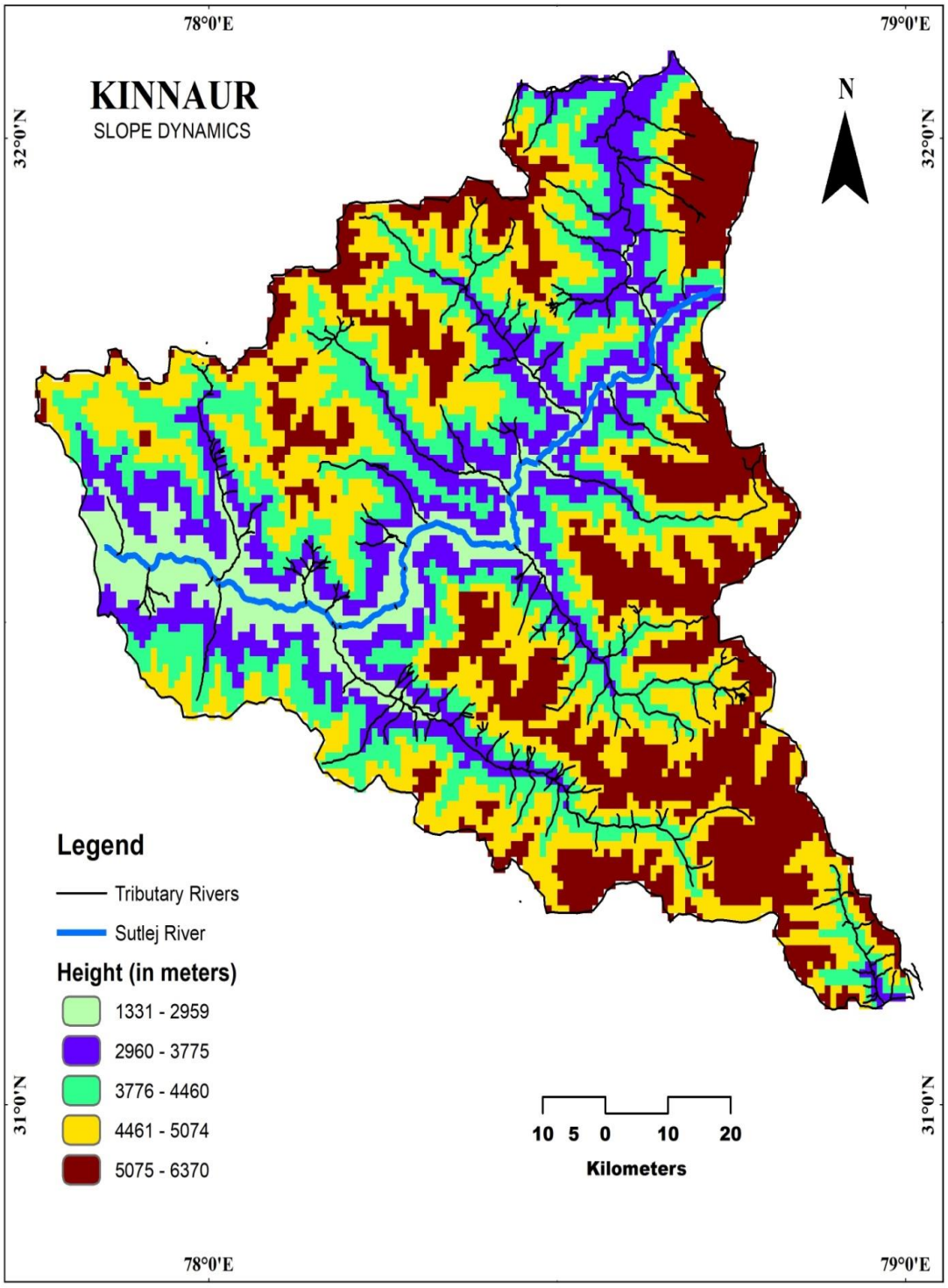
Gravity Profile

River profiling based on gravity in terms of slope analysis of the regional setup of basin area which is equipped from several bank tributaries flowing through different slope areas and showing the level of slope gradient with changes in slope dynamics from the Figure 6. Slope and Height as an important factor, which limits the nature of the river in the process to profiling as per gravity or height which fluctuates between slow and fast as compared from profiling drawn by the river after Roper, from when it enters into the plains. The height also comes into play when construction of gravity dam such as Bhakhra Nangle which uses the water resources and its availability due to changing slope in different region of the districts.

Dams equipped with gravity nature, which act as hurdle in the flow of river, which further affects the ecosystem of respective region at large scale are heavily depends upon the regional and particular slope nature (Workman. 2009). It covers many positive and negative outcomes such as, vegetation loss at large scale due to high slope gradient with high surface runoff and surface velocity of the river followed by flora and fauna loss which comprises endangered and red list spices. River as per change in latitudinal extent, changes its ecosystem implants which further alters the ecological sustainability which is been encircled by the Hydro Electric Power Projects(SANDRP, 2005).

The Hydro Power Projects are one of the major catalysts in changing the basic essence of ecosystem in the region. The gravity profiling and placement also helps in the establishment of new HEPs based on slope dynamics assessment and altitude. Slope dynamics of Kinnaur depicts that elevation varies from approx. 1300 metres and goes beyond 6500 metres in height.

Figure 6: Slope dynamics in Kinnaur



Source: Authors

Thus it is evident that Satluj river has carved the study area deeply. The major V shape valley can be noticed from difference in low and high regions. Baspa and Kashang rivers have also contributed in valley deepening in the study area. The South eastern margin of Kinnaur experiences steep slopes whereas lower regions have moderate slope aspect. North western section also have slope similarities with Chitkul valley in S-E orientation.

Conclusion and Suggestions

The hydroelectric installation activities utilizes hydro resource for generating electricity which otherwise would have been generated through alternate fossil fuel based power plants, thereby contributing to reduction in specific emissions (emissions of pollutant/unit of energy generated) including GHG emissions. Furthermore, as hydro power projects produce no end products in the form of solid waste (ash etc.) during operation, they address the problem of solid waste disposal encountered by most other sources of power. Above explained variables and ecological impacts under river ecosystem has shown enough rigidity and forced which indicates towards the complexity which is about to rise due to excess use of mountain slope at the cost of wildlife and natural vegetation. The mountain ecosystem is at risk due to large economic burden is been established in the form of Hydro-electric Power projects by the government. The planning and suggestions are the current demand to take care the need of the people along with the economic dynamics which is kept changing. All prevailing conditions points towards the need of extensive study to be done in wake to protect the regional resource and ecosystem balance so that nature and human can walk side by side. Based on overall findings, the chapter also summarises the integrated system analysis need at urgent basis to understand the overall complexity of upstream-downstream linkages of hydrological processes and in the context of river basin.

The Integrated Land and Water Resource Management (ILWRM) approach can be into the play dynamics to unfold the solutions of the problems been developed during the stakeholders interconnections in the upstream and downstream dynamics to develop a better and efficient water management of land and its water resources (S. Nepal, 2012). As a part of this, the special conditions in the upstream ecosystem utilizes the water logged effects and put hydrological pressure on the region of downstream, which needs to be addressed via proper and effective planning and management for uninterrupted hydro ecosystem throughout the year and after it.

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