# PLANNING FOR SUSTAINABLE DEVELOPMENT OF ALAKNANDA WATERSHED REGION IN LIGHT OF HUMAN INTERVENTION

## A DISSERTATION

*Submitted in partial fulfillment of the*

*Requirements for the award of the degree*

*Of*

**MASTER OF URBAN AND RURAL PLANNING**

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**JUNE, 2014**

# ABSTRACT

There exists an incessant interaction between man and the environment. In this process of interaction, man has been altering nature through his activities. Factors like population explosion, technical knowhow and changing social and cultural behavior has led to massive increase in the scale of consumption of the natural resources. This in turn is creating disturbance in the equilibrium of the ecosystem. If this rate of consumption of natural resources surpasses its rate of natural regeneration, the system is likely to collapse much before than it would in its natural cycle. The above mentioned issue is even more severe in the case of ecologically sensitive areas like the Garhwal Himalayas. These areas have abundant natural resources but are inherently very fragile ecologically. Exploitation of resources in these areas in an uncontrolled manner is certain to have profound negative impact on the environment. In order to minimize the same, the approach of development has to be sustainable.

The Alaknanda River and its tributaries comprises of a complex ecosystem. Natural resource is abundant in this region. It provides us with perennial water resource, power, fishes, sand, medicinal herbs and so on. This ecosystem also acts as a habitat for a large number and kind of flora and fauna. In the process of development, man has landed up in abusing these resources. The various issues with regard to the same are uncontrolled encroachment in the river bed; rapid population growth and decreasing waste assimilation capacity leading to pollution and health hazards; changing social and cultural values leading to inclination towards urban life which in turn is responsible for increasing migration; dense allocation of hydro power projects which directly affects the river flow as well as the land cover surrounding it; construction of roads across the contours leading to massive soil erosion and triggering landslide in the fragile mountains; massive blasting for road construction and other structures; deposition of sediments in the river bed and so on. Deposition of sediments on the river bed reduces the capacity of hydroelectric projects, decreases irrigation potential, aggravates floods and at times also changes the course of river in the Shivalik Ranges.

The above issues can be minimized or resolved only if a sustainable approach towards planning and development is made.

# Contents

# List of figures

# List of Tables

# CHAPTER 1

## 1 INTRODUCTION

Man derives all its basic needs for survival from the nature. It provides us air to breath in, water to drink, food to eat and land to live in. There exists an incessant interaction between man and the environment. Natural resources or "ecosystem services" like land, water, flora, fauna, sun, rain and wind acts as a "life support system".

In this process of interaction, man has also been altering nature through his activities. In the initial stages of human existence, man interacted directly with the nature in the form of primary activities like agricultural practice, mining, livestock rearing, fisheries and forestry. But with the passage of time, factors like population explosion, technical knowhow and changing social and cultural behavior has led to massive increase in the scale of consumption of the natural resources than before. This in turn is affecting the ecological source and sink and creating disturbance in the equilibrium of the system. If this rate of consumption of natural resources surpasses its rate of natural regeneration, the system is likely to collapse much before than it would in its natural cycle.

In developing countries like India, population pressure followed by migration and urbanization; change in social structure and less technical knowhow has led to utilization of resources in a very exploitative manner. This has resulted in land degradation, deforestation, aggravated resource depletion, increase in pollution and threat to existence of several species.

The above mentioned issues are more severe in the case of ecologically sensitive areas like the Garhwal Himalayas. These areas have abundant natural resources but are inherently very fragile ecologically. Exploitation of resources in these areas in an uncontrolled manner is certain to have profound negative impact on the environment. In order to minimize the same, it is necessary to streamline the process of development in such a way so as to make it sustainable.

### 1.1 Need for study

In the light of the above, an attempt has been made through this dissertation, to study the impact of human activities in the Alaknanda Watershed Region in Uttarakhand. The Alaknanda River and its tributaries comprises of a complex ecosystem. It provides us with a huge resource of water,

power, sand, fishes and so on. This ecosystem also acts as a habitat for a large number and kind of flora and fauna.

In the process of development, man has landed up in abusing these resources. The various issues with regard to the same are uncontrolled encroachment in the river bed; rapid population growth and decreasing waste assimilation capacity leading to pollution and health hazards; changing social and cultural values leading to inclination towards urban life which in turn is responsible for increasing migration; dense allocation of hydro power projects which directly affects the river flow as well as the land cover surrounding it; construction of roads across the contours leading to massive soil erosion and triggering landslide in the fragile mountains; massive blasting for road construction and other structures; deposition of sediments in the river bed and so on. Deposition of sediments on the river bed reduces the capacity of hydroelectric projects, decreases irrigation potential, aggravates floods and at times also changes the course of river in the Shivalik Ranges.

The above issues can be minimized or resolved only if a sustainable approach towards planning and development is made. Current planning practices or allocation of activities are on the basis of administrative boundaries but in naturally eco-sensitive areas dominated by fragile young mountains and high drainage density needs a more practical and applicable area demarcation. This delineation can be done on the basis of natural boundaries like watersheds.

## 1.2 Aim and Objective

### 1.2.1 Aim of the study

The aim of the study is to analyze the effects of human intervention and optimize the same by formulating guidelines for sustainable development in upper Ganga watershed of Uttarakhand State.

### 1.2.2 Objectives

The objectives of the study are -

- To review the concept of Sustainable Development.
- To identify and assess the indicators of human intervention in the study area.
- To assess the sensitivity of the natural setting of the study area.

- To address the issues pertaining to activities which area influencing the sustainability of the area.

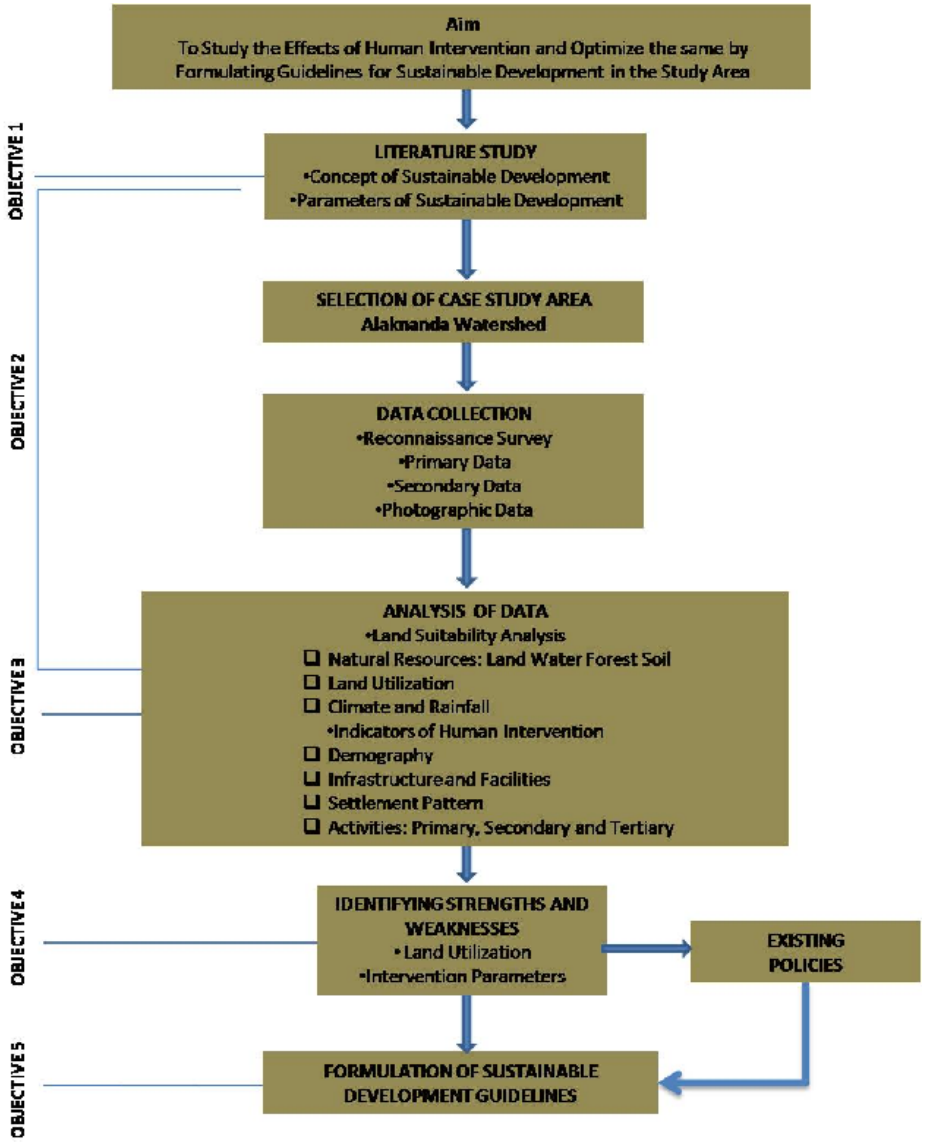
- To evolve a set of guidelines for sustainable development in the study area.

The study conducted with plausible recommendations and the investigator hopes that if the recommendations are implemented in time, sustainable development is anticipated in the System.

## 1.3 Methodology

The methodology of the study has been shown in Fig 1.

Figure 1: Methodology



The methodology initiates with realizing the need for study and undertaking literature search to understand the concept of sustainable development and identify and assess the indicators of human intervention. This is followed by data collection for the case study area and analyzing the land suitability and the indicators of human intervention. Next, the strength and weaknesses of land utilization and intervening parameters are identified. Based on the same, sustainable development guidelines have been formulated.

## 1.4 Scope and Limitation

The scope of the study is limited to watershed region in the Alaknanda River watershed. The findings of the study are subject to availability of required data and time constraint.

# CHAPTER 2

## 2 LITERATURE REVIEW

This chapter aims in defining the key terms and concepts related to the study, followed by research methodologies and relevant existing acts and policies, respectively.

### 2.1 Key Concepts and Definitions

#### 2.1.1 Watershed Region

According to Central Ground Water Board (CGWB), "The watersheds are natural hydrological entities that cover a specific aerial expanse of land surface from which the rainfall runoff flows to a defined drain, channel, stream or river at any particular point."

Watershed is defined as a hydrological unit spread over the land surface from where water accumulated through precipitation flows downwards through a common outlet owing to its position in an elevated area composed of ridges and raised points.

Watersheds are of different shapes and sizes. A unit watershed is made up of several sub watersheds. While watersheds are spread over large area in the plains, its spatial coverage in mountainous region is relatively smaller. There is a continuous interaction between the abiotic components (land, water, temperature, humidity, atmosphere, soil, rain, wind, altitude) and the biotic components comprising of human beings, flora, fauna and other living organisms. As per Wani et al.2008, watershed is a "socio- political-ecological entity".

Watersheds differ from one another in terms of its living and non-living components and the type of interaction between them. Human beings' residing in a watershed region also gets closely associated with its environment. He is dependent on the ecosystem to meet his needs.

#### 2.1.2 Watershed Management

In order to meet his needs, human beings undertake certain activities which have a profound influence on the watershed ecosystem. In some cases, local communities adapt themselves to the nature of the watershed ecosystem. They are usually "self-contained" and streamline their

livelihood as per the watershed ecology. These communities were predominant before the advent of technology.

But with the passage of time, the social structure and behavior of man have undergone changes. They have undertaken activities which have been affecting the environment negatively. Some of these activities are road building, illegal construction along river beds, tourism, shift from primary to secondary and tertiary activities, negligence of local indigenous knowledge, building of dams and promoting of large hydro power projects. These activities have resulted in degradation of forests, drying up of water stretches, and destabilization of landforms, excessive soil erosion, change in natural water course, landslides, pollution, low agricultural activity, extinction of species and climate change.

This realization has given birth to the concept of watershed management. Broadly speaking, watershed management involves wise use and conservation of natural resources like land, water and soil, minimizing the impacts of natural hazards, utilization of resources as per its capacity, conservation and preservation of the biodiversity, improving the productivity of natural resources, improving the socio economic condition of the people and encouraging community participation for the management of watersheds.

As per a review on Watershed Management by FAO, "Watershed management is the implementation of management systems that ensure the preservation, conservation and sustainable use of all land resources".

### 2.1.3 Concept of Sustainability

The adopted definition of sustainable development is that 'meets the need of the present generation without compromising the needs of future generations' (Brundtland Commission 1987) by UN.

As per World Bank's definition, "any development project should not exceed the regenerative capacity of the environment i.e., the capital of natural resources should not be spent. It is only the cyclic, renewable, additionally accrued natural wealth that should be spent or utilized."

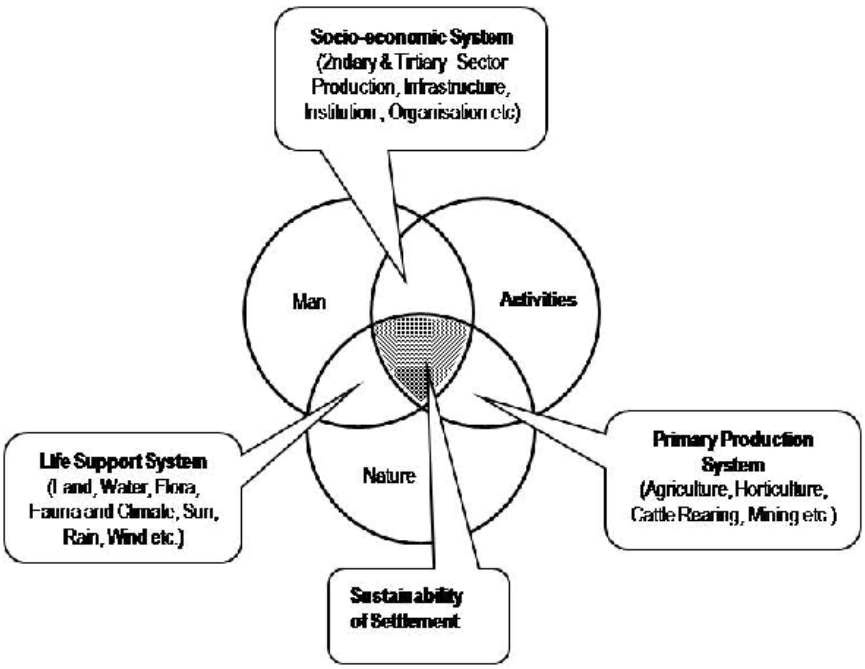
The concern of the present generation is to check that they do not "overuse, misuse or abuse" the existing resources. They should efficiently use the resources so that future generations do not find it difficult to fulfill their needs.

Sustainable development encompasses three aspects of development namely society, economy and environment. It intends to address the social and economic development along with environmental protection. All these three components are interlinked and interdependent.

Social Development involves enhancing the social well-being of the people. It envisages healthy, educated and productive human resource. Some of the principles underlying social development are "equity, empowerment, participation, social mobility and cultural preservation. Economic development refers to enhancement of economic well-being of the people and intends to improve the quality of life. Broadly speaking, economic development comprises of growth in agricultural and industrial sectors, employment opportunities and capability to fulfill one's household needs. Environmental protection aims in conserving the natural resources and biodiversity of the ecosystem. It intends to ensure that resources are not used beyond their "regenerative capacity" and encourages use of renewable resources.

Man depends on the environment to meet all his needs. Directly, he interacts with the environment in the form of primary activities. Indirectly, he derives his needs from the nature when he gets involved in secondary and tertiary activities. These activities affect the environment. Improper and extreme exploitation of the resources leads to environmental degradation and ecological imbalance which in turn affects the socio-economic development of the people.

Figure 2: Concept of Sustainability




Source:

### 2.1.4 Development

As per Prof.H.B.Singh, development is "the process of enhancement of quality of life through production, provision and utilization of goods and services with people's choice, their safety & security with environmental sustainability".

### 2.1.5 Planning

As per Prof.H.B.Singh, planning is the "process of organizing people and their activities over space and time considering resources and technology to achieve development."

## 2.2 Research Methodologies

### 2.2.1 Geometrics' technology for natural resources management

*Micro watershed characterization and prioritization using Geomatics technology for natural resources management (Binay Kumar, Uday Kumar)*

*INTERNATIONAL JOURNAL OF GEOMATICS AND GEOSCIENCES, Volume 1, No. 4, 2011*

Watershed Management involves watershed delineation to watershed monitoring. The four physical factors that affect a watershed significantly are landuse/landcover, slope, geomorphology and soil. The extent to which land is suitable for development is dependent on both physical and economic factors. The ranking of the different micro watersheds in accordance to the order in which they have to be developed is called watershed prioritization.

#### *2.2.1.1 Suitability Assessment – Weighted Indexing Method*

Saaty's Analytic Hierarchy Process is a method for scaling the weights of parameters. Here, a pair wise comparison matrix of parameters is constructed. The entries in the same indicate the strength with which one element dominates over another. The pair wise comparison of parameters results into the "importance matrix" which is based on a scale of importance intensities.

Table 1: Saaty's Scale of Importance

| Assigned Value | Definition | | Explanation |
|---|---|---|---|
| 1 | Parameters are of equal importance | | Two parameters contribute equally to the objective |
| 3 | Parameter j is of weak importance compared to parameter i | | Experience and Judgment slightly favour parameter i over j |
| 5 | Essential or strong importance of parameter i compared to j | | Experience and Judgment strongly favour parameter i over j |
| 7 | Demonstrated importance | | Criteria i is strongly favoured over j and its dominance is demonstrated in practice |
| 9 | Absolute importance | | The evidence favouring parameter i over j to the highest possible order of affirmation |
| 2,4, 6,8 | Intermediate values between two adjacent judgment | | Judgment is not precise enough to assign values of 1, 3, 5, 7 and 9 |

The importance matrix can be analyzed by Eigen Vector Method or Least Square Method.

a) **Least Square Method:**

This is a method used to determine the line best fit for a model. It is mostly used in regression analysis ad estimation.

b) **Eigen Vector Method:**

In this method the basic input is the pair-wise comparison matrix of n parameters given by the form of

$A = [ a_{ij} ]$, where $i, j = 1, 2, 3, \ldots\ldots\ldots, n$ .. . . . . .(1)

The matrix A has generally the property of reciprocality and also the consistency. This is mathematically,

$a_{ij} = 1/a$ ..... .. . . . . .(2)

and, $a_{ij} = a_{ik} / a_j$ ..... .. . . . . ..... .(3)

Thus, multiplying equa ion (1) with the weighting vector - W of (nx1) size yields

$(A - nI) W = 0$ ..... (4)

Where, I is an identity matrix of (n x n).

The matrix A is judgment matrix and it may not be possible to determine the elements of A accurately to satisfy the property of consistency. Therefore, it is estimated by a set of linear homogenous equations:

$A^* W^* = \lambda_{max} W^*$. . . . . ..... (5)

Where A* is the estimate of A and W* is the corresponding priority vector and max is the largest Eigen value for the matrix A. The equation (3) yields the weightages W which are normalized to 1.

#### 2.2.1.2 Parameters Considered for the Model

The parameters for wasteland development can be gullied land, stony waste, wasteland with or without scrubs and sandy area while the parameters for forest management may be forest blank, scrubs, open forest, dense forest and forest plantation.

#### 2.2.1.3 Assignment of Ranks

After assigning weightages to the parameters, each category of the parameters is assigned rank for assessing the suitability. The categories with higher rank is has higher suitability for development while the ones with lower rank has more limitations.

Following this, a Composite Suitability Index (CSI) is calculated for each composite unit by multiplying weightages with rank of each parameter and summing up the values for all the parameters. The CSI is then divided into classes of different ranges, each class indicating the amount of limitation acceptable. Higher the CSI value, higher is the priority for watershed development.

### 2.2.2 Vulnerability Assessment

As per IPCC, "vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climatic variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity."

Vulnerability Assessment is helpful in formulating developing policies. Livelihood Vulnerability Index is one of the existing methods for assessing vulnerability.

Figure 3: Indicators of vulnerability

| Component | Input | | Output |
|---|---|---|---|
| | **Profile** | **Indicators** | |
| | Climate | Average Temperature<br>Rainfall | 1.Climate Profile |
| Exposure | Demographics | Sex Ratio<br>Population in the age group 0-6<br>Decadal Population Growth<br>Below Poverty Line (BPL) Population | 2. Demographic profile |
| Sensitivity | Ecosystem | Change in forest cover<br>Land use pattern (*Kharif* & *Rabi)*<br>Groundwater extraction | 3. Ecosystem Profile |
| | Agriculture | Crop Production<br>Land Capability<br>Irrigation pattern<br>Ratio of agricultural workers | 4. Agriculture profile |
| Adaptive Capacity | Socio–Economic structure | Livestock population density<br>Literacy rate<br>Access to basic amenities (Drinking water, electricity, *pucca* houses)<br>Biomass Dependency<br>Infrastructure (Educational, Health, Banking and Communication facilities) | 5. Socio-Economic Profile |

Steps to calculate the vulnerability index:

The steps to calculate vulnerability index are as follows-

Step 1: Indicators

- Values for all the indicators are to be standardized for all the districts.
- Indicator Index (Ix) = [Id – I (min)]/[I(max) – I (min)]

Where, Ix = Standardized value for the indicator

Id = Value for the Indicator I for a particular district, d.

I (min) = Minimum Value for the indicator across all the districts

I (max) = Maximum Value for the indicator across all the districts

Step 2: Profiles

- Indicator Index Values are combined to get the values for the profiles.
- Profile (P) = $\sum_{i=1}^{n}$ Indicator Index/n

Where, n = Number of indicators in the profile

Indicator Index i – Index of the i th indicator.

Step 3: Components

- Values of the profiles under a component are to be combined to get the value for that component.
- Component (C) = $[\sum_{i=1}^{n} W_{Pi} Pi] / [\sum_{i=1}^{n} W_{Pi}]$

Where, $W_{Pi}$ = Weightage of Profile i

- Weightage of the profile will depend on the number of indicators under it such that within a profile each indicator has equal Weightage.

Step 4: Vulnerability Index

- The combination of the values of the three components will give the vulnerability index.
- Vulnerability Index = (Exposure – Adaptive Capacity) * Sensitivity
- Scaling is done from -1 to +1 indicating low to high vulnerability.

## 2.3 Existing Policies

### 2.3.1 The Environment (Protection) Act, 1986

It was introduced in the year 1986. This is an Act to "Provide for the Protection and Improvement of Environment and for Matters Connected therewith". By "environment", the Act means the water, air and land and their inter-relationship with human beings and other living creatures.

In brief, it addresses the need to examine causes of environmental pollution and prevent and minimize the same, preparation of standards for quality of environment, regulation of industrial activities and handling of hazardous substances

### 2.3.2 Environment Impact Assessment

As per MoEF, Govt. of India, EIA is a "management tool for ensuring optimal use of natural resources for sustainable development. The sectors for which environment committee has been set up include projects related to mining; industries; thermal power; river valley, multipurpose, irrigation and hydro power; infrastructure and miscellaneous; and nuclear power projects. As a part of EIA, the projects are appraised by the Environmental Appraisal Committees and approved or rejected. For site specific projects like mining and river valley projects, site clearance is sought from the concerned authorities along with environmental clearance. Site Clearance is sought to check that the site selected is not ecologically fragile and environmentally sensitive. Following this, it is ensured that the project implementation takes into consideration the stipulated environmental safeguards. MoEF has also been sponsoring for Carrying Capacity Studies for different regions.

### 2.3.3 Forest (Conservation) Rules, 2003

These rules deal with the use of forest land for any non forest purpose. The Advisory Committee is directed under these rules to verify if the proposed forest land is a part of natural reserve, biosphere reserve or habitat of any endangered flora and fauna. It also examines the purpose for which the use of forest land is proposed such as for agricultural or for rehabilitation of persons displaced due to river valley or hydro power projects. It also inspects the existence of alternative sites other than the forest land.

### 2.3.4 The Wildlife (Protection) Act (1972)

This Act provides for the "the protection of [wild animals, birds and plants] and for matters connected therewith or ancillary or incidental thereto". In short, it deals with restrictions and prohibition of hunting and picking or uprooting of specified plant; declaration of sanctuary, national parks, game reserves and closed area; and prohibition of trade or commerce in wild animals and animal articles.

### 2.3.5 Drought Prone Area Program (DPAP)

This program has been introduced to minimize the impact of drought on agricultural productivity; livestock productivity and land, water and human resources productivity. The program also intends to uplift the socio economic condition of the poor living in the program areas.

### 2.3.6 National Watershed Development Project for Rainfed Areas (NWDPRA)

National Watershed Development Project for Rain fed Areas (NWDPRA) was launched in 1990-91 in 25 States and 2 Union Territories. The main objective of the scheme is as under conservation, development and sustainable management of natural resources; enhancement of agricultural production and productivity in a sustainable manner; restoration of ecological balance in the degraded and fragile rain fed ecosystems; reduction in regional disparity between irrigated and rain fed areas and; creation of sustained employment opportunities for the rural community including the landless.

### 2.3.7 Integrated Wasteland Development Program

This scheme is under implementation since 1989-90, and has come to this Department along with the National Wastelands Development Board. The basic objective of this scheme is an integrated wastelands development based on village/micro watershed plans.

The major activities taken up under the scheme are in situ soil and moisture conservation; planting and sowing of multi-purpose trees; promoting natural regeneration; promotion of agro-forestry & horticulture; wood substitution and fuel wood conservation measures; encouraging people's participation ;drainage line treatment ;development of small water harvesting structures; and a forestation of degraded forest.

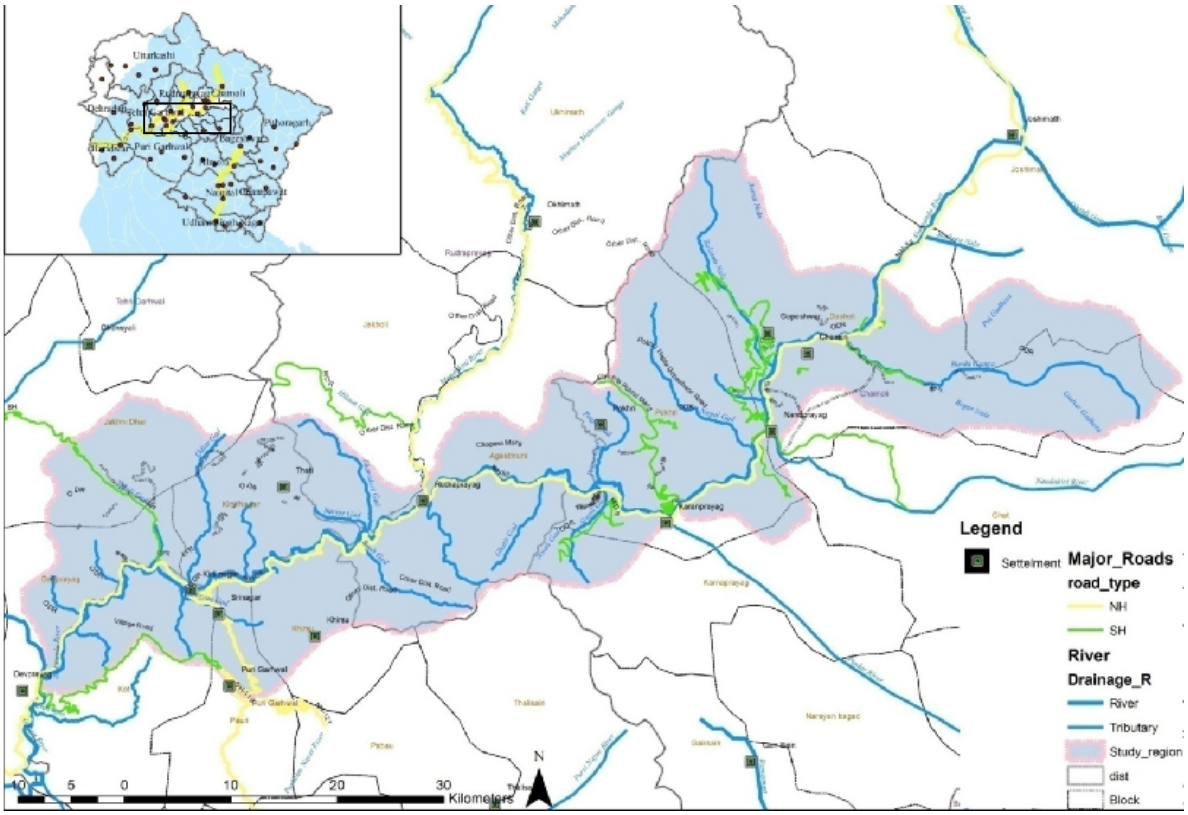
# CHAPTER 3

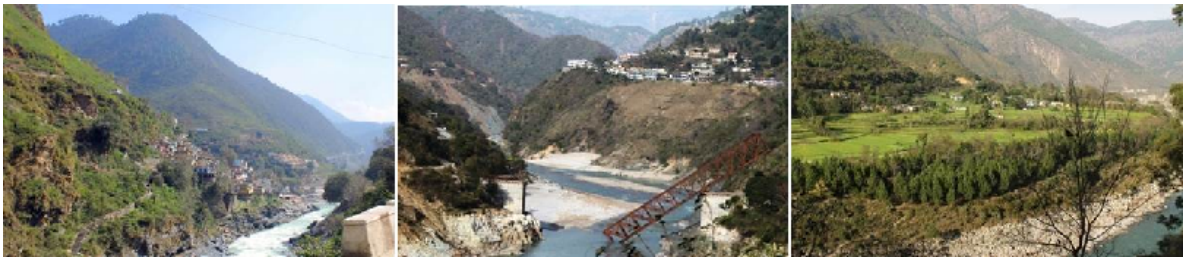
## 3 SELECTION TO THE STUDY AREA

### 3.1 Introduction

The Alaknanda Basin covering an area about 10882 km$^2$, represents the eastern part of the Garhwal Himalaya. 1924.6 sq. km area of this basin has been taken up for this study. This area extends between 30° 08' 28" N to 30° 35' 24" N and 78° 36' 10" E to 79° 43' 11" E. The Alaknanda Basin is characterized by hilly terrain, deep gorges, and river valleys.

Figure 4: Base map of study area

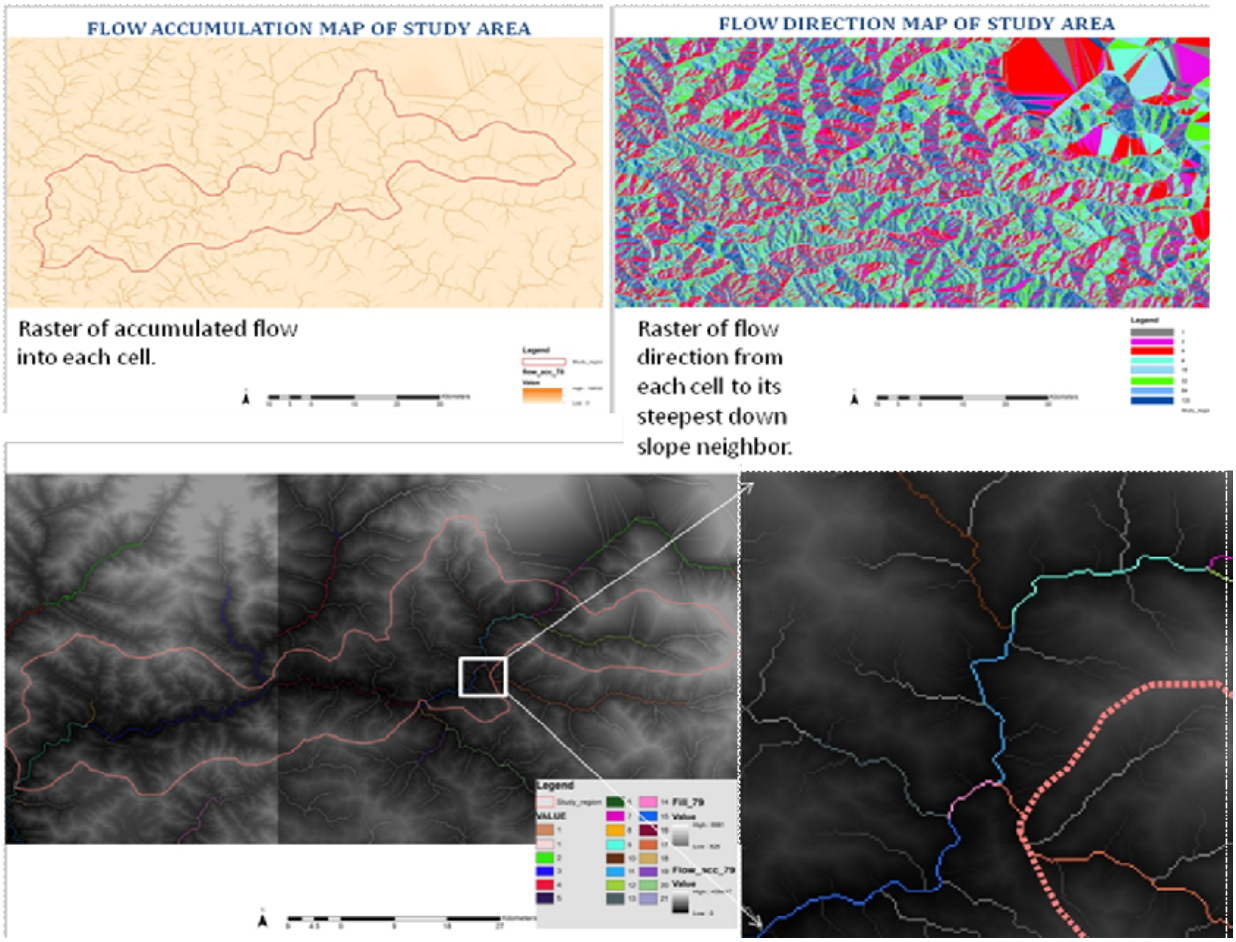


## 3.2 Study Area Delineation

To analyze the physical features of the study area it is needed to acquire SRTM (Shuttle radar topography mission) data provided by landcover.org. It is a kind of raster dataset which contains elevation data for all the pixels. SRTM data has been acquired which is available in two tiles covering the study area. After combining both tile and recalculate values of raster dataset with the help of raster calculator, it is ready for further analysis.

Figure 5: Catchment area delineation process




In order to calculate catchment area or watershed there are various functions have to be performed. This part of analysis is done through Hydrology tool followed by Arc Hydro toolbox. First of all we have to fill sinks in the area. A sink is a cell with an undefined drainage direction; no cells surrounding it are lower. The pour point is the boundary cell with the lowest elevation for the contributing area of a sink. If the sink were filled with water, this is the point where water would pour out. This gives a raster dataset in which sinks has been filled up which is an important dataset

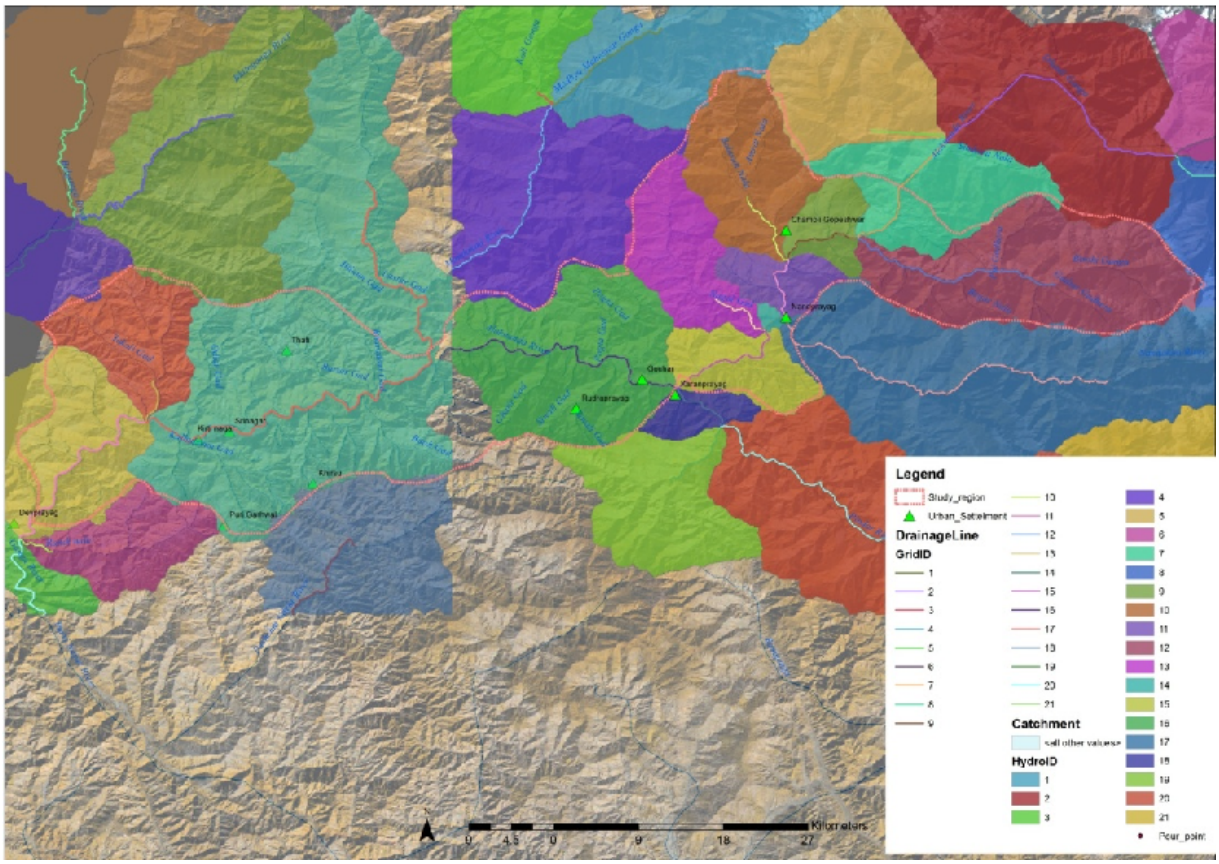
for calculating flow direction and accumulation. Next knowable feature is flow direction on the surface. To perform this there is tool in hydrology toolbox called flow direction and Fill raster is used as a input for the same. It creates a raster of flow direction from each cell to its steepest down slope neighbor. Output raster is same as aspect surface which gives an idea of the direction of slopes. Followed by this flow accumulation has been calculated using flow accumulation tool from Hydrology toolbox using Flow direction raster as an input raster data. Flow accumulation creates a raster of accumulated flow into each cell. So the each cell will have values representing numbers of cells which flows into that cell.

Output gives a raster dataset which contains values for all flow accumulation but in order to find steams and river this raster data set needs to filter values lower than threshold value. Threshold value is pixel value of flow accumulation raster below which streams are not formed. After comparing pixel values with ground reality real stream pixel starting pixel value has been identified. In the study area streams and river on imagery, matching with pixels in accumulation raster are having pixel value more than 12000. So threshold value for the flow accumulation rater threshold value would be 12000. This processing gives us stream grid raster having value 1 for stream and 0 for non-stream pixels. Stream segmentation is another function from arc hydro tools which creates a grid of stream segments that have a unique identification. This unique identification is a field provided by flow direction raster for which all the cells in a particular segment have the same grid code that is specific to that segment. Output grid contains count of pixels for each segment which represent length of the segment in pixels. Segmentation gives an idea of extent for a particular segment of stream so it is possible to calculate upslope area for that particular segment of stream in order to obtain catchment area for each stream. Catchment area is a whole area in which each pixel is having a number regarding its catchment which has been calculated through a function called Catchment grid delineation. Raster dataset in which each cell carries a value (grid code) indicating to which catchment the cell belongs obtain as an output. Flow direction and stream segmentation raster are used as input for the above function. But this is still in raster form which is required to convert in polygons in order to calculate areas, input required data and perform further analysis. This could be done by catchment polygon processing function which takes as input a catchment grid and converts it into a catchment polygon feature class. Drainage lines also need to be converted in vector form. Calculation of drainage line could be done by drainage line processing which gives us line feature which shows streams in the area with shape length.

Table 2: Information regarding Catchment area

| | |
|---|---|
| Total area | 1924.6 Km2 |
| Total length of Alaknanda River Stretch in the study area | 127.8 Kms |
| Elevation range | 420- 5300m Above Sea Level |
| Number of Watershed | 3 |
| Number of Sub-watershed | 35 |
| Number of catchment area obtain from Arc Hydro | 12 |
| Number of watershed by overlaying the above two catchment area maps. | 56 |

Figure 6: Catchment area output with drainage line in vector form



# Chapter 4

## 4 LIFE SUPPORT SYSTEM

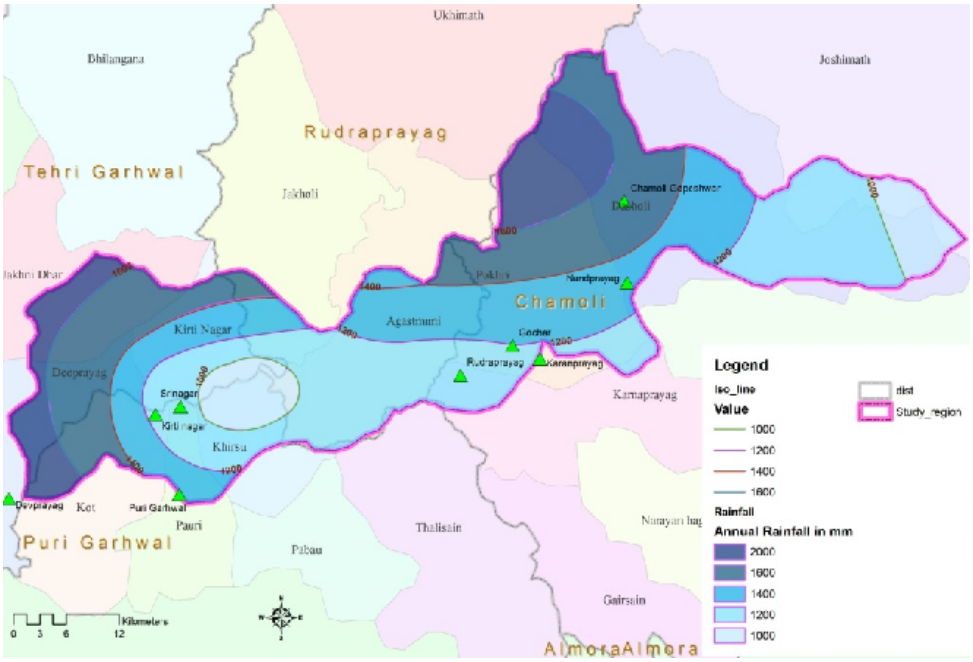
### 4.1 Introduction

This chapter deals with the "Life Support System", i.e., it deals with those components which are essential for life to exist. It includes climate and rainfall; land resource; water resource and forest resource.

### 4.2 Climate and Rainfall

The climatic condition in the study area is diverse in nature. The temperature varies from season to season as well as from highly elevated regions to low lying areas. The highlands are characterized by cold chilly winters while the valley regions are characterized by humid monsoon climate. During winter, heavy snowfall occurs in areas above 2000 m which continues for four months. The temperature remains about 30° average in the low areas lying between Karanprayag and Devprayag.

Figure 7: Annual average Rainfall in mm




The monsoon season spans from June to October. Rainfall mostly occurs during monsoon season from June to October. The average annual rainfall is 125.7 cm. Heavy rainfall occurs in the

highlands. The rainfall also varies from north-facing (leeward) to south-facing (windward) slopes. Highest rainfall has been recorded in Ukhimath (1578 mm and 199.4 cm) followed by Karanprayag (883 mm and 147.1 cm) while lowest rainfall has been recorded in Srinagar (550 mm and 92.5 cm). Joshimath, Karanprayag, Ukhimath, and Srinagar are the places located in leeward direction.

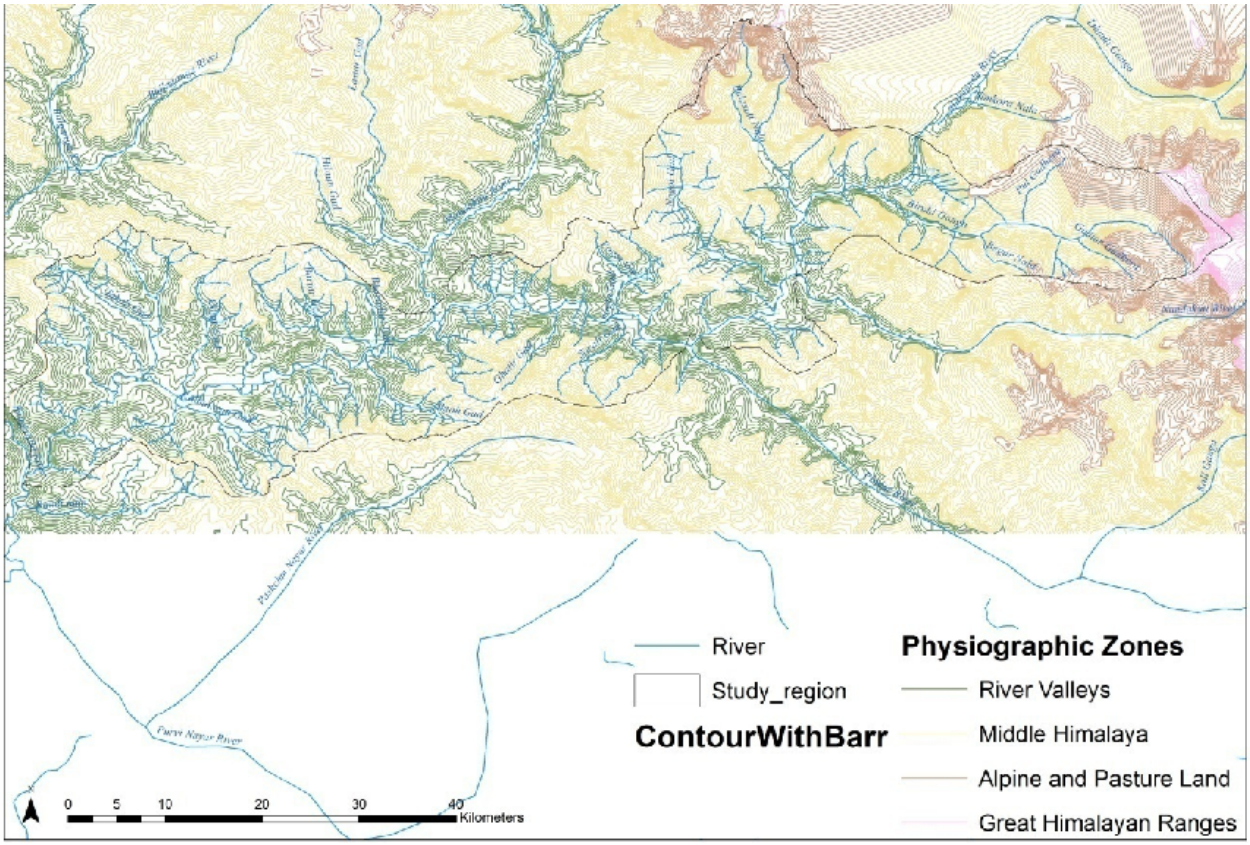
## 4.3 Land

This segment of the report gives information and analysis of physiographic features, soil, land Utilization and sensitivity analysis based on ranking and weightages of above parameters.

### 4.3.1 Physiographic Division

The Alaknanda Basin is characterized by hilly terrain, deep gorges, and river valleys. The region is broadly divided into four major physiographic zones.

Figure 8: Physiographic zones in Study area




The Great Himalayan Ranges: These regions constitute the highest altitude zone. The whole region remains snow covered throughout the year. No development is possible here.

The Alpine and Pasture Land: These are second highest altitudinal area. This region remains snow covered during the four months of year. These areas act as pastures for livestock during the other months. During this period, seasonal crops are grown at some places.

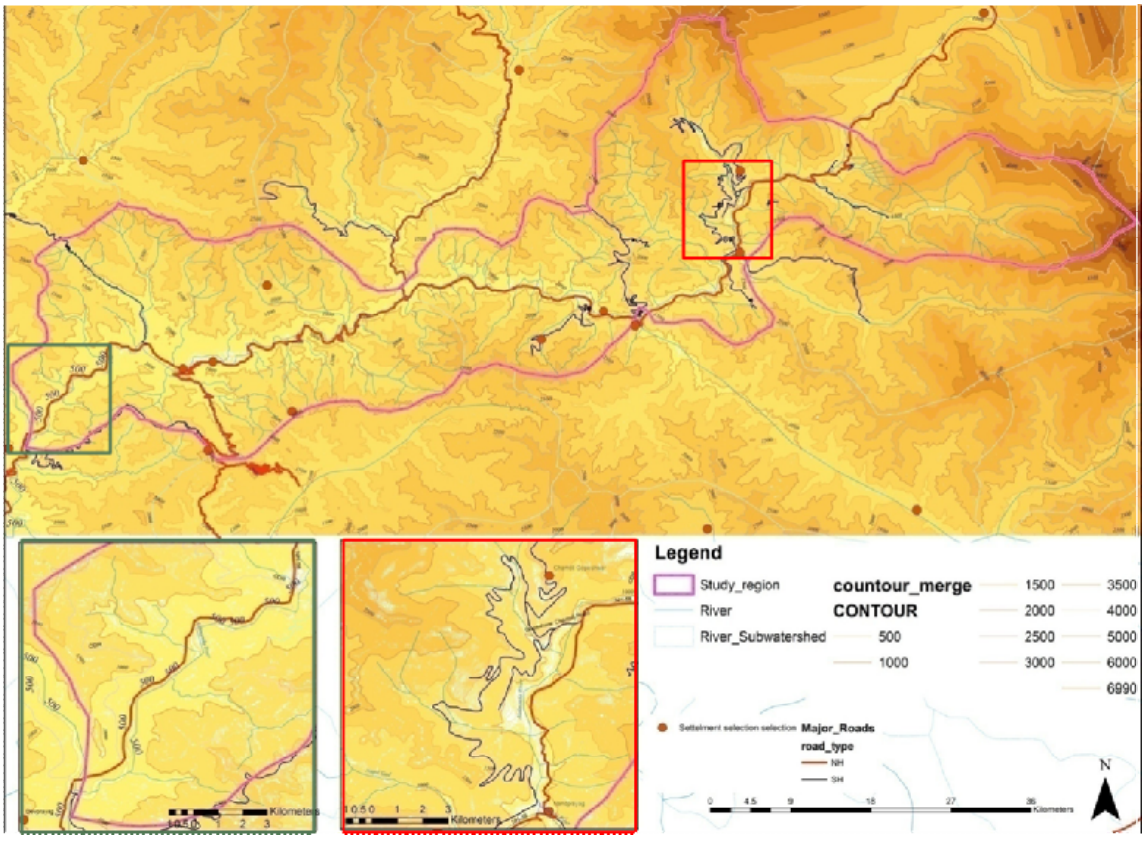
Middle Himalaya: Here, snowfall is replaced by rainfall. These are the regions where large number of settlements is visible. Crops are grown here about 2 to 3 times a year.

River Valleys: This region has a hot and humid climate. The major roads like National and State Highways pass across this region. Dense commercial development is dominant in the river beds.

#### *4.3.1.1 Elevation and Slope*

Elevation varies from 420m to 5300m ASL across the study area. Lower elevations are observed along the river for obvious reasons. Increase in elevation is observed with increasing distance from river. There is a gradual increase in elevation resulting in wide valleys near Gochar and Srinagar in downstream area contrary to upstream where rapid elevation changes form narrow valleys and gorges as can be seen in the inset map of the figure below.

Figure 9: Contour map (500m Interval)



Slope map for the area has been prepared with the help of surface toolbox in GIS. It helps to understand the gradient or change in elevation for unit distance. It can be calculated in either degrees or percentage rise. To carry out development practice or any other activity it is important to study slope of the area in hilly terrain.

Figure 10: Slope map

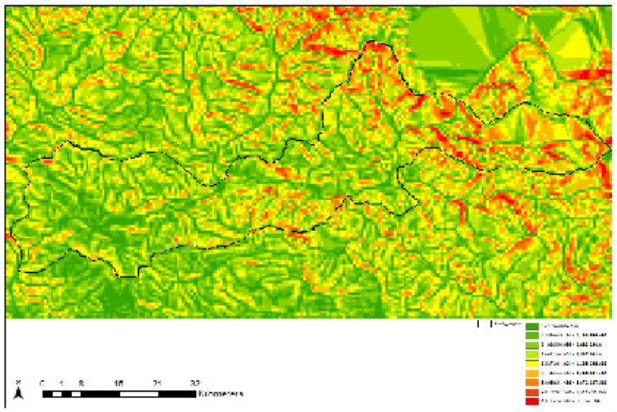
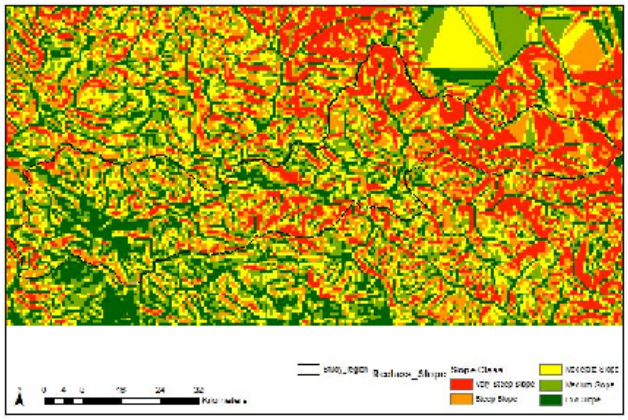
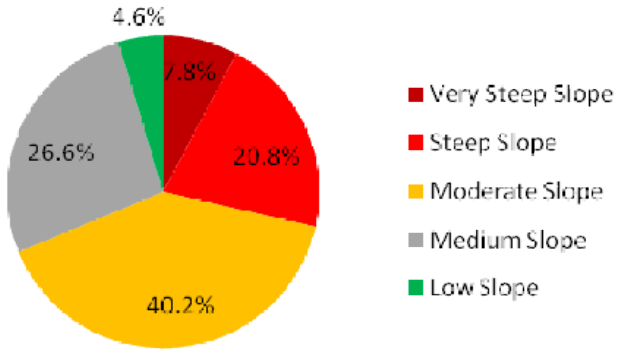


Figure 11: Slope map Reclassified in to five classes



Orange and red colors pixels in map below represent steep and very steep area while yellow and green pixels represent moderate and low slope area. The percentage of area coming under different slope classes is given below. Approx 40% area falls in moderate slope while approx 30% falls in medium and low slope zone. 28.65% of study area is governed by steep to very steep slopes which is scattered in the upper catchment area and along river Alaknanda between Srinagar to Rudraprayag.




| Slope Class | Land percentage |
|---|---|
| Very Steep Slope (more than 40%) | 7.8 |
| Steep Slope (35-40%) | 20.8 |
| Moderate Slope (20-35%) | 40.2 |
| Medium Slope (10-20%) | 26.6 |
| Low Slope (0-10%) | 4.6 |

### 4.3.1.2 Aspect, Hillshade and Tin

The aspect identifies the down slope direction of the maximum rate of change in value from each cell to its neighbors. Aspect can be thought of as the slope direction. It gives information regarding horizontal direction to which mountain slope is facing. Aspect map gives us idea regarding Sun and wind exposures, which makes micro climatic situation in hilly region. The above factors affects vegetation type and cover, temperature, increase in evapotranspiration on southern slopes, snowfall on northern slopes etc.

Figure 12: Aspect map

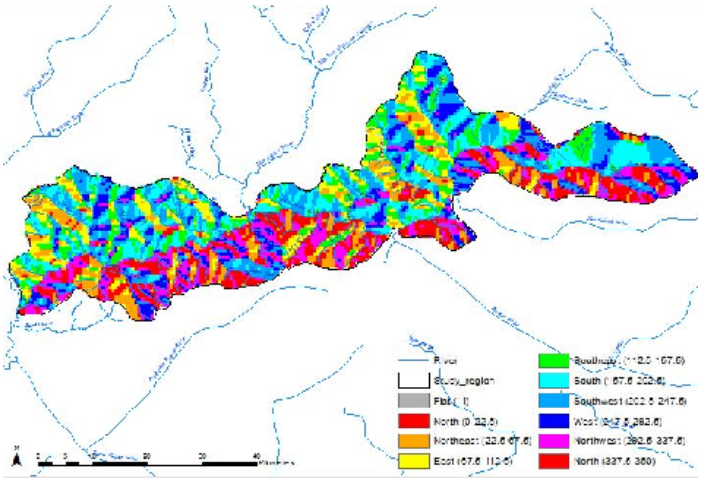
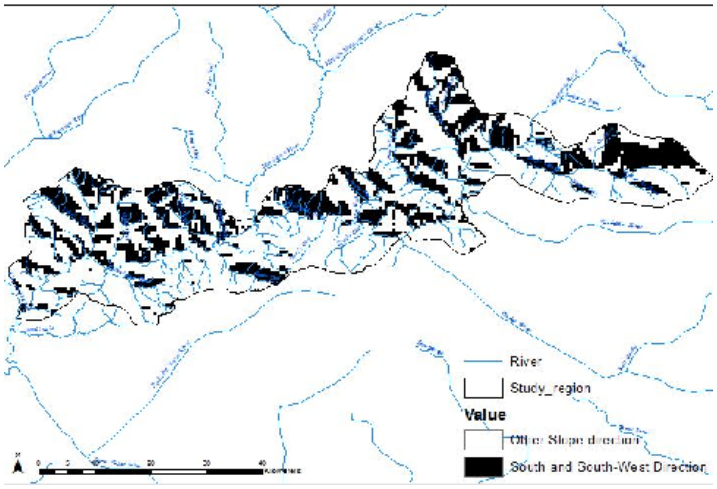


Figure 13: Aspect map Reclassified in to two classes




In aspect map analysis, it is found that 32% area of total study area have south and south west direction surface while 68% comprising all other slope direction; flat, north, northeast, east, southeast, west and northwest. Areas with south-facing slopes being warm, wet, forested and are more suitable for agriculture while areas having north-facing slopes are cold and dry and much more heavily glaciated in upper elevation range.

Hillshade shows the intensity of lighting on a surface given a light source at a particular location; it can model those parts of a surface which are likely to be shadowed by other parts. This information is superimposed with the elevation raster to have a fair idea about the surface formation with the changing elevation.

Figure 14: Hill shade map of the area

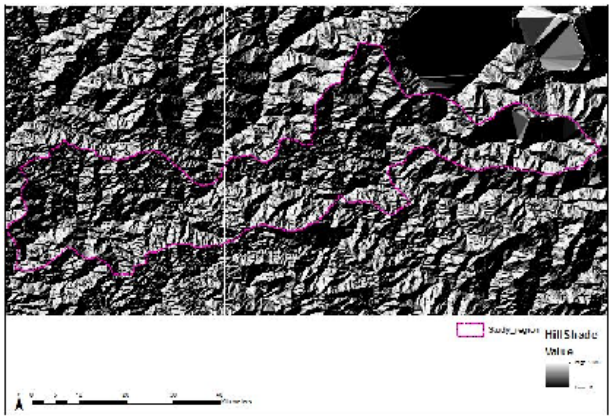


Figure 15: Elevation Raster for the study area

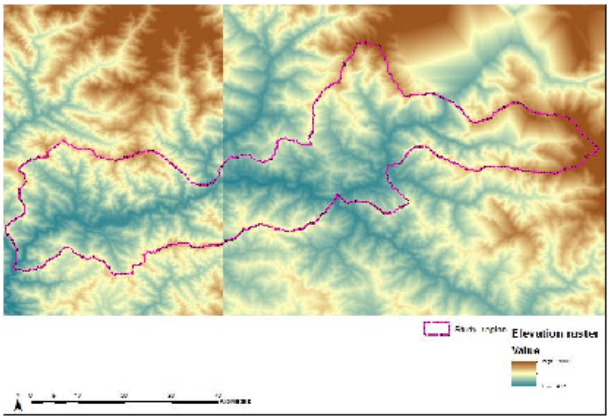
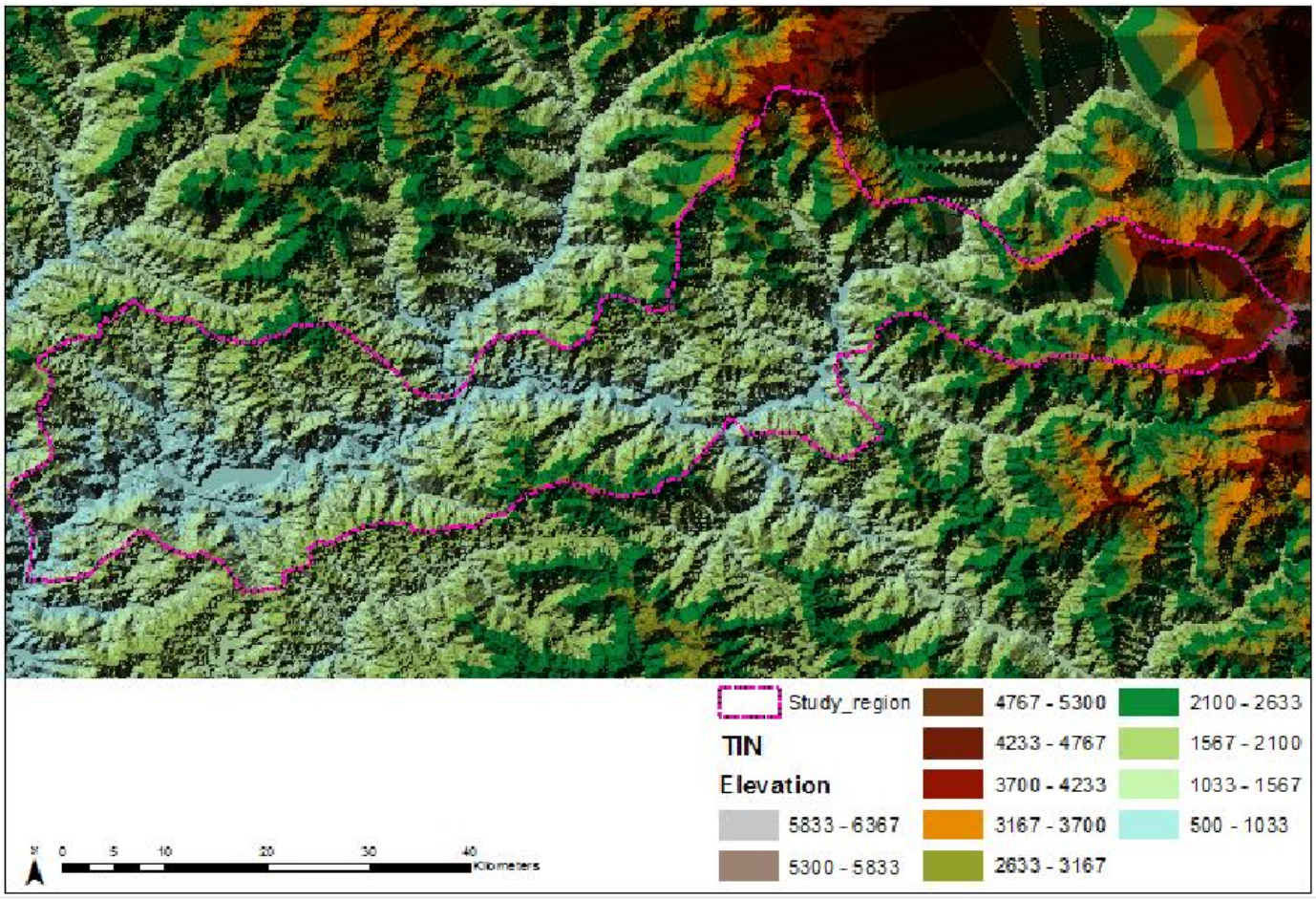
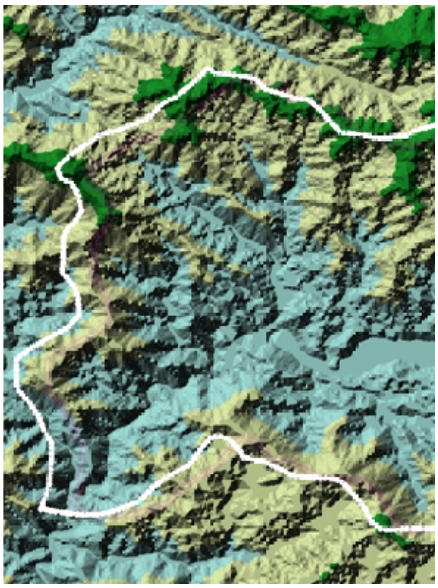


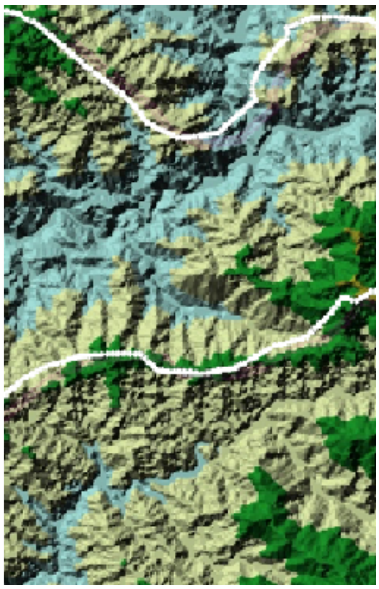
Figure 16: Elevation map superimposed on Hill shade Surface

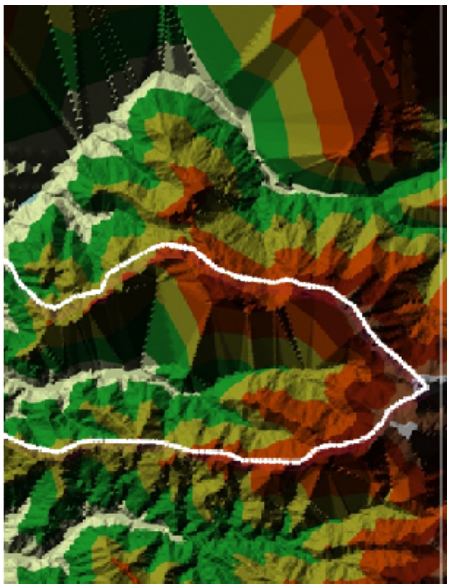
Triangulated Irregular Network (TIN) surface creation is used to create a TIN for a specific area and to add vector features to it from a raster elevation dataset. It also gives picture of land surface of the study area by giving vector form of elevation data with 3D view for the watershed. This generated TIN contains fields regarding elevation, slope and aspect. Advantage of TIN over raster elevation data is that it can create and change the elevation ranges according to requirement of analysis and overlay.

Figure 17: TIN Surface of the study area







### 4.3.2 Soil Resources

#### *4.3.2.1 Soil Types*

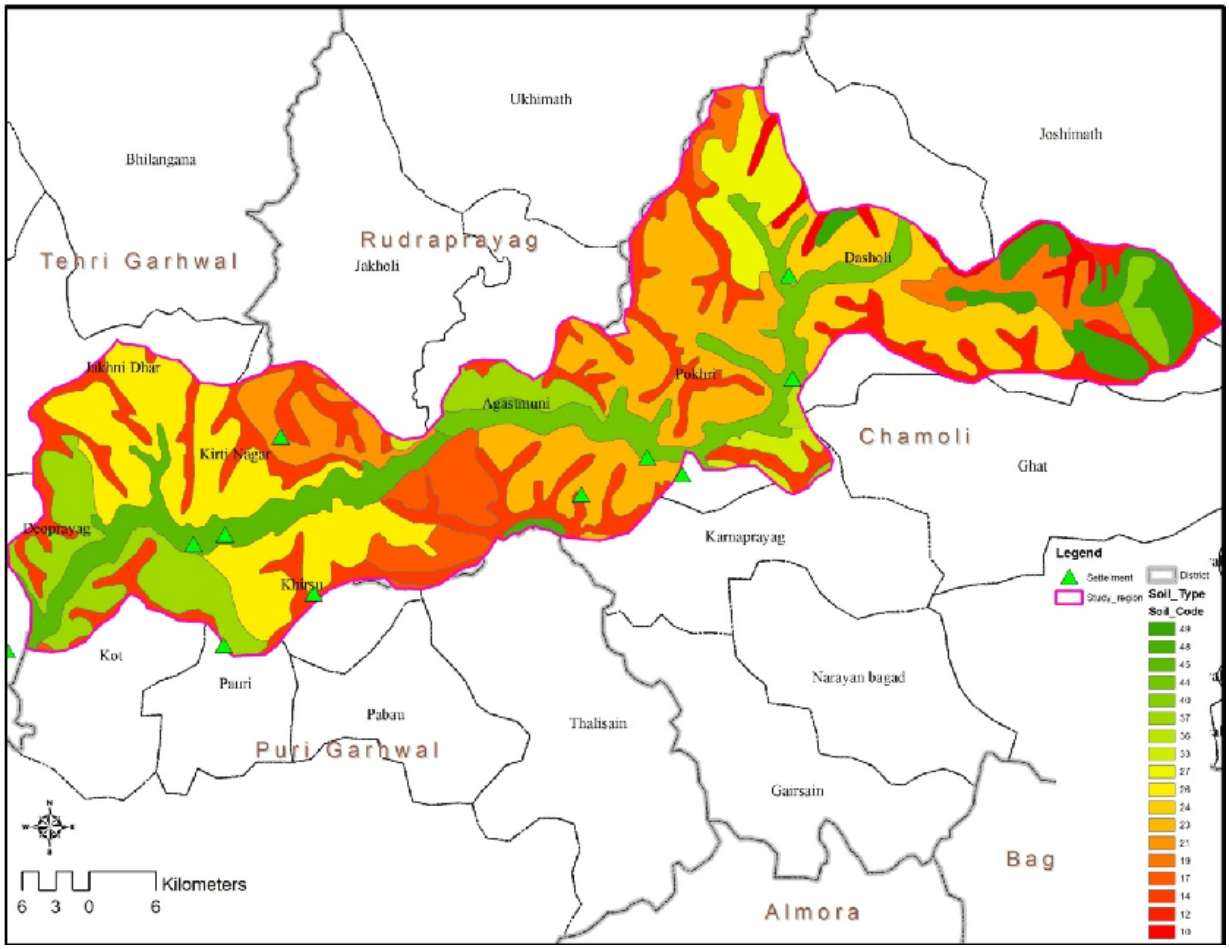
Soil contains and texture varies from the Greater Himalaya to the mid-slopes and valley regions. The table below represents the variation in depth, structure, pH value and water bearing capacity of soil with respect to altitudinal variation.

Table 3: Attributes of Soil across the Himalayan Range

| Region | Slopes | Depth | Drained | Structure | Acidic/Basic | Water Bearing Capacity |
|---|---|---|---|---|---|---|
| **Greater Himalaya** | Very Steep to Steep Slopes | Dominantly Occupied With Very Shallow to Moderate Shallow | Excessively Drained | Sandy-Skeletal And Loamy Skeletal | Neutral to Slightly Acidic | Low Available Water Capacity Soils |
| **Lesser Himalaya** | Steep to Moderately Steep Slopes | Shallow to Moderately Shallow | Excessively Drained | Sandy/Loamy-Skeletal/Loamy | | With Moderate Erosion And Moderate To Strong Stoniness |
| **Side Slopes/ Terrace Slopes** | | Soils Are Moderately Deep to Deep | Excessively Drained | Fine Loamy Slightly | Too Moderately Acidic | Moderate Erosion And Stoniness |
| **Glacial Fluvial** | | Moderately Shallow | Excessively Drained | Coarse Loamy | Slightly Acidic | Moderately Stony |
| **Fluvial** | | | Deeply Well Drained | | Moderately Acidic | Slightly Eroded |

*Source: Sati (2005)*

Figure 18: Soil map




*Source: adopted from AHEC/2011: Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins*

### 4.3.2.2 Soil Erosion

Soil erosion is the detachment, transport & deposition of soil particle on land surface. It occurs when the amount of soil eroded exceeds the amount of soil formed. It is measured as mass /unit area measured as mass /unit area - tonne/ha or Kg/sq.m. Both natural and manmade causes are responsible for soil erosion.

Previous studies have revealed that all processes of soil erosion-surface erosion, erosion of rivers and mass movements-are at work in the Himalaya. The denudation rates ranges from 0.5 mm per year to 20 mm per year in different part of the Himalayas.

#### 4.3.2.2.1 Climatic Erosion

Climatic soil erosion takes place due to:

- Heavy Rainfall: As a result of heavy rainfall in the upper regions during the monsoon season erodes the soil as it flows downwards.
- Steep Slopes: The soil cannot rest on the land surface owing to gravity in the steep slopes which thrusts it downwards.
- Structural Instability

*"Huge amount of water runoff, due to rainfall and snow result in a natural erosion process. It has been estimated that if heavy rains double the water flow, 'scouring capacity increases four times, carrying capacity thirty two times and the size of particle carried sixty four times.' (Tempany and Grist, 1958, p. 88)"*

#### 4.3.2.2.2 Man Made Erosion

Manmade soil erosion takes place majorly due to deforestation.Trees increases the soil permeability and holds it. With growth in population, grows the need for more land for agriculture, settlements and other uses. This is met by clearing forests. Moreover, large tracts of forests are cleared for road building and hydro power projects. As a result deforestation takes place resulting in soil erosion. Blasting for road construction further causes soil erosion and triggers small landslides. Traditional agriculture practices too are responsible for soil erosion.

### *4.3.2.3 Soil Erodability – Preparation of K-Factor Map*

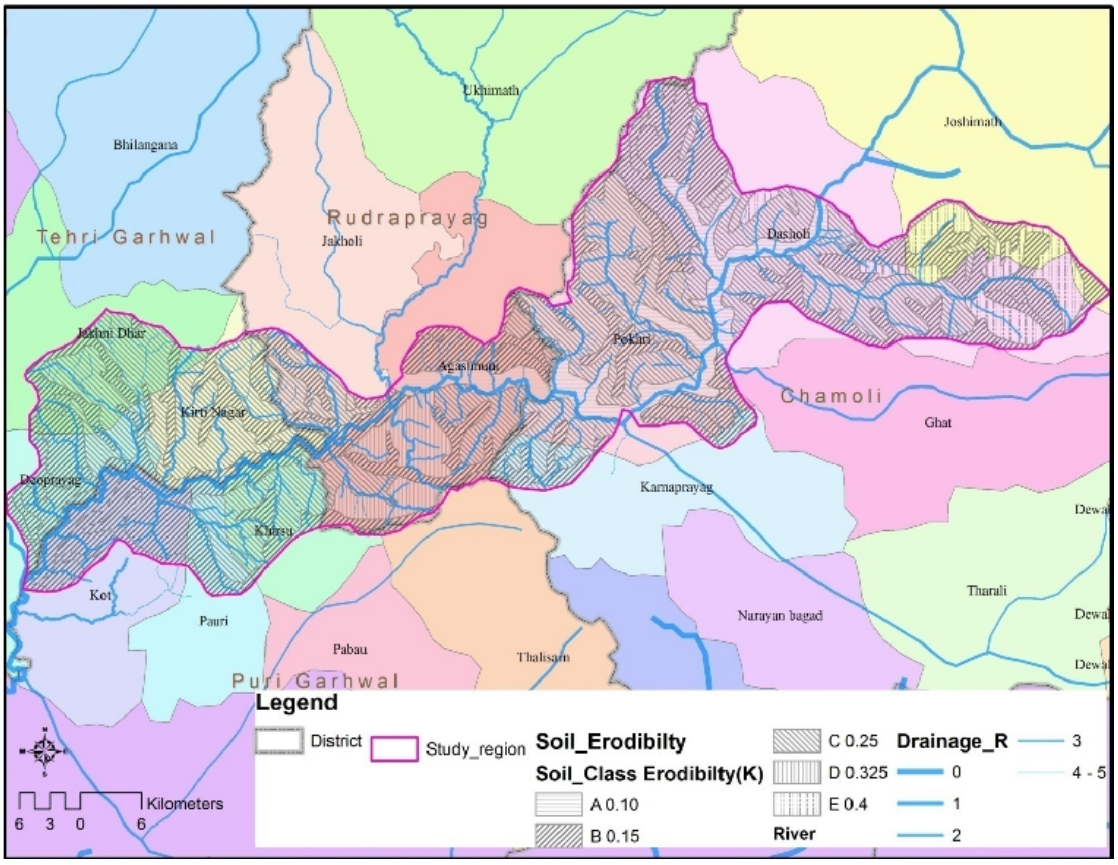
The K-Factor map has been prepared by considering the soil classification map. The K value for different types of soils is shown in the Table below. Depending upon the soil class, suitable K values have been assigned and the map is presented in Fig below.

Table 4: Soil Erodability Factor for Different Types of Soils in Alaknanda Basin

| S.No | Soil Codes | Soil Type | Erosion Rate | K Value |
|---|---|---|---|---|
| 1 | 1,2,38,39, 43,44,47 | Moderately -Deep/Soil of Side Slopes/Fluvial | Slight Erosion | 0.1 |
| 2 | 8,12,14,15,18,19,20,27,28,29,30,32,33,35,36,37,40,41,,42,45,46 | Moderately Shallow/Soil of Side Slopes | Moderate Erosion | 0.15 |
| 3 | 7,10,11,13,21,23,24,25,26,34 | Shallow/ Soil of Side Slopes | Severe Erosion | 0.25 |
| 4 | 3,4,5,6,16,17,22,31 | Very Shallow/Soil of Side Slopes | Very Severe Erosion | 0.325 |
| 5 | 9,48,49 | Soil at Cliff | Extreme Severe Erosion | 0.4 |

*Source: Pg 7-88, AHEC/2011: Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins*

Figure 19: Soil Erodability Index



#### *4.3.2.4Soil Erosion - Issues*

The main issues which arise due to soil erosion are:

**Floods:** Soil retains water flowing through it. Due to soil erosion, the surface water runoff increases. When the quantity and speed of runoff water surpasses the quantity and speed of downstream, flood takes place.

**Dry Streams**: As the water penetration into the ground decreases due to soil erosion, the ground water level comes down. As a result, springs and streams dry up.

**Landslide**: As increases water runoff takes place on the bedrocks, it continuously erodes its surface. At some points, this weakens the support of the slopes leading to landslides.

**Rivers**: Owing to landslides, huge masses of rocks descend downwards and block the path of big rivers. This results in damming up of rivers.

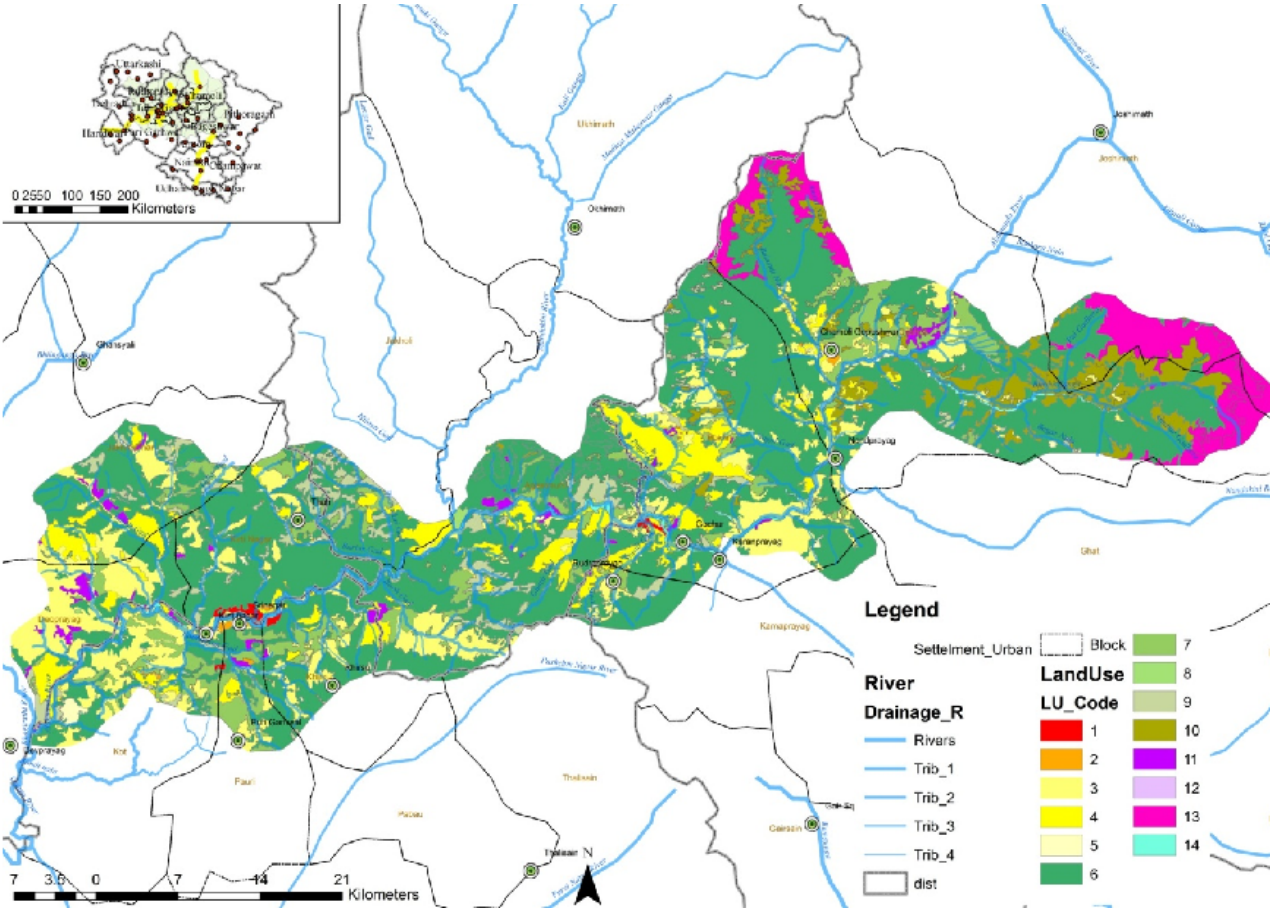
**Dams and Irrigation Canals**: Excessive soil erosion results in accumulation of soil in dams and irrigation canals. As a result, they become non-functional.

### 4.3.3 Land Utilization

This section illustrates the land utilization map in the study area.

#### *4.3.3.1 Land Utilization map and their Area Breakup*

Figure 20: Land utilization Map of Study Area, 2005



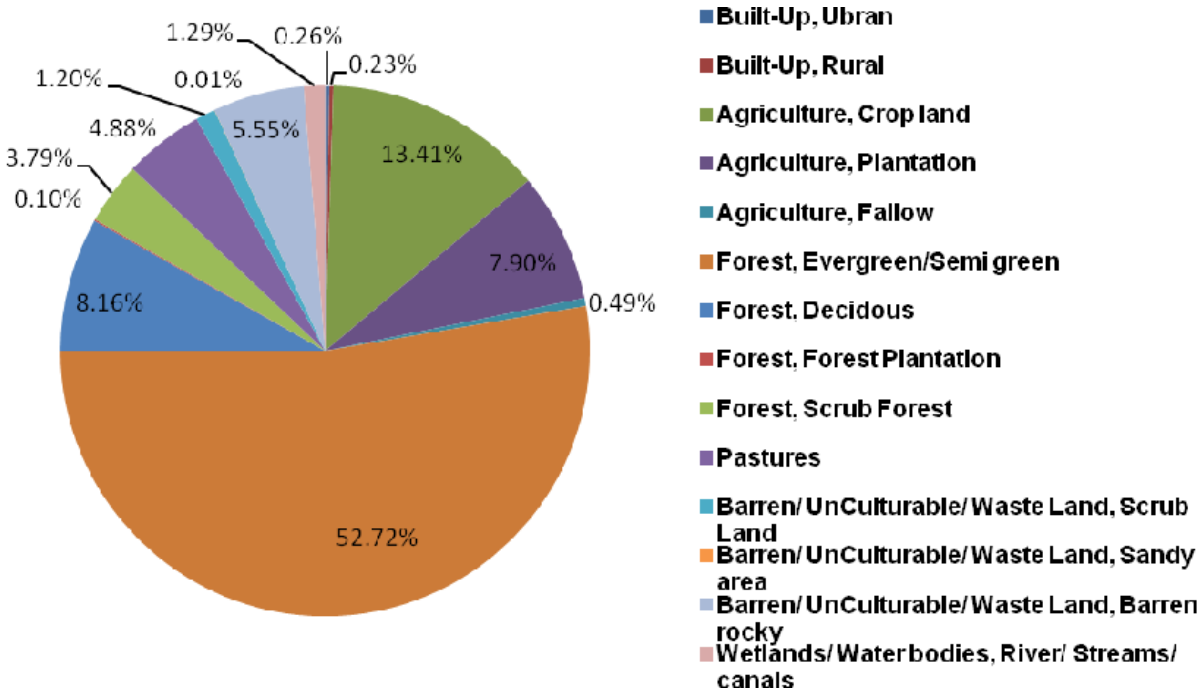

Land utilization is studied in 9 fold classifications but as per requirement of study, LULC map has been created considering 14 fold classification which is having 4 Sub-classes of forest, 3 Sub-categories in cropland and 2 classes in land under nonagricultural use which is urban and rural settlements.

| LU Code | Land Utilisation |
|---|---|
| 1 | Built-Up, Ubran |
| 2 | Built-Up, Rural |
| 3 | Agriculture, Crop land |
| 4 | Agriculture, Plantation |
| 5 | Agriculture, Fallow |
| 6 | Forest, Evergreen/Semi green |
| 7 | Forest, Decidous |
| 8 | Forest, Forest Plantation |
| 9 | Forest, Scrub Forest |
| 10 | Pastures |
| 11 | Barren/UnCulturable/Waste Land, Scrub Land |
| 12 | Barren/UnCulturable/Waste Land, Sandy area |
| 13 | Barren/UnCulturable/Waste Land, Barren rocky |
| 14 | Wetlands/Water bodies, River/Streams/canals |

Table 5: Land Utilization area break-up for study area

| *LU Code* | *Land Utilisation* | *Area(In Sqm)* | *Area(In %age)* |
|---|---|---|---|
| *1* | *Built-Up, Ubran* | *5,087,483.56* | *0.26%* |
| *2* | *Built-Up, Rural* | *4,579,739.20* | *0.23%* |
| *3* | *Agriculture, Crop land* | *262,775,552.61* | *13.41%* |
| *4* | *Agriculture, Plantation* | *154,754,725.47* | *7.90%* |
| *5* | *Agriculture, Fallow* | *9,526,539.05* | *0.49%* |
| *6* | *Forest, Evergreen/Semi green* | *1,033,265,653.17* | *52.72%* |
| *7* | *Forest, Decidous* | *160,004,421.80* | *8.16%* |
| *8* | *Forest, Forest Plantation* | *1,907,725.02* | *0.10%* |
| *9* | *Forest, Scrub Forest* | *74,340,896.89* | *3.79%* |

| | | | |
|---|---|---|---|
| *10* | *Pastures* | *95,705,880.95* | *4.88%* |
| *11* | *Barren/ UnCulturable/ Waste Land, Scrub Land* | *23,485,825.18* | *1.20%* |
| *12* | *Barren/ UnCulturable/ Waste Land, Sandy area* | *269,477.80* | *0.01%* |
| *13* | *Barren/ UnCulturable/ Waste Land, Barren rocky* | *108,829,108.57* | *5.55%* |
| *14* | *Wetlands/ Water bodies, River/ Streams/ canals* | *25,323,211.06* | *1.29%* |
| *15* | *Total* | *1,959,856,240.33* | *100.00%* |



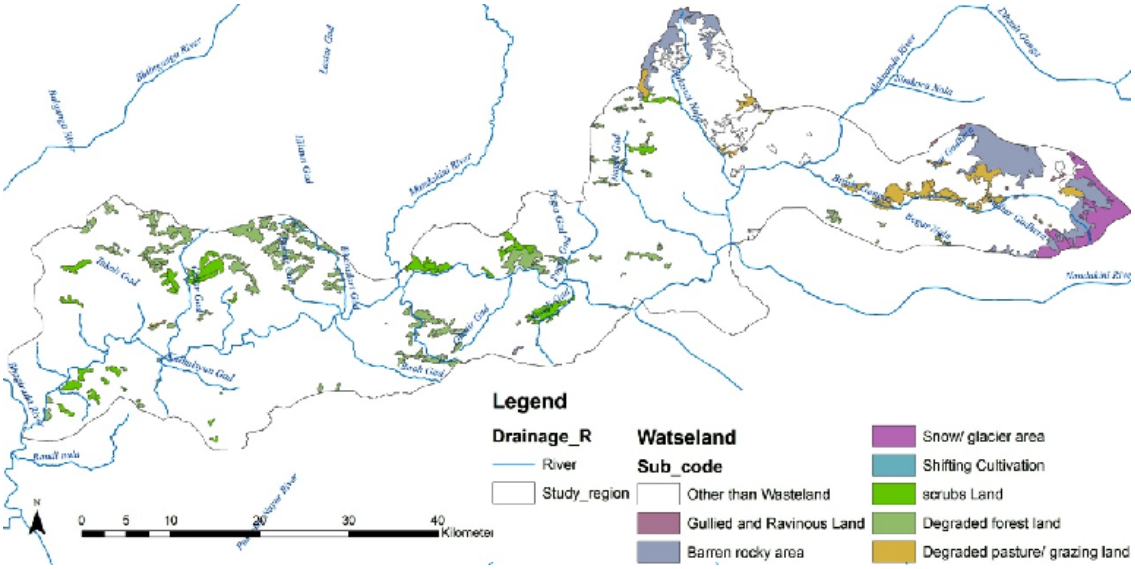
### *4.3.3.2 Observation*

63 % of the area is under forest out of which 55% of the area is covered by evergreen forests. Area under agricultural cropland and plantation is 21.3%, Percentage of barren land is 6.76% and 4.88% of land is under pastures.

Pauri and Devprayag have the least forest cover in comparison to other blocks. Maximum percent of forest (both evergreen and coniferous) is in Pokhri, Dasholi and Augustmuni. Pasture land is dominant in Pokhri and Dasholi. Maximum percent of area under water body is in Augustmuni and Dasholi.

## 4.3.4 Wasteland

Figure 21: wasteland map showing seven categories of wasteland present in study area



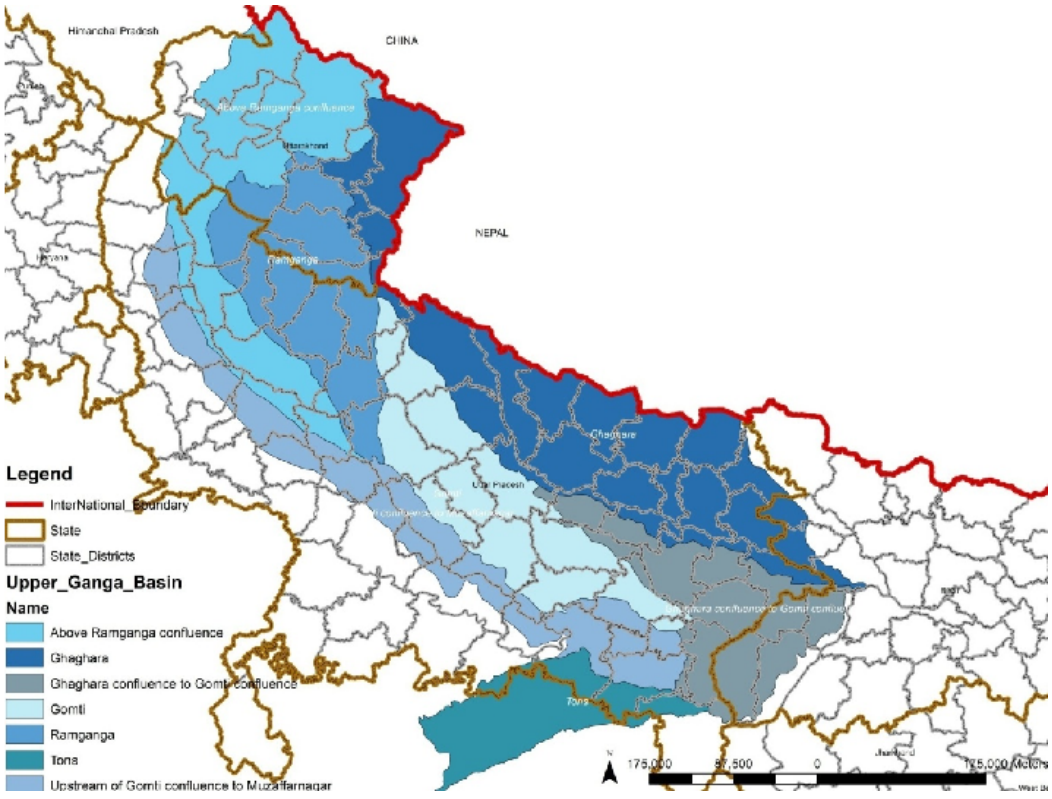

Around 7% of the study area is under wasteland. The various types of wasteland in the study area include scrub land, waste land due to shifting cultivation, degraded forest, degraded pastures, sandy area and barren rocky area.

## 4.4 Water Resource

### 4.4.1 Rivers and Drainage Pattern

The Alaknanda Basin accounts for 8% of the total water resources in the country. The Alaknanda River originates from Satopanth and Bhagirath Kharak glaciers and runs a distance of 224 km till its confluence with Bhagirathi at Devprayag (472m). The basin is extended between 30°0' N - 31°0' N and 78°45' E - 80°0' E, covering a total catchment area of about 12587.23 sq.km, representing the eastern part of the Garhwal Himalaya. The Alaknanda catchment can be subdivided into Alaknanda, Mandakini, Nandakini, Pindar, Dhauliganga and Birahi Ganga sub-catchments. In many areas, the tributaries and sub-tributaries provide ideal sites for micro-hydropower projects. Alaknanda River Watershed I fall in the Srinagar Block in District Pauri Garhwal and Devprayag Block in Tehri Garhwal. Alaknanda River Watershed II falls in the District Rudraprayag and Pokhri Block, north of Chamoli Block and western part of Karanprayag Block in Chamoli District,The figure below shows the river confluences in the Upper Ganga Basin.

Figure 22: River Confluences in Upper Ganga Basin



The detail of drainage system in the Alaknanda River Basin is shown in the table below:

Figure 23: Drainage Detail

| Sl. No. | River | Total Length ' (m) | Elevation Range | | Gradient | Confluence Location |
|---|---|---|---|---|---|---|
| | | | Highest Point | Confluence Point | | |
| 1 | Alaknanda | 224000 | 4016 | 480 | 1.36% | Joins Bhagirathi at Devprayag |
| 1a | Alaknanda - Dhauli Ganga | 47000 | 4016 | 1446 | 5.47% | Confluences at Vishnuprayag |
| 1b | Alaknanda-Pindar | 60000 | 1446 | 795 | 1.09% | Confluences at Karanprayag |
| 1c | Alaknanda - Devprayag | 109000 | 795 | 480 | 0.29% | |
| 2 | Dhauli Ganga | 50000 | 2880 | 1446 | 2.87% | Confluences at Vishnuprayag |
| 3 | Rishi Ganga | 38500 | 4000 | 1900 | 5.45% | Confluences Dhauli Ganga at Tapovan |
| 4 | Birahi Ganga | 29500 | 2150 | 994 | 3.96% | Confluences at Birahi village |
| 5 | Nandakini | 44500 | 2200 | 880 | 2.97% | Confluences Alaknanda at Nandprayag |
| 6 | Pindar | 114000 | 2200 | 775 | 1.25% | Confluences at Karnprayag |
| 7 | Mandakini | 81000 | 3562 | 640 | 3.61% | Confluences at Rudraprayag |

Source: *AHEC/2011: Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins*

### 4.4.2 Water Resource- Issues

The main issues with regard to water source are as follows:

**Recurring Floods:** Heavy rainfall and deforestation leads to excessive soil erosion thus leading to flood. Sometimes the quantity and speed of water runoff surpasses the quantity and speed of downstream rivers as a result of which flood occurs in the valleys and low lying areas.

**Drainage Congestion:** The tributaries/distributaries of rivers along with the main rivers flow in close proximity to each other in certain areas. When floods occur in this region, drainage congestion takes place.

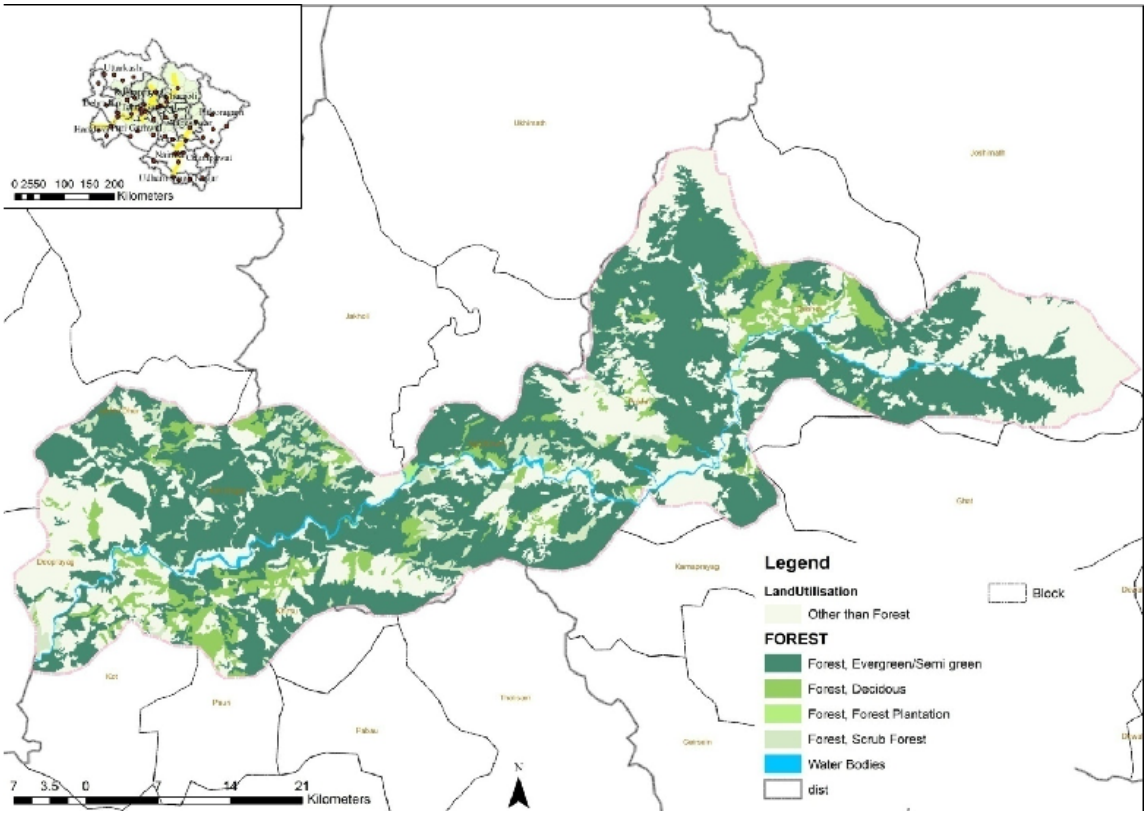
**Soil Erosion:** High speed of run-off water erodes enormous amount of soil from the elevated areas which in turn leads to excessive sedimentation on river bed.

**Human Influence on Environment:** Human Intervention in the form of activities like construction of roads along river, promotion of hydro power projects and non-conforming commercial activities on river bed has a negative impact on water resource. Construction of roads sometimes cuts across the natural water flow direction in the mountains leading to landslides, hydro power projects dries up long stretches of rivers, commercial development along river bed contributes to water pollution.

## 4.5 Forest Resource

Forests are most important both economically and environmentally in the Alaknanda Basin. The geographical area covered by forest is 119517.78 hectares. Forest provides fodder, firewood, timber, non-timber products, herbs, and environmental services. 63 % of the study area is under forest out of which 55% of the area is covered by evergreen forests.

Figure 24: Forest map showing Four classes of forest




### 4.5.1 Ownership of Forests

The ownership of the forest in the state is mainly shared between:

Table 6: Ownership Wise Forest Area

| Forest Ownership | Area(in %age) |
|---|---|
| Forest Department | 69.1 |
| Civil and Soyam (community forest) | 23.4 |
| Forest Panchayats ( *Van Panchayat*) | 6.9 |
| Private (including cantonment) Forests | 0.6 |

### 4.5.2 Type of Forest

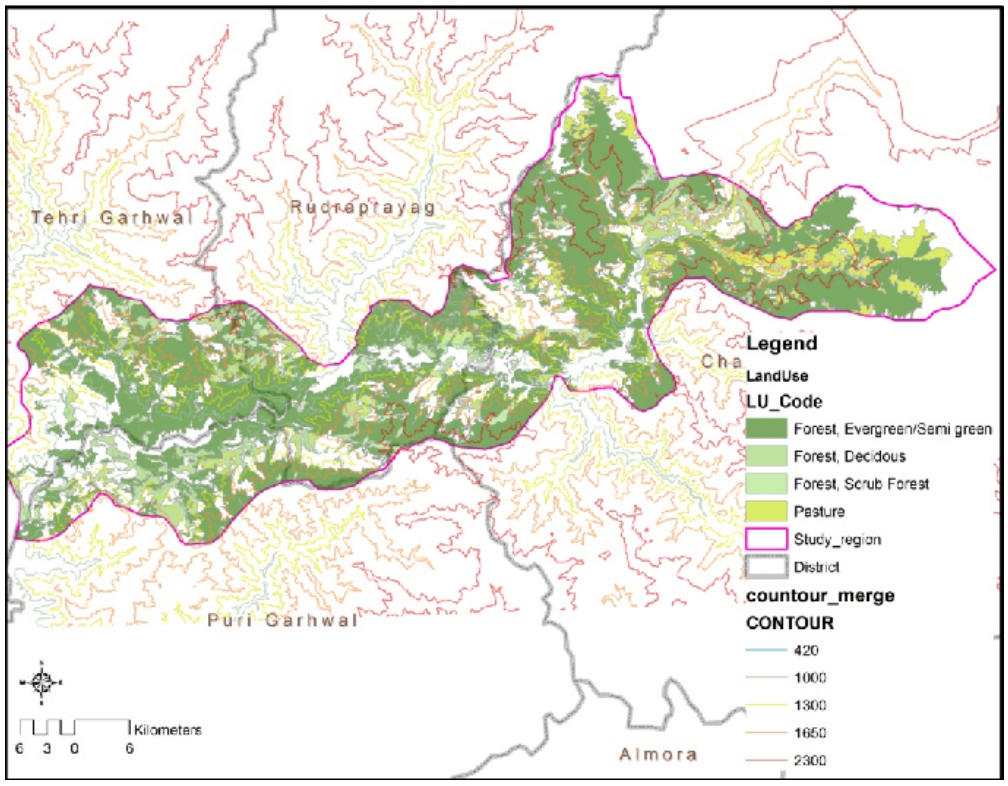
Alpine, temperate and sub-temperate forests are predominant in the study area. The temperate coniferous forest is abundantly found in the upper reaches. Oak forests are dominant in the highlands while pine forests are dominant in the valley regions and mid altitude patches. Fodder

plants like, bhimal and khadik, are also grown along edges of agricultural fields. The table below shows the different types of forest existing in the study area.

Table 7: Types of Forest

| Forest | Scientific Name | Heights | Place | Use |
|---|---|---|---|---|
| Deodar | Cedrus Deodara | 1650 to 2300 m | | |
| Blue Pine/ Kail | Pinus Wallichiana | 1650 to 2300 m | Joshimath | Timber for Furniture and Fetmers in Houses |
| Chir | Pinus roxburghii | 1000 to 1650 m | Entire Basin | Making Packing Cases, Panelling in Interior Decoration; Fuel Wood |
| Oak | Quercus species | 1325 to 1625 m | | Fuel Wood and Charcoal Manufacturing |
| Fir and Spruce | Abies Pindrow and Picea Smithiana | | | |

Figure 25: Forest Map Overlapped with Contour



### 4.5.3 Role of Forests

**Evapotranspiration:** Trees provide us with a clean source of oxygen and absorb some of the carbon dioxide in the Earth's atmosphere. The combined loss of water by evaporation from the soil and transpiration through plant leaves is termed as evapotranspiration.

Deep rooting trees like oak and pine (4 to 6 meter deep) transpire large quantities of water. It is estimated that for every ton of new tree that grows and transpires, about 1.07 tons of oxygen will be supplied and an estimated 1.47 tons of carbon dioxide will be removed from the Earth's atmosphere, which can lessen the worsening condition of global warming (Cantoria, S.Ciel "What is Transpiration and Its Importance to Plants, Agriculture and the Environment?" (19.11.2010), Retrieved from: http://www.brighthub.com/, Last Accessed: 4/10/14)

**Soil Fertility:** Trees in forests increases soil fertility by providing high infiltration rates and reducing runoff of water.

**Fodder:** Forests provide fodder for livestock. Oak and pine forests are useful for fodder.

**Hydrological Cycle:** Forests influence hydrological cycle by evaporating the rainwater back to air, transpiring and increasing infiltration of water into the ground.

**Forest Products**:

- Oak and pine forests are useful for firewood as there are no other alternatives for fire. According to Robbe, 1954, annual firewood consumption is of the order of 0.6 cum/family or well over 1 million cum for the whole of Nepal. As per FAO, it is no less than 6.6 million cu m in 1967 (Donner, 1972, p.354).
- Timber is used for construction of railway sleepers while resin for turpentine production.
- Other forest products include medicinal plants, honey and honey bees, organic materials, bamboo, oak bark, natural dyers and environmental services.
- Rosin is extracted from pine trees and used in making varnishes, inks and other products. Rosin is extracted mainly in North and South Jakholi.

- Wild Fruits plays an important role in subsistence economy. There are a variety of wild fruits in the valley, mid slopes and highlands. The different potential wild edibles in Alaknanda Valley are shown in the table below.

Table 8: Wilde edibles and its uses found in Alaknanda Basin

| Height | Wild Edibles | Uses |
|---|---|---|
| Upto 1200 | Bel | Fruit, Juice and Squash, Medicinal |
| Upto 1800 | Guriyal | Vegetable, Pickle, Leaves for Fodder |
| Upto 1200 | Semal | Vegetable, Pickle, Leaves for Fodder |
| 600-2700 | Kingore | Juice, Squash, Medicine |
| 1000-2000 | Lingra | Vegetable, Pickle, Medicine |
| 1200-3000 | Gweain | Juice, Squash, Medicine |
| 1000-1200 | Timla | Fruits, Pickle, Vegetable |
| 500-1800 | Bedu | Fruits, Pickle, Vegetable, Medicine, Leaves for Fodder |
| 900-1400 | Khanu | Pickle, Leaves for Fodder |
| 2000-3000 | Ames | Food, Cosmetic, Medicine |
| 1200-2600 | Sahut | Rearing Silkworms and Juice, Squash |
| 1400-2000 | Kaphal | Fruits, Juice, Squash |
| 800-1800 | Chingaru | Fruits, Jam, Juice, Sauce, Squash, Medicine |
| 1200-2400 | Burans | Juice and Squash |
| 1000-2000 | Hinsul | Fruits and Jam |
| 700-1500 | Amara | Fruits, Juice, Sauce, Squash, Medicine |
| 900-1500 | Gular | Fruits, Pickle, Vegetable, Leaves for Fodder |
| 500-1500 | Anwala | Pickle, Murabba, Squash, Juice, Medicine |
| upto 1500 | Ber | Juice, Squash, Murabba |
| 1500-2500 | Bhamore | Fruit, Jam |
| 1500-2800 | Bhatmoliya | Fruits, Juice, Squash |

Source: Adopted from Sati (2010)

The type of sacred plant species found in Uttarakhand include Doob, Peepal, Bargad, Tulsi, Dhoop or Kunju, Banana, Bail, Amla, Mango, Pine, Paiya, Deodar, Timroo, Neem and Oak.

### 4.5.4 Forest Resource Issues

The biggest issue with regard to forest is its depletion and degradation. Forests are cut for extraction of timber and firewood. Forest is also cleared for cultivation and grazing. The reasons for forest degradation area:

**Population Increase:** Population increase results in increase in agricultural land which in turn results in depletion/degradation of forests. People clear forests for settling down, grow crops, rear livestock etc. As per Mauch, 1976, owing to exponential increase in population growth, extraction of forest is surpassing the natural regeneration of the same.

**Trees Cutting:** Trees are chopped for firewood, timber and fodder.

**Forest Fire:** Forest fire is of three types namely, natural, intentional and accidental. Natural fires occur in forests due to lightning or rubbing of tree branches due to strong wind. Intentional fires are created for the better growth of fodder grass, to drive away herbivores which destroy crops and for collecting forest products like gum and honey. Incidental fire occurs due to human carelessness such as throwing of lighted cigarettes or spread of fire from camping sites or other recreational areas.

**Forest Clearing:** Vast tracts of forest land are cleared because of road construction and promotion of hydro power projects.

Due to depletion in forest areas, water retaining capacity of the natural vegetation is reduced and runoff is increased, both in quantity and speed.

"A good forest cover in the Himalayas constitutes the safest land use to reduce floods but if deforestation is replaced by terraced agriculture and well maintained grasslands, there should be a little effect on downstream floods, said Lawrence Hamilton. If deforestation results in an extremely abusive land use in the form of intensively overgrazed grasslands which lead to heavily compacted surface soils, eroded and gullied terraces and roads and channels which speed water run off on a sufficiently extensive scale across the river basin. This can aggravate downstream floods." (Sati, 2005)

# Chapter 5

## 5 PRIMARY PRODUCTION AND SOCIO-ECONOMIC SYSTEM

This chapter deals with the "Primary Production and Socio Economic System". It includes settlements, demography, activities (primary, secondary and tertiary) and infrastructure (social and physical). Block wise data has been used owing to their availability.

### 5.1 Settlements

The study area extends over 10 development blocks across the four districts of Rudraprayag, Chamoli, Pauri Garhwal and Tehri Garhwal. These 10 development blocks consists about 2200 villages of which 8.3% are uninhabited villages. Out of 2200 villages, 1980 villages have a population size of less than 1000.

Figure 26: Administrative Boundary

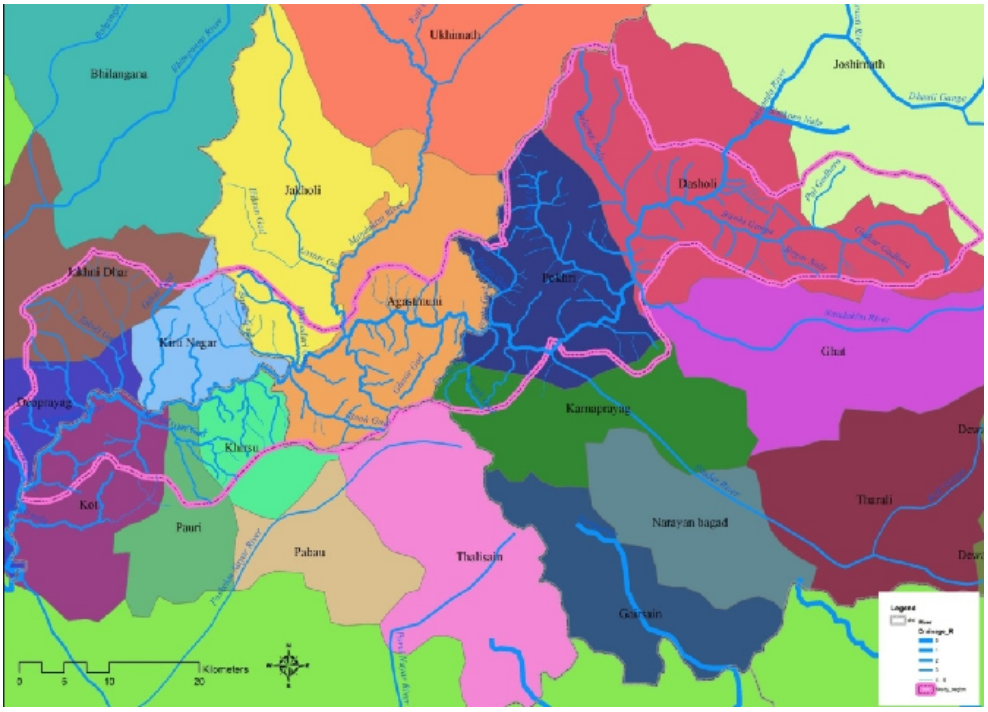


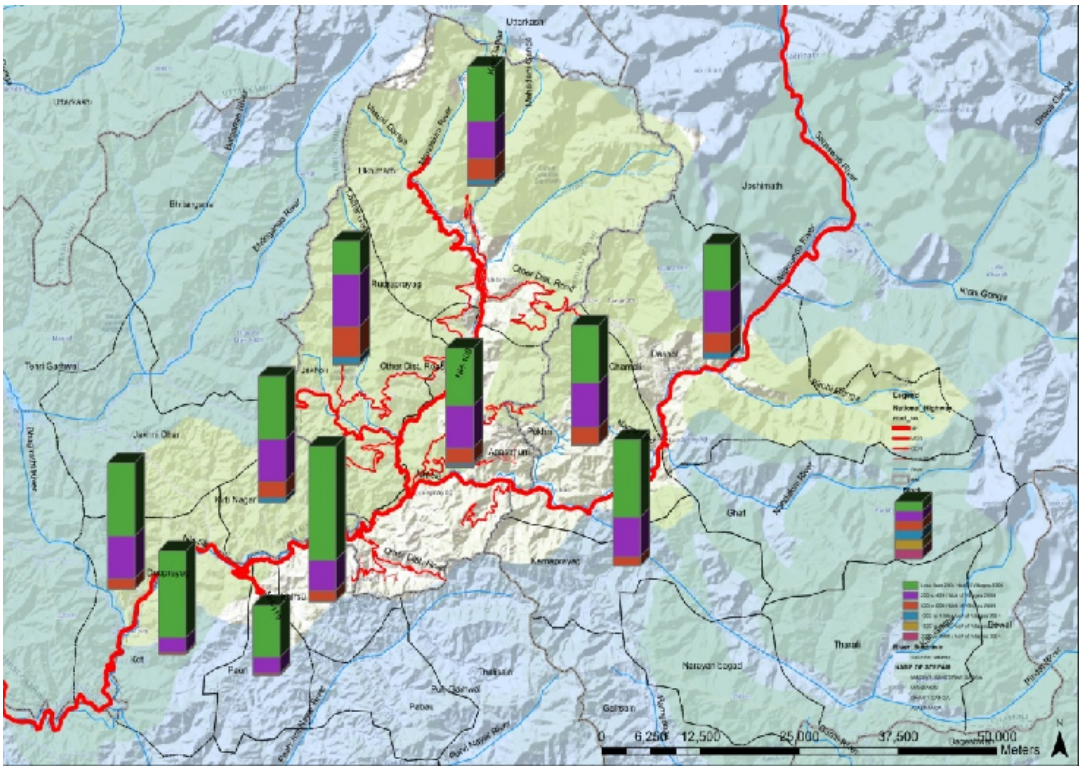

Table 9: District wise list of blocks falling into Study area

| District | Blocks |
|---|---|
| Rudraprayag | Augustmuni and Jakholi |
| Chamoli | Karanprayag, Dasholi and Pokhri |
| Pauri Garhwal | Pauri, Khirsu and Kot |
| Tehri Garhwal | Devprayag and Kirti Nagar |

*Source: compiled by author*

There are 934 villages in our delineated study area out of which 63 are uninhabited. 611 villages out of these 934 have a population size of less than 1000. The figure below shows the block level population wise settlement.

Figure 27: Block Level Population Wise Settlement




*Source: Author*

Table 10: Number of Villages in Blocks falling into Study Area (2011-12)

| Development Blocks | No. of Villages | Percentage of Inhabitable Villages | Percentage of Uninhabitable Villages |
|---|---|---|---|
| Augustmuni | 374 | 94.12 | 5.88 |
| Jakholi | 170 | 98.24 | 1.76 |
| Karnprayag | 221 | 92.76 | 7.24 |
| Dasholi | 122 | 90.98 | 9.02 |
| Pokhri | 140 | 95.00 | 5.00 |
| Pauri | 214 | 84.11 | 15.89 |
| Khirsu | 146 | 82.88 | 17.12 |
| Kot | 266 | 81.95 | 18.05 |
| Devprayag | 248 | 96.37 | 3.63 |
| Kirti Nagar | 155 | 99.35 | 0.65 |

*Source: District statistical handbook of Dist. Chamoli, Tehri, Pauri and Rudraprayag*

Percentage of uninhabited villages are more than 15% is observed in Pauri, Khirsu, Kot. All three exist in Pauri Garhwal district which lies in downstream area, south of river Alaknanda.

Table 11: Number of Villages by Population Size

| Population Size Range | Augustmuni | Jakholi | Karnprayag | Dasholi | Pokhri | Pauri | Khirsu | Kot | Devprayag | Kirti Nagar |
|---|---|---|---|---|---|---|---|---|---|---|
| Less than 200 | 171 | 45 | 126 | 45 | 64 | 88 | 132 | 183 | 144 | 77 |
| 200 to | 125 | 70 | 64 | 41 | 49 | 27 | 35 | 31 | 83 | 51 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 499 | | | | | | | | | | |
| 500 to 999 | 44 | 41 | 15 | 19 | 19 | 3 | 12 | 4 | 21 | 20 |
| 1000 to 1499 | 7 | 9 | 0 | 6 | 1 | 1 | 1 | 0 | 0 | 6 |
| 1500 to 1999 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 to 4999 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 5000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Source: Calculated from District statistical handbook of Dist. Chamoli, Tehri, Pauri and Rudraprayag*

Figure 28: Settlements, Roads and Rivers in Study Area

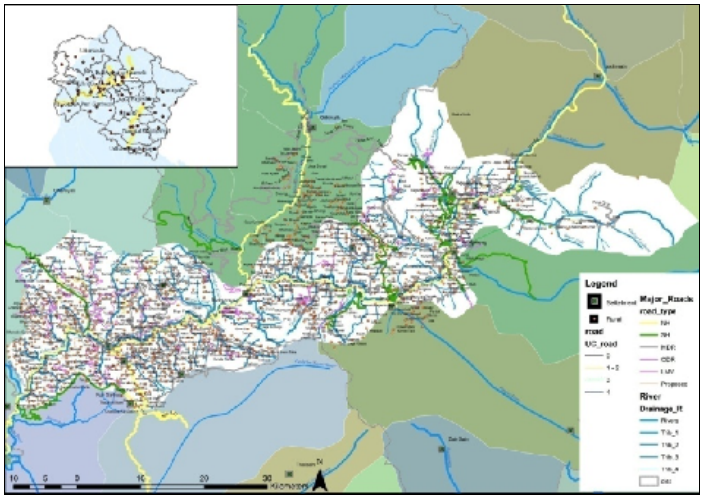
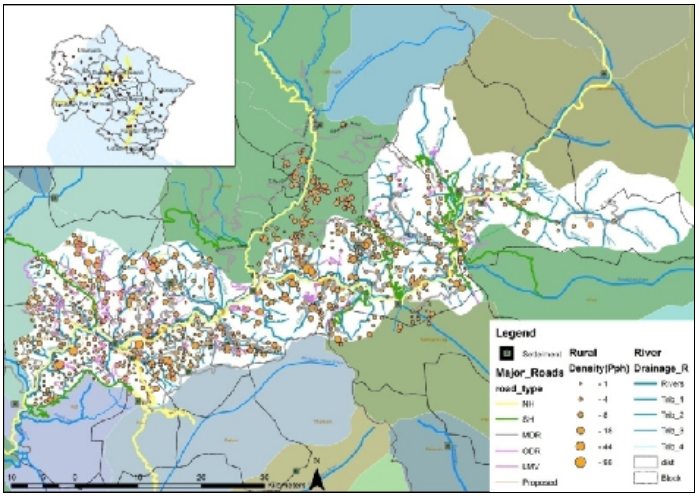
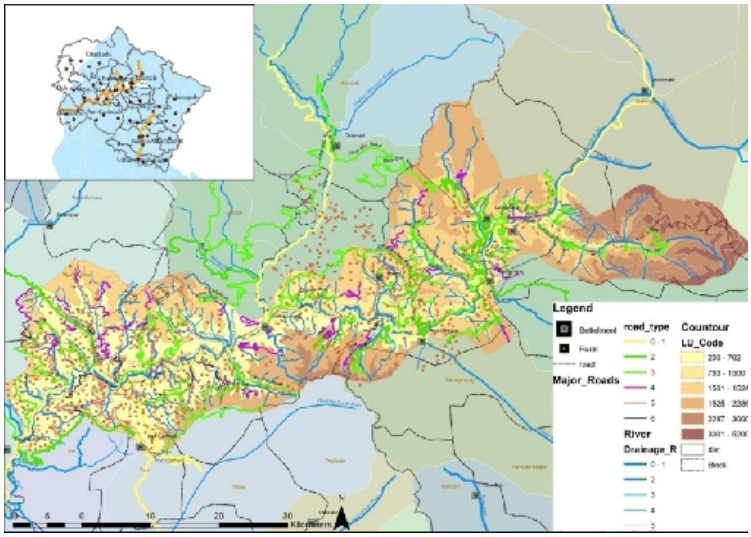



Figure 29: Village Wise Density Map (2001)



As can be observed from the figure below, dense settlements are dominant in downstream region. Sparse settlement is dominant in the uplands which may be attributed to high degree of slopes in the upstream region. Concentration of villages can be observed in the downstream and mid stream region. Rural density is highest in the downstream areas.

Figure 30: Roads, Villages, River and Contour 500 M Overlay




The downstream region of the river is severely affected by population pressure and development activities owing to proximity near the river and existence of low and medium slopes (0 to 20) %.

## 5.2 Demography

### 5.2.1 Introduction

The demographic analysis has been done at the block level due to availability of the same. The various demographic parameters that have been considered area population density, decadal population growth rate, household size, sex ratio, literacy rate and workers profile.

### 5.2.2 Population Density

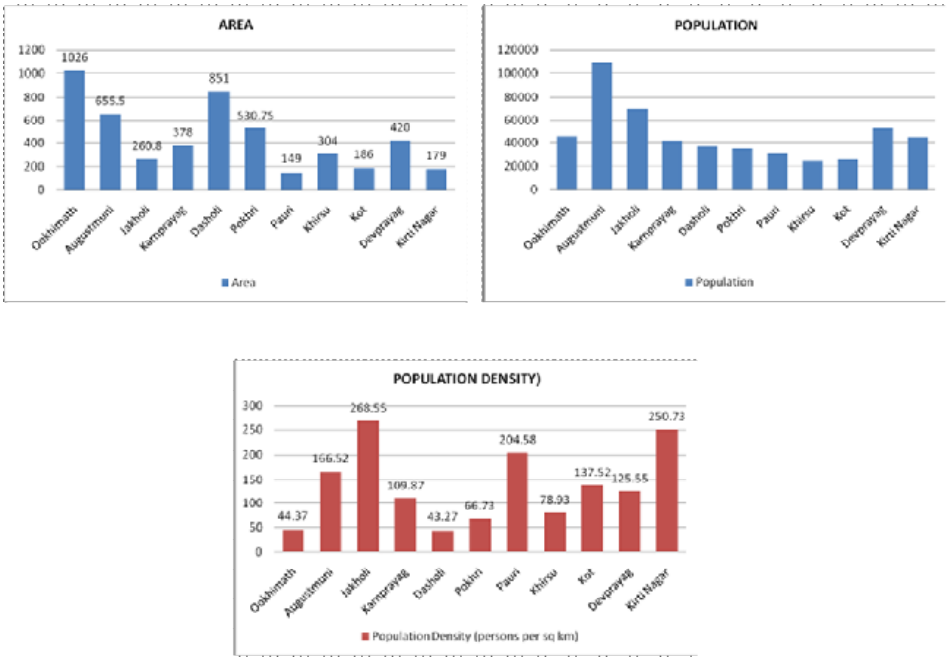
Table 12: Area and Population of Blocks in Study Area (2001)

| District | Development Blocks | Area (sq. km.) | Population | Density (persons per sq. km) |
|---|---|---|---|---|
| Rudraprayag | Augustmuni | 655 | 109151 | 166.52 |
| | Jakholi | 260 | 70037 | 268.55 |
| Chamoli | Karnprayag | 378 | 41529 | 109.87 |
| | Dasholi | 851 | 36826 | 43.27 |
| | Pokhri | 530 | 35417 | 66.73 |
| Pauri Garhwal | Pauri | 149 | 30482 | 204.58 |
| | Khirsu | 304 | 23995 | 78.93 |
| | Kot | 186 | 25579 | 137.52 |
| Tehri Garhwal | Devprayag | 420 | 52729 | 125.55 |
| | Kirti Nagar | 179 | 44880 | 250.73 |

*Source: Calculated from District statistical handbook of Dist. Chamoli, Tehri, Pauri and Rudraprayag*

Area wise Dasholi block from Chamoli district is the largest among and population wise Augustmuni block is the largest but if we analyze it density wise which is considered to be a comparative indicator, it is found that Jakholi and Kirti Nagar have the highest densities that is more than 250 persons per square kilometer. These are neighboring blocks from two different districts Rudraprayag and Tehri respectively.

Figure 31: Area, Population and Population Density




*Source: Author*

Dasholi, Pokhri and Augustmuni spread over more than 50% of the study area. The highest populated blocks include Augustmuni, Jakholi, Devprayag and Kirti Nagar. Jakholi and Devprayag have the maximum population density. Population density in Dasholi is the least i.e. 44 persons per sq. km of area.

### 5.2.3 Decadal Growth Rate Block Wise (91-01)

The figure and the table below give the block wise decadal growth rate in the study area. Population growth has taken place mostly in the central region of the study area with Jakholi and Khirsu experiencing the highest growth rate. Negative growth rate has been observed in Kot and Pauri which falls in the downstream region in the southern part of River Alaknanda.

**Figure 32: Decadal Growth Rate Block Wise**

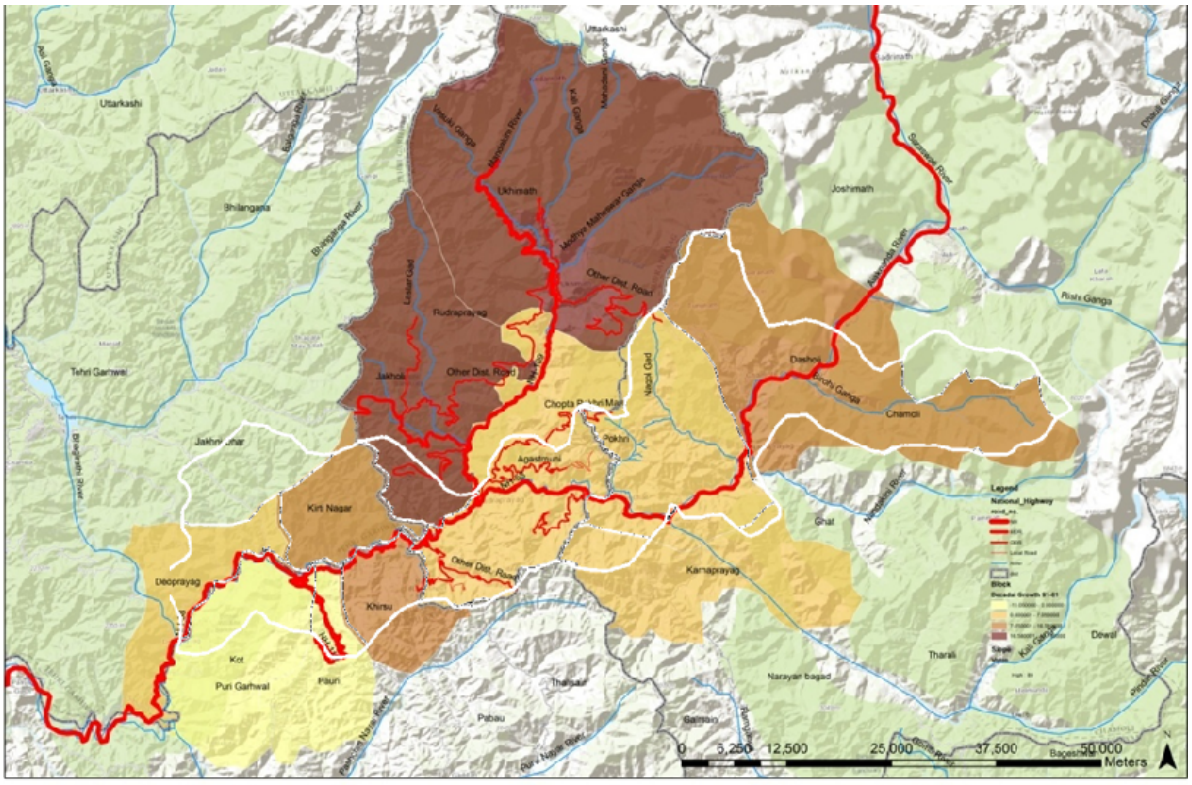



Table 13: Population Decadal Growth (91-01)

| Development Blocks | Decadal Growth Rate |
|---|---|
| Augustmuni | 3.5 |
| Jakholi | 16.93 |
| Karnprayag | 6.83 |
| Dasholi | 11.12 |
| Pokhri | 7.05 |
| Pauri | -2.88 |
| Khirsu | 16.58 |
| Kot | -11.05 |

| | |
|---|---|
| Devprayag | 6.87 |
| Kirti Nagar | 10.98 |

Figure 33: Map Showing Settlement Population Density (persons per sq.m) (2001)

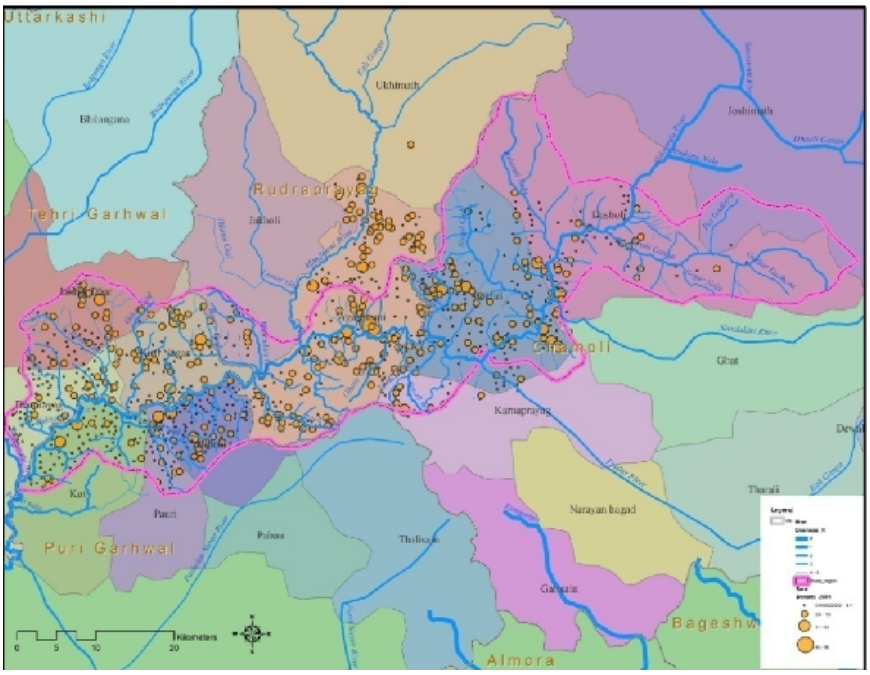
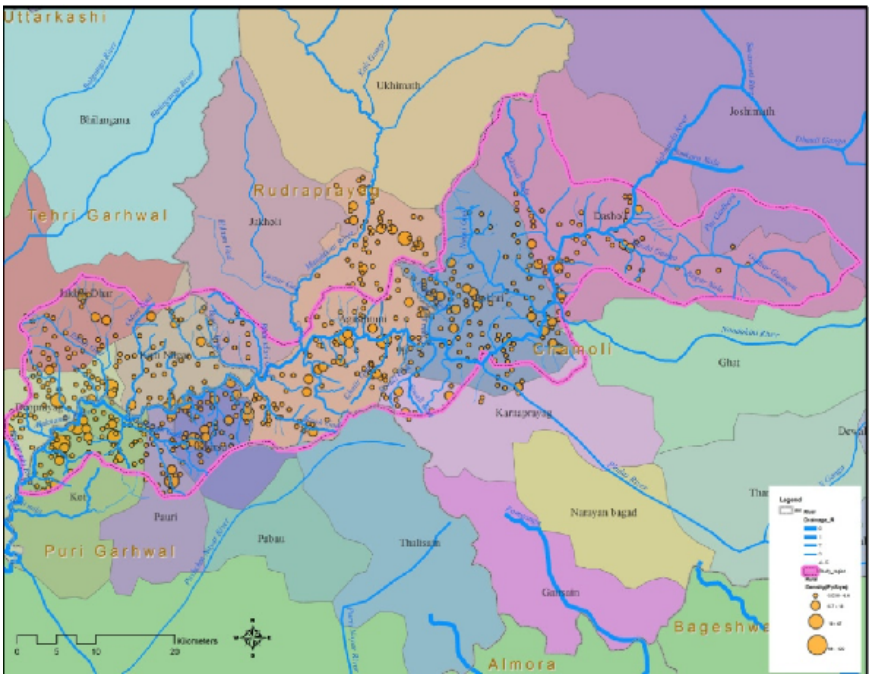



Figure 34: Map Showing Settlement Population Density (persons per sq.m) (2011)




In 2001, maximum density has been observed in Kirti Nagar, Jakholi and Pauri which fall in the downstream region on either side of the river. Similarly, even in 2011, increase in the density of population has been observed in the downstream region.

### 5.2.4 Household Size and Sex Ratio

Average household size varies from 4 to 5 indicating the dominance of nuclear families in the region Sex ratio is much better as compared to the nation. Female population is dominant in the region.

Table 14: Household Size in Study Area (2001)

| Development Blocks | Population | No. of HH | Household Size |
|---|---|---|---|
| Augustmuni | 109151 | 23602 | 4.6 |
| Jakholi | 70037 | 14239 | 4.9 |
| Karnprayag | 41529 | 9090 | 4.5 |
| Dasholi | 36826 | 7705 | 4.8 |
| Pokhri | 35417 | 7960 | 4.4 |

| | | | |
|---|---|---|---|
| Pauri | 30482 | 6943 | 4.4 |
| Khirsu | 23995 | 5585 | 4.3 |
| Kot | 25579 | 6219 | 4.1 |
| Devprayag | 52729 | 11364 | 4.6 |
| Kirti Nagar | 44880 | 9379 | 4.8 |

Figure 35: Bare Graph for HH Size

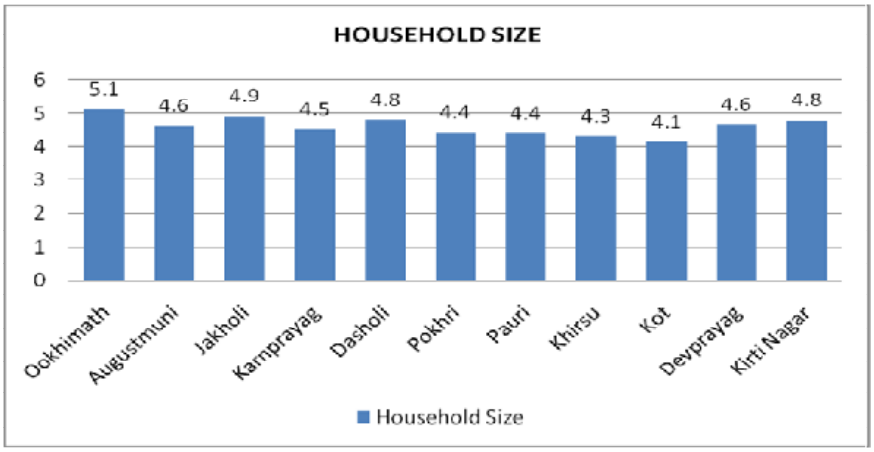
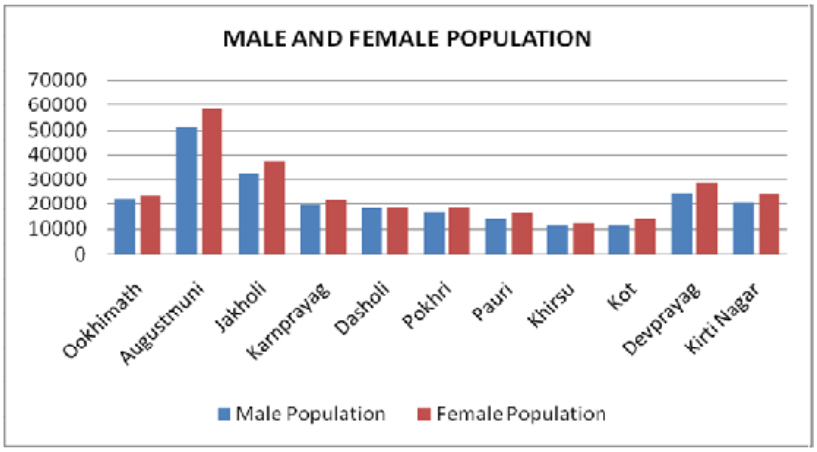



Table 15: Sex Ratio in Study Area (2001)

| Development Blocks | Male Population | Female Population | Sex Ratio |
|---|---|---|---|
| Augustmuni | 51080 | 58071 | 1137 |
| Jakholi | 32343 | 37694 | 1165 |
| Karnprayag | 19587 | 21942 | 1120 |
| Dasholi | 18219 | 18607 | 1021 |
| Pokhri | 16752 | 18665 | 1114 |

| | | | |
|---|---|---|---|
| Pauri | 14090 | 16392 | 1163 |
| Khirsu | 11598 | 12397 | 1069 |
| Kot | 11416 | 14163 | 1241 |
| Devprayag | 24188 | 28541 | 1180 |
| Kirti Nagar | 21111 | 23769 | 1126 |

Figure 36: Block wise Male and Female population distribution




### 5.2.5 Literacy Percentage in Study Area

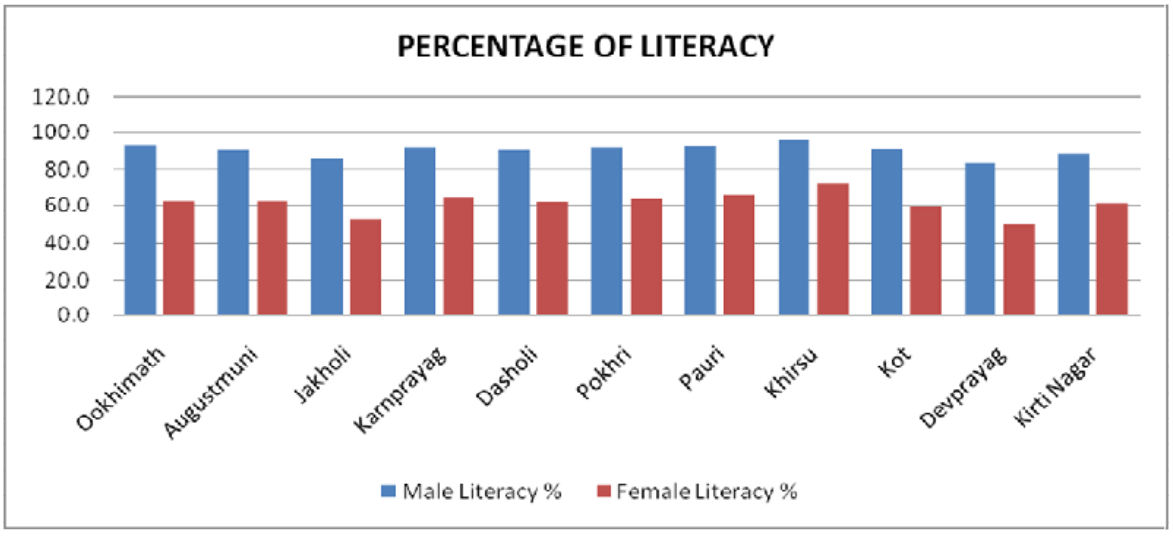
Though the region has a dominance of female population, the percentage of female literacy is much lower than that of male. Minimum literacy has been observed in Jakholi and Devprayag.

Table 16: Literacy Percentage in Study Area

| Development Blocks | Literacy % (2001) | Male Literacy % (2001) | Female Literacy % (2001) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Ookhimath | 77 | 92.6 | 62.4 |
| Augustmuni | 75.3 | 90.4 | 62.4 |
| Jakholi | 67.6 | 86.2 | 52.2 |
| Karnprayag | 77 | 91.7 | 64.2 |
| Dasholi | 75.9 | 90.3 | 62.2 |
| Pokhri | 76.9 | 91.7 | 64 |
| Pauri | 77.8 | 92 | 65.7 |
| Khirsu | 83.5 | 95.6 | 72.6 |
| Kot | 73.1 | 91 | 59.4 |
| Devprayag | 64.9 | 83.2 | 50 |
| Kirti Nagar | 74 | 88.5 | 61.5 |

Figure 37: Block wise Literacy percentages



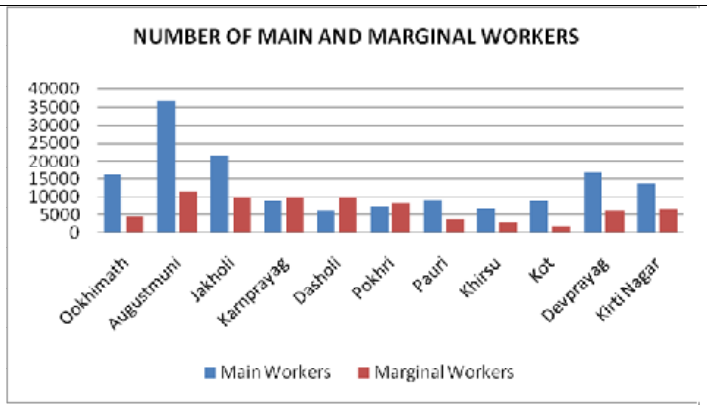
### 5.2.6 Workers Profile

#### *5.2.6.1 Main and Marginal (2001)*

Agricultural labourers are negligible in the region. The number of marginal workers in Dasholi is almost twice the number of main workers in Dasholi. Karnprayag and Pokhri too have more marginal workers than main workers indicating the employment instability in the same region. The number of main workers is dominant in Jakholi and Augustmuni.

Table 17: Main and Marginal Workers and ratio (2001)

| Development Blocks | Main Worker | | | | | Marginal Workers | Ratio |
|---|---|---|---|---|---|---|---|
| | Cultivators | Agricultural Labourers | Household Industry Workers | Other Workers | Total | | Main Workers/Marginal Workers |
| Augustmuni | 26875 | 136 | 521 | 9032 | 36564 | 11638 | 3.1 |
| Jakholi | 16845 | 65 | 197 | 4689 | 21796 | 9975 | 2.2 |
| Karnprayag | 5758 | 43 | 179 | 3073 | 9053 | 9979 | 0.9 |
| Dasholi | 3225 | 10 | 538 | 2530 | 6303 | 10116 | 0.6 |
| Pokhri | 5073 | 71 | 157 | 2236 | 7537 | 8392 | 0.9 |
| Pauri | 6556 | 63 | 108 | 2450 | 9177 | 3959 | 2.3 |
| Khirsu | 3712 | 48 | 71 | 2760 | 6591 | 2892 | 2.3 |
| Kot | 6979 | 41 | 61 | 1942 | 9023 | 1924 | 4.7 |
| Devprayag | 13033 | 44 | 208 | 3457 | 16742 | 6305 | 2.7 |
| Kirti Nagar | 9123 | 81 | 143 | 4367 | 13714 | 6510 | 2.1 |




Cultivators are predominant in the region followed by other workers. This implies that more number of workers is involved in tertiary activities than those involved in secondary activities. Agricultural labourers are negligible in the region. Number of marginal workers in Dasholi is almost twice the number of main workers in Dasholi. Karnprayag and Pokhri too have more marginal workers than main workers indicating the employment instability in the same region. Main workers are dominant in Jakholi and Augustmuni.

## 5.3 Activities

Activities are further divided into three categories namely primary, secondary and tertiary activities. Majority of the study area population is involved in primary sector activities followed by tertiary sector (predominantly tourism) while the secondary sector lacks behind.

### 5.3.1 Primary activities

The major primary activities observed in study area are agriculture, livestock, forestry and fisheries.

#### *5.3.1.1 Agriculture*

Agriculture of cereal crops and livestock farming are the primary occupations of the people in the study region .The main crops are millets, pulses, paddy, wheat, barley, and oilseeds.

Table 18: Area under Agricultural Use Block Wise

| Name | Agriculture - Crop Land | Agriculture - Plantation | Agriculture - Fallow |
|---|---|---|---|
| Agastmuni | 273.19 | 2656.51 | 56.21 |
| Jakholi | 35.64 | 886.59 | 25.41 |
| Karnaprayag | 517.44 | 345.30 | 0.00 |
| Dasholi | 2945.35 | 1161.41 | 246.47 |
| Pokhri | 5669.29 | 5485.56 | 125.89 |
| Pauri | 549.95 | 258.19 | 4.36 |
| Khirsu | 1604.52 | 646.89 | 30.35 |
| Kot | 3634.13 | 646.09 | 325.88 |
| Deoprayag | 4573.23 | 1152.08 | 2.22 |
| Kirti Nagar | 1655.45 | 505.22 | 73.95 |

| | | | |
|---|---|---|---|
| **Total** | 21458.17 | 13743.85 | 890.75 |

*Source: Calculated by author from map and block boundary map*

The net sown area and gross sown area is low in highland blocks. Land under Agriculture is dominant in Pokhri and Khirsu

Figure 38: Agriculture map (2005)

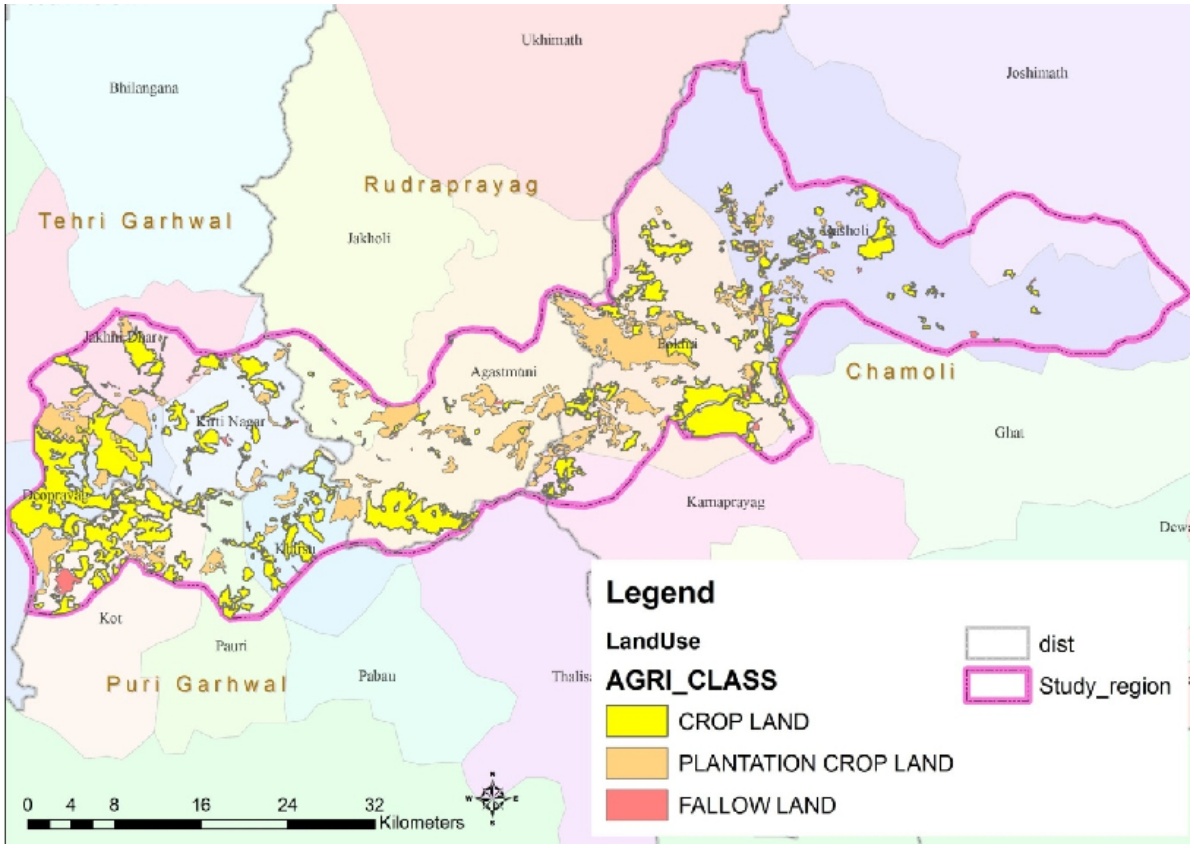
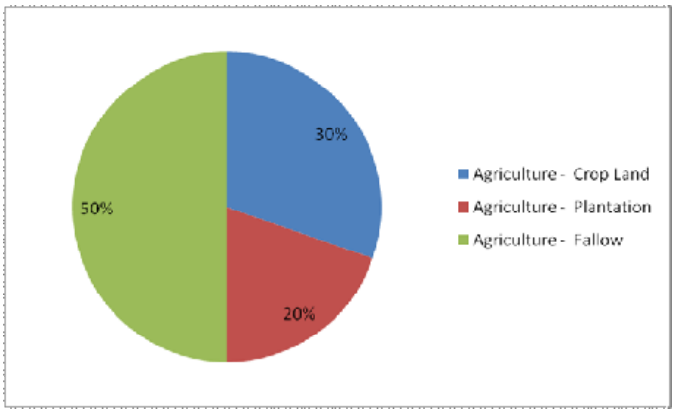



Figure 39: Area distribution of total agriculture land into sub classes



#### 5.3.1.1.1 Land Holding Size

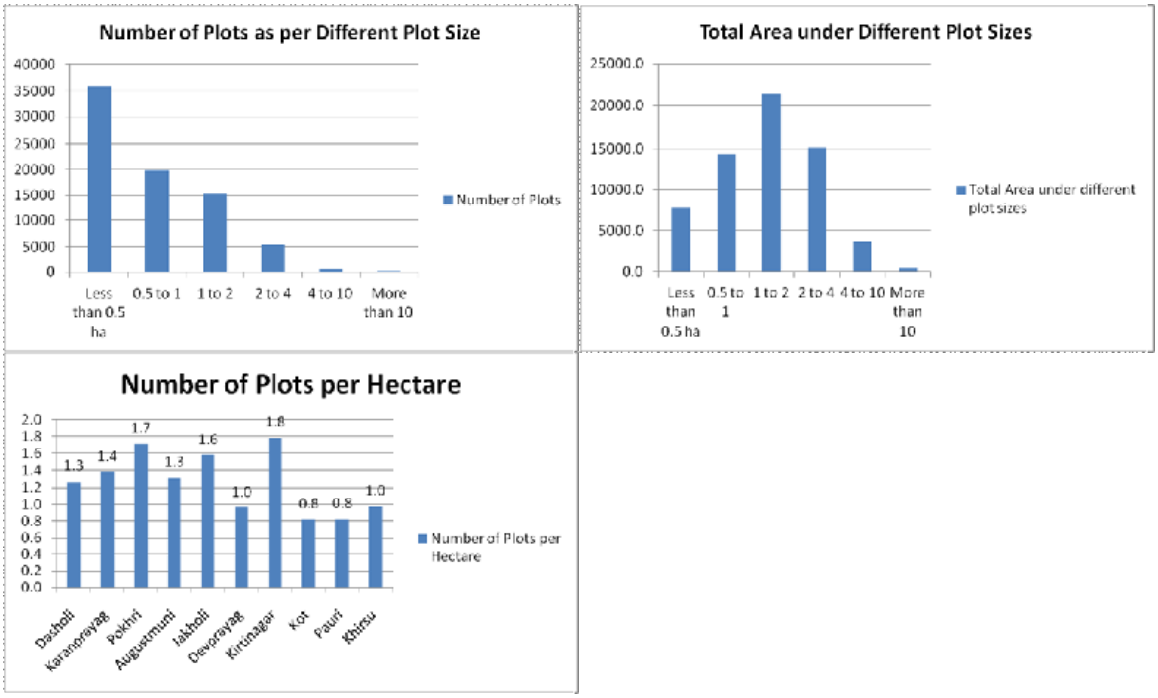
Land holding size means the ownership distribution of land parcels. The land holding size has been classified into six sub divisions ranging from >0.5ha to < 10ha. Information regarding these divisions is given in terms of number of owners in that particular range and area falling in that class of ownership.

| Blocks | Less than 0.5 ha | | 0.5 to 1 | | 1 to 2 | |
|---|---|---|---|---|---|---|
| | Number | Area | Number | Area | Number | Area |
| Dasholi | 2872 | 585.19 | 1389 | 1001.25 | 972 | 1412.69 |
| Karanprayag | 3961 | 742.627 | 1426 | 1037.16 | 1108 | 1577.84 |
| Pokhri | 4637 | 757.48 | 1010 | 747.14 | 803 | 1152.24 |
| Augustmuni | 3110 | 657 | 404 | 413 | 661 | 872 |
| Jakholi | **8557** | 2065 | **5178** | 3508 | 2542 | 3401 |
| Devprayag | 3882 | 916 | 3010 | 2163 | **2822** | 4011 |
| Kirtinagar | 4954 | 1043 | 2430 | 1901 | 1105 | 1479 |
| Kot | 1144 | 316 | 1528 | 1151 | 1619 | 2272 |
| Pauri | 1471 | 407 | 1990 | 1499 | 2036 | 2862 |
| Khirsu | 1262 | 302 | 1427 | 1059 | 1672 | 2341 |
| Total | 35850 | 7791.3 | 19792 | 14479.6 | 15340 | 21380.8 |

| Blocks | 2 to 4 | | 4 to 10 | | More than 10 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number | Area | Number | Area | Number | Area | Number | Area |
| Dasholi | 468 | 1226.4 | 54 | 283.71 | 3 | 28 | 5758 | 4537.24 |
| Karanprayag | 553 | 1489.96 | 43 | 242.52 | 5 | 62 | 7096 | 5152.11 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Pokhri | 305 | 804.67 | 86 | 455.61 | 6 | 84 | 6847 | 4001.14 |
| Augustmuni | 186 | 825 | 109 | 588 | 3 | 52 | 4473 | 3407.00 |
| Jakholi | 447 | 1495 | 29 | 161 | 0 | 0 | 16753 | 10630.00 |
| Devprayag | 990 | 3115 | 215 | 1097 | 0 | 0 | 10919 | 11302.00 |
| Kirtinagar | 274 | 464 | 3 | 18 | 0 | 0 | 8766 | 4905.00 |
| Kot | 733 | 1959 | 84 | 428 | 5 | 94 | 5113 | 6220.00 |
| Pauri | 971 | 2595 | 83 | 423 | 7 | 125 | 6558 | 7911.00 |
| Khirsu | 466 | 1213 | 6 | 27 | 0 | 0 | 4833 | 4942.00 |
| Total | 5393 | 15187 | 712 | 3723.8 | 29 | 445 | 77116 | 63007.50 |

Kirti Nagar, Pokhri and Jakholi have the highest number of plots per hectare. Although the average size of the holdings is quite small (<1ha) the number of crops may vary from 17 to 30 per household (Sharma and Sharma, 1993; Rao and Saxena, 1994; Maikhuri et al., 2000; Sen et al., 2002).




### 5.3.1.1.2 Irrigation

Agriculture is dependent on rain fed irrigation. Only 8.8% of cropped area is irrigated. Irrigation is done only in valley regions. Irrigation is mainly done by small canals locally known as gools.

| S. No. | Name | Net irrigated Percentage |
|---|---|---|
| 1. | Augustmuni | 12.6 |
| 2. | Jakholi | 12.6 |
| 3. | Devprayag | 12.7 |
| 4. | Kirtinagar | 13 |
| 5. | Kot | 4.9 |
| 6. | Pauri | 6 |
| 7. | Khirsu | 7.2 |
| 8. | Pokhri | 7.6 |

| | | |
|---|---|---|
| 9. | Karanprayag | 2.9 |
| 10. | Dasholi | 8.4 |

*Source: Sati (2005)*

#### 5.3.1.1.3 Cropping Pattern

Mixed cropping is practiced in the Alaknanda basin. Paddy is the only crop whose cultivation is not carried out with other crops. At a given agricultural plot, different crops are grown in different times. Table 20 represents percentage of cropped area in the Alaknanda basin as per a study conducted by Sati (2005). Sati's study has revealed that the number of crops cultivated by a household may vary from 17 to 30.

Table 19: Cropping Pattern in Alaknanda Basin

| Crop | Percentage of cropped area |
|---|---|
| Rice | 25.4 |
| Wheat | 34.4 |
| Barley | 2.9 |
| Maize | 0.8 |
| Mandua | 19.9 |
| Sava | 11 |
| Urd | 0.7 |
| Masur | 0.3 |
| Pea | 0.03 |
| Tour | 0.2 |
| Mustered | 0.7 |

| | |
|---|---|
| Linseed | 0.2 |
| Soya Bean | 0.2 |
| Potato | 2.6 |
| Total | 100 |

*Source: Sati (2005)*

#### 5.3.1.1.4 Cropping Intensity

Throughout the study area, agriculture of subsistence crops is dominant.

| SUBSISTENCE CROP AND SOWN AREA | | | |
|---|---|---|---|
| Development Blocks | (Subsistence Crop Area/Net Sown Area)*100 | | |
| | 2001-02 | 2008-09 | 2009-10 |
| Augustmuni | 78.4 | 28.5 | 28.5 |
| Jakholi | 113.5 | 40.9 | 40.9 |
| Karnprayag | 88.1 | 89.9 | 91.0 |
| Dasholi | 91.4 | 91.2 | 92.3 |
| Pokhri | 97.0 | 100.1 | 101.4 |
| Pauri | 89.2 | 75.4 | 74.5 |
| Khirsu | 92.7 | 96.1 | 95.3 |
| Kot | 86.8 | 76.2 | 75.8 |
| Devprayag | 89.3 | 94.4 | 95.6 |
| Kirti Nagar | 90.7 | 106.1 | 113.3 |

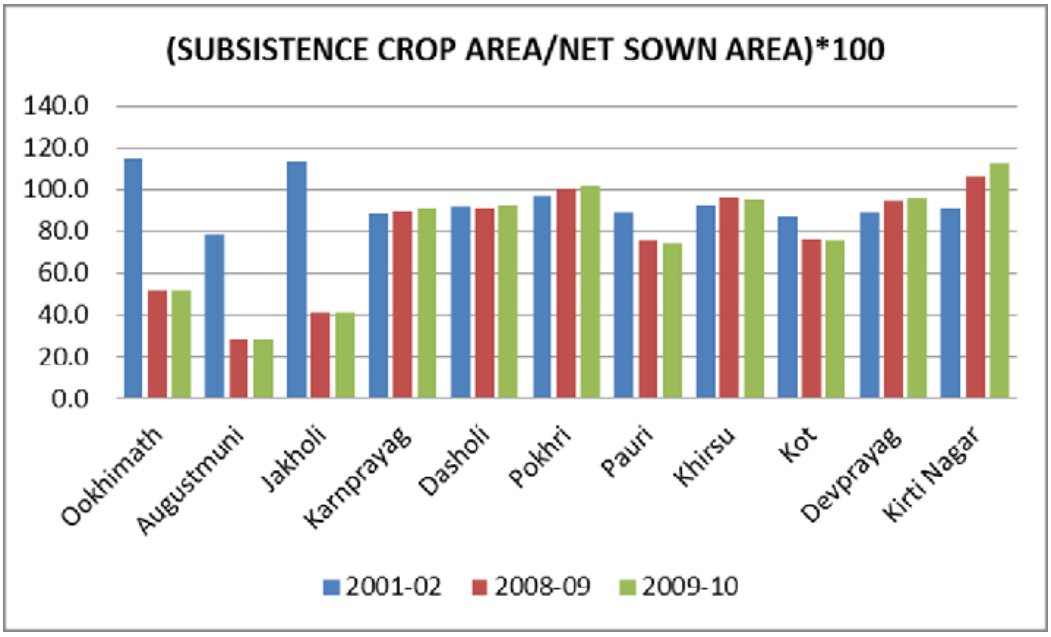
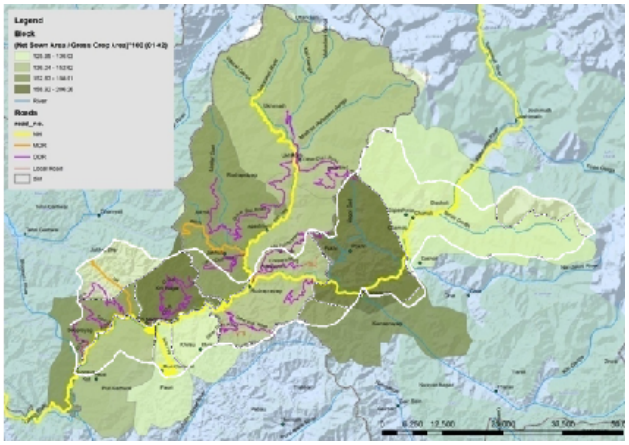



Figure 40: Cropping intensity (01-02) & (09-10)



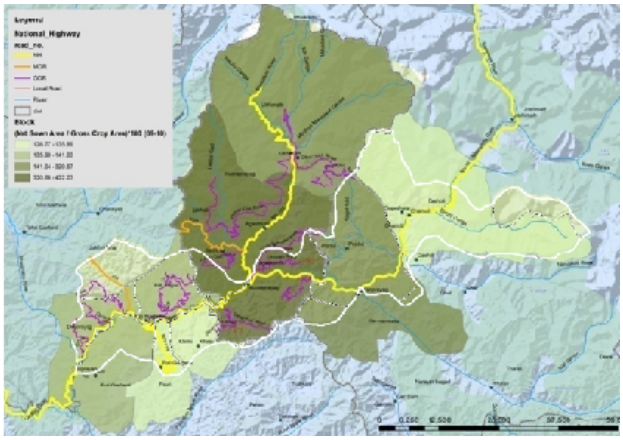


Table 20: Block wise Cropping Intensity

| Development Blocks | (Net Sown Area/Gross Crop Area) *100 | | |
|---|---|---|---|
| | 2001-02 | 2008-09 | 2009-10 |
| Augustmuni | 152.6 | 418.3 | 418.3 |
| Jakholi | 152.6 | 422.2 | 422.2 |

| | | | |
|---|---|---|---|
| Karnprayag | 157.5 | 157.7 | 157.7 |
| Dasholi | 136.0 | 132.5 | 132.5 |
| Pokhri | 206.3 | 204.1 | 204.1 |
| Pauri | 126.0 | 138.6 | 135.9 |
| Khirsu | 135.2 | 96.1 | 126.8 |
| Kot | 145.6 | 143.8 | 141.0 |
| Devprayag | 158.9 | 133.0 | 139.1 |
| Kirti Nagar | 166.0 | 129.2 | 136.6 |

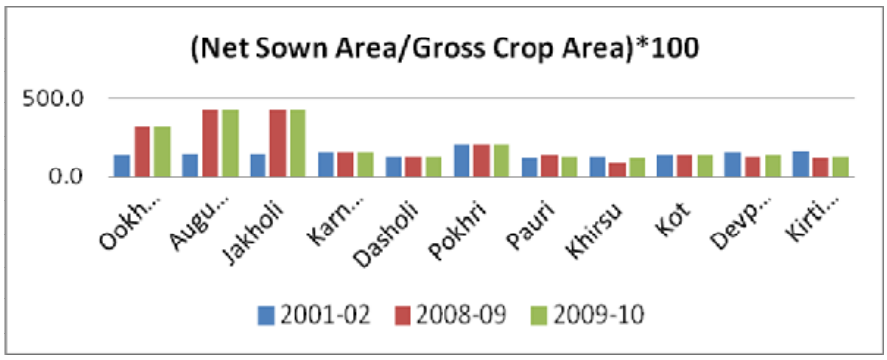
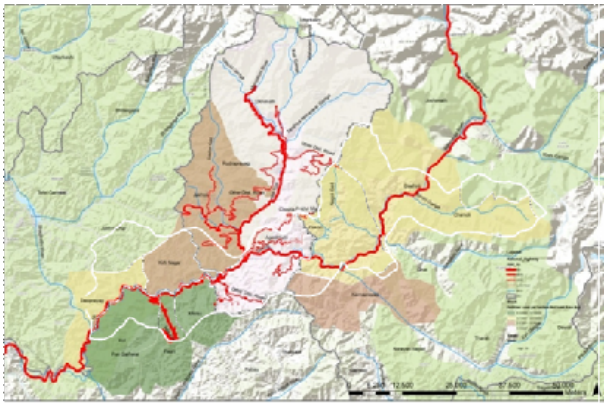
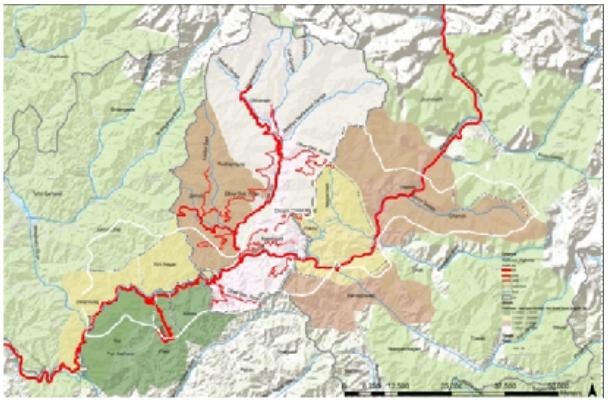



Figure 41: Fertilizer used per hectare Net Sown Area (kg) 2001 & 2009-10





#### 5.3.1.1.5 Type of Farming Practice:

Subsistence cereal farming is dominant in the region. The main crops grown during the Rabi Season (September to May) include wheat, barley, pulses, oilseeds, vegetables and potatoes. The main crops grown during Kharif season (April to September) include paddy, mandua and potatoes. Studies reveal that the productivity of vegetables is much higher than the traditional crops. The different type of cash crops includes potato, onion, tomato, pumpkin, cucumber, beans, radish, carrot, ginger, turmeric, garlic, chili, bay leaf coriander and green leaves.

Terrace forming is practiced on narrow patches of land. Owing to fragility of land, intensive cultivation cannot be carried out. Area under subsistence crop is much higher than vegetables. The different types of crops grown vary from season to season and valley to higher regions. Agriculture carried on narrow patches of terraced fields.

#### 5.3.1.1.6 Issues

The main issues with regard to agriculture are lack of irrigation facilities, smaller land holding sizes, fragile terrain, soil erosion and traditional methods of agricultural practice.

### *5.3.1.2 Horticulture*

Only 0.6% of total cultivated area (12%) is under fruit cultivation. The agro-ecological condition and landscape of basin have altitudinal diversity. This provides cultivation of various kinds of fruits.

Table 21: Distribution of Fruits in the Alaknanda basin

| Type | Altitude (m) | Agro-ecological zone | Producing area |
|---|---|---|---|
| Apple, Pear, Peach, Almond, Apricot, and Nut | 1600-2200 | Temperate Cold | Bhyundar Ganga, Hathi Ganga, Upper Reaches of Nandakini, Pindar and Mandakini Rivers |
| Citrus-lemon, orange, mandarin, and elephant crans | 1000-1600 | Sub-Temperate to Temperate | Mid-Altitudinal Regions of Nandakini, Pindar and Mandakini, Higher Reaches of Lower Alaknanda Basin |
| Guava, papaya and mango | 500-1000 | Sub Tropical | Low-Lying Areas (River Valleys), Nandakini, Pindar, Mandakini and Alaknanda |
| Wild fruits- pear, peach, kafal, ber, hansul, and bhamore | 500-2200 | Sub Tropical to Temperate Cold | In entire region of the Alaknanda River and its Tributaries |

*Source: Sati (2005)*

#### 5.3.1.3 Livestock

Animal husbandry is the second main primary occupation. Livestock are reared for ploughing agricultural land and providing manure; dairy farming and poultry farming. Wool is extracted from goats and sheep. Bee keeping is also practiced in some areas.

### 5.3.2 Secondary activities

#### 5.3.2.1 Industries

Very few industries exist in the Alaknanda river basin. As can be seen from the map below, only three mini industrial estates exist in the region. Less than 5% of the total workers are engaged in secondary activities in the mid stream and upstream. 5 to 10 percent of the total workers are involved in the industrial sector.

Figure 42: Industries and Industrial Worker in Study Area

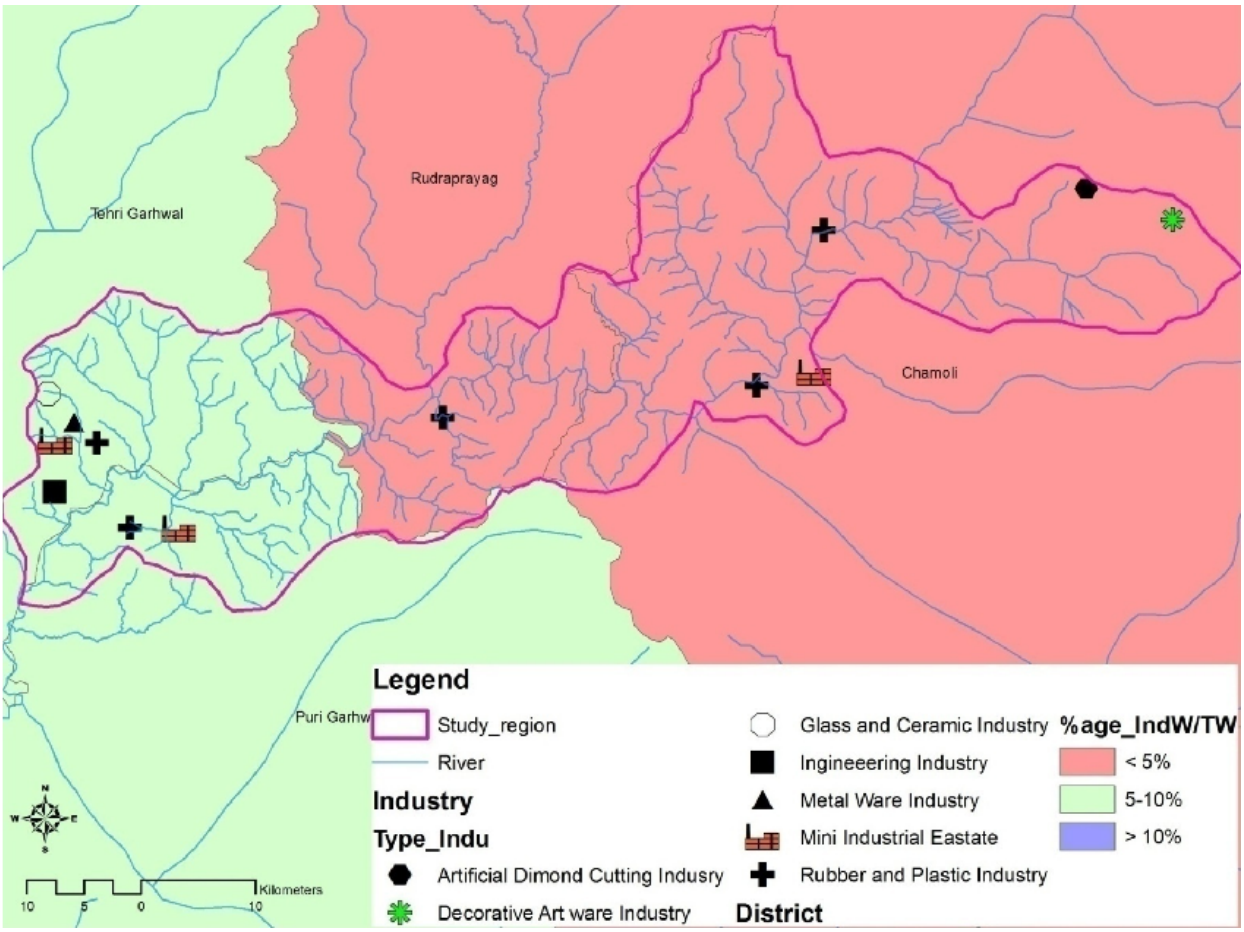
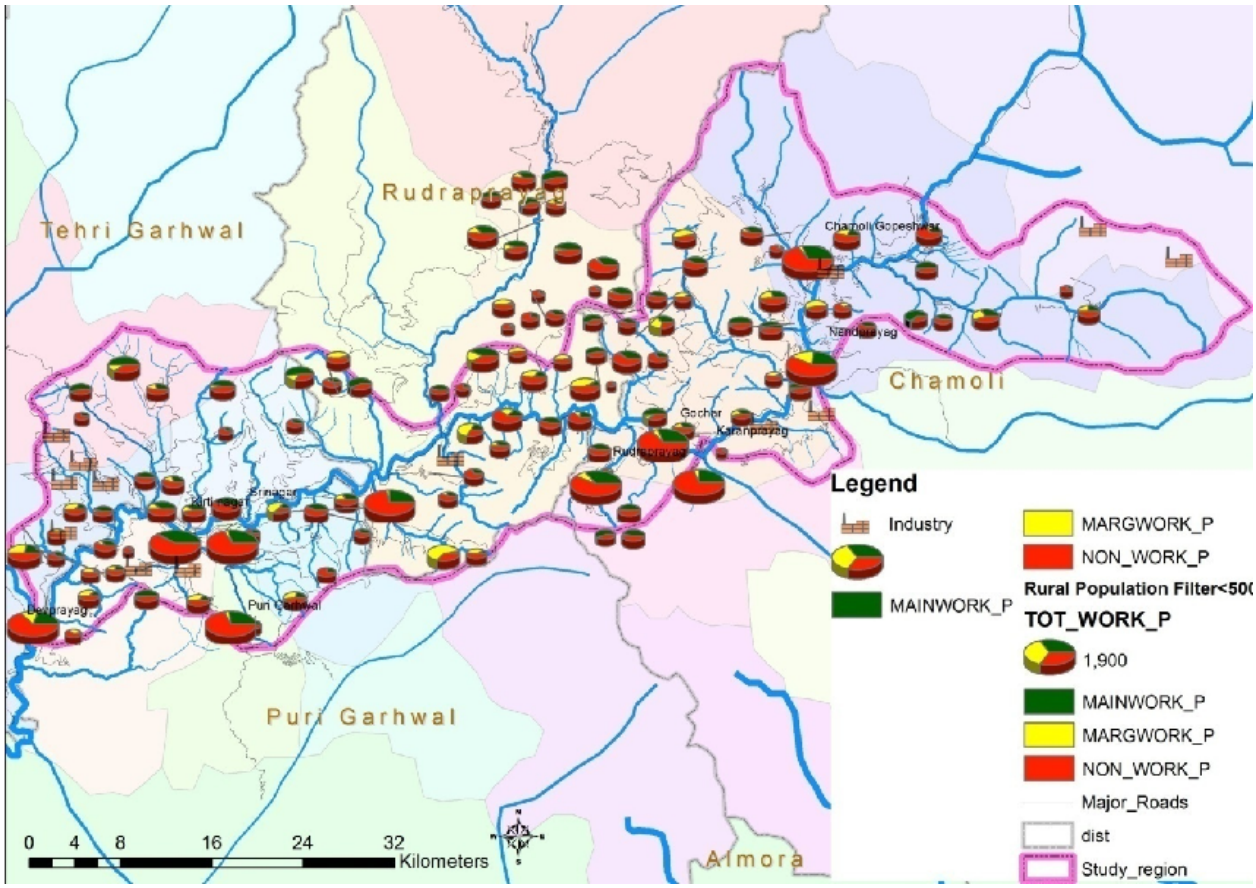


Figure 43: Workers Distribution in study area



### 5.3.3 Tertiary Activity

#### *5.3.3.1 Tourism*

Tourism plays a significant role in the economy of the concerned area. Various types of tourism exist in this region. The different types of tourism include natural tourism, adventure tourism, wildlife tourism, cultural tourism and pilgrim tourism.

| Tourist Inflow in Uttarakhand in % | |
|---|---|
| Garhwal | 11.3 |
| Kumaon | 17.5 |
| Other State | 71.2 |

| Percentage of Tourist by Purpose in Uttarakhand | |
|---|---|
| Pilgrimage | 60 |
| Pleasure | 25 |
| Business | 10 |
| Others | 5 |

| Percentage of Tourist by Physiographic Zone | |
|---|---|
| Sivaliks | 60 |
| Lesser Himalayas | 25 |
| Middle Himalayas | 10 |
| Higher Himalayas | 5 |

| Tourist Inflow in Gopeshwar and Karnaprayag | | |
|---|---|---|
| Year | Gopeshwar | Karnaprayag |
| 1985 | 7445 | 18000 |
| 1986 | 8644 | 19996 |
| 1987 | 10008 | 24359 |
| 1988 | 8961 | 70110 |
| 1989 | 10313 | 10350 |

| | | |
|---|---|---|
| 1990 | 13050 | 11389 |
| 1991 | 10271 | 13552 |
| 1992 | 13092 | 15200 |
| 1993 | 13535 | 17350 |
| 1994 | 7777 | 16245 |
| 1995 | 9681 | - |

#### 5.3.3.1.1 Natural Tourism

The Alaknanda basin is comprised of high elevation snow-clad mountains, deep valleys, waterfalls, gorges and lush green landscapes. The area has a rich biodiversity comprising of varied flora and fauna.

#### 5.3.3.1.2 Adventurer Tourism

Adventure tourism attracts a major number of tourists per year. Alaknanda River is famous for river rafting. Trekking routes also dominate this region.

#### 5.3.3.1.3 Wildlife Tourism

Binsar Wildlife Sanctuary is located in this region. It is 33 km away from the town of Almora. The different fauna here include leopard, deer, bear, fox, monkey and variety of birds. Flora consists of pine, oak, alpine and hanging mosses.

#### 5.3.3.1.4 Pilgrimage Tourism

The Alaknanda basin is famous for its pilgrimage tourism. Tourists cross this region while performing the "Char Dham Yatra". The four pilgrim centres include Badrinath, Kedarnath, Yamnotri and Gangotri

*Panch Prayag*

Major rivers meet with the Alaknanda River. These places are known as 'Prayags'. 'Prayags' are only found in the Alaknanda River.

| Place of Confluence | Name of Rivers |
|---|---|
| Vishnu Prayag near Joshimath | Dauli Ganga and Alaknanda |
| Nandprayag | Nandakini and Alaknanda |

| | |
|---|---|
| Karanprayag | Pindar and Alaknanda |
| Rudraprayag | Mandakini and Alaknanda |
| Devprayag | Bhagirathi and Alaknanda |

*Panch Kedars*

Panch Kedar includes Kedarnath, Tungnath, Madhyamaheshwar, Rudranath, and Kalpeshwar. Amongst these, only Tungnath falls in the study area.

#### 5.3.3.1.5 Issues for tourism

The main issues with respect to tourism include poor road condition, lack of infrastructural facilities, land degradation, increased use of firewood in dhabas, and garbage problems.

## 5.4 Infrastructure and Services

Infrastructure is categorized in two subdivision named Social infrastructure and Physical infrastructure.

### 5.4.1 Social Infrastructure

Social infrastructure includes facilities related to education, health, communication and security.

#### *5.4.1.1 Education*

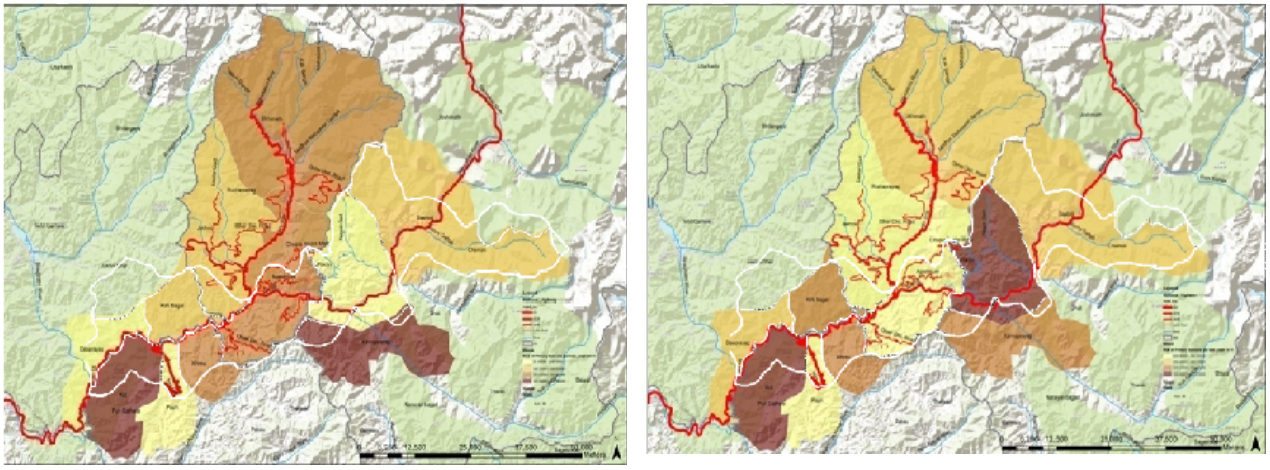
The number of primary and middle schools has increased considerably in Pokhri and Devprayag. Number of primary schools per lakh population has experienced negative growth in case of Karnprayag and Pauri. The growth of educational facilities has remained almost stagnant in other blocks.

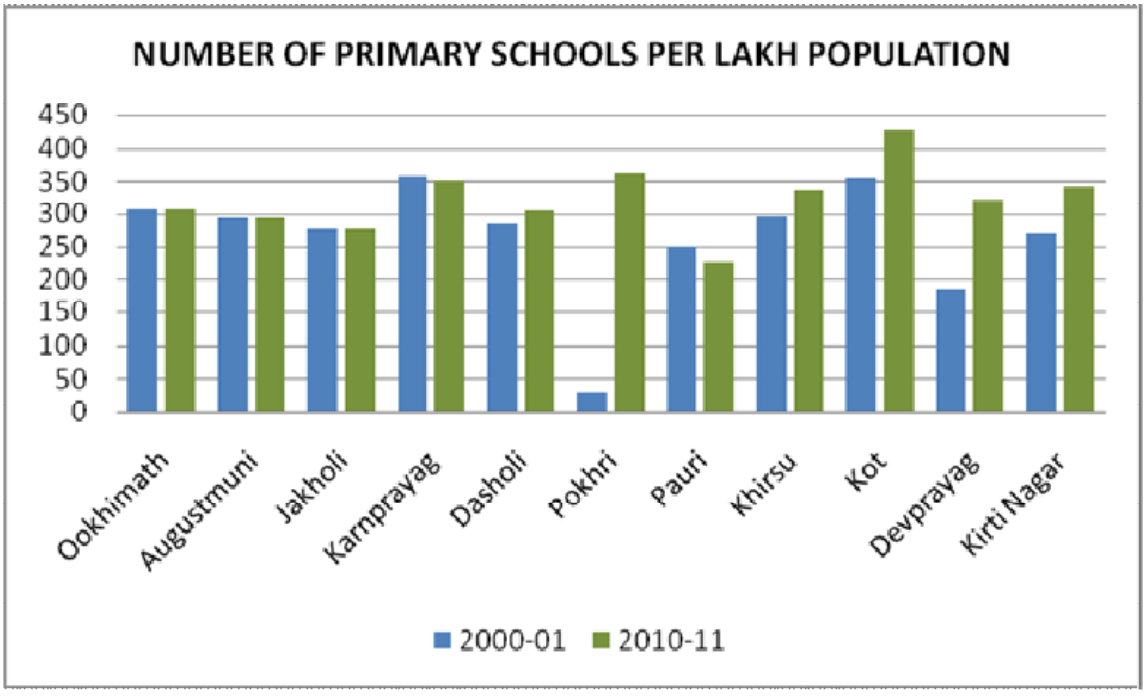
Table 22: Educational Facilities per Lakh Population (2010-11)

| Development Blocks | No. of Primary Schools per lakh Population | | No. of Middle Schools per lakh Population | | No. of Higher Secondary Schools per lakh Population | |
|---|---|---|---|---|---|---|
| | 2000-01 | 2010-11 | 2000-01 | 2010-11 | 2000-01 | 2010-11 |
| Augustmuni | 292.26 | 292.26 | 53.14 | 53.14 | 35.73 | 35.73 |
| Jakholi | 277 | 277 | 78.53 | 78.53 | 45.69 | 45.69 |
| Karnprayag | 357.56 | 350 | 56.59 | 64.29 | 66.69 | 71.43 |
| Dasholi | 283.63 | 305.471 | 66.38 | 59.46 | 71.43 | 56.76 |
| Pokhri | 29.18 | 362.86 | 51.39 | 122.88 | 36.27 | 60 |
| Pauri | 248.7 | 225.89 | 73.3 | 45.93 | 41.4 | 91.86 |
| Khirsu | 296.3 | 337.57 | 72.8 | 62.51 | 68 | 87.52 |
| Kot | 354.7 | 426.13 | 97.3 | 89.92 | 45.2 | 66.46 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Devprayag | 184.44 | 320.51 | 38.51 | 104.31 | 28.38 | 43.62 |
| Kirti Nagar | 269.66 | 340.91 | 44.53 | 73.53 | 42.06 | 55.7 |

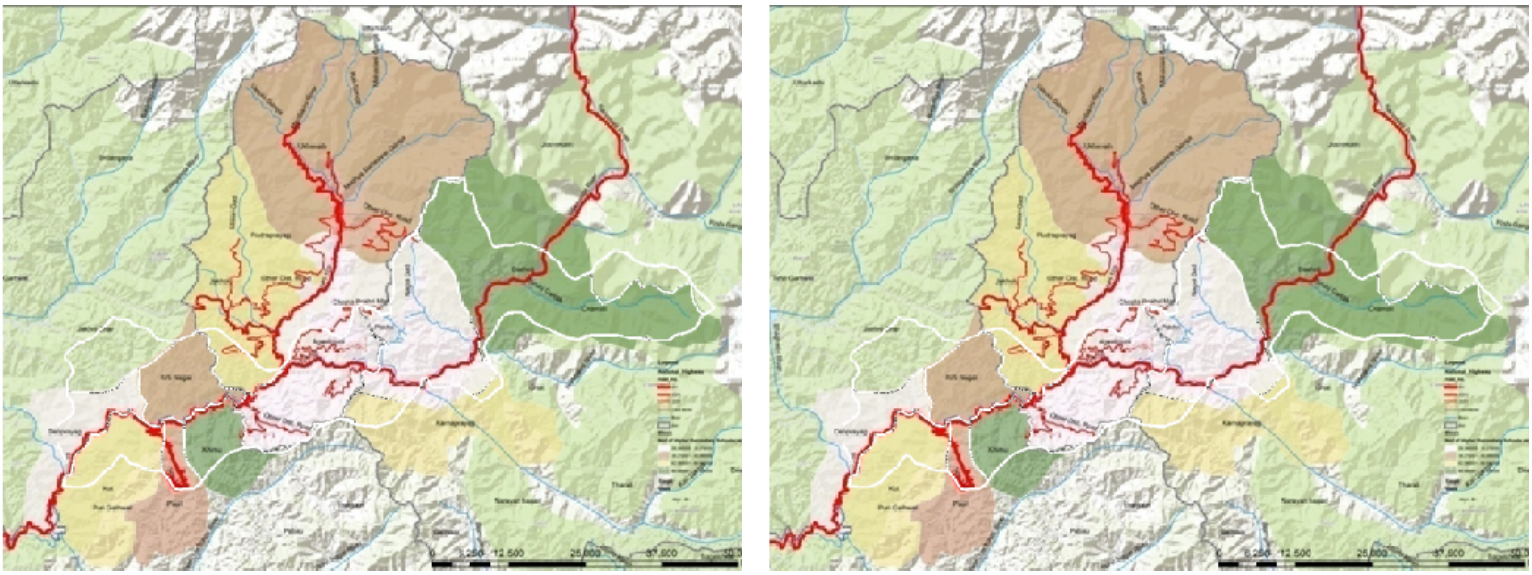
Figure 44: Number of Primary School per Lakh Population (2001& 2011)





Number of primary and middle schools has increased considerably in Pokhri and Devprayag. Number of primary schools per lakh population has experienced negative growth in case of Karnprayag and Pauri. The growth of educational facilities has remained almost stagnant in other blocks.

Figure 45: No. of Higher Secondary Schools per lakh population (2001 & 2011)



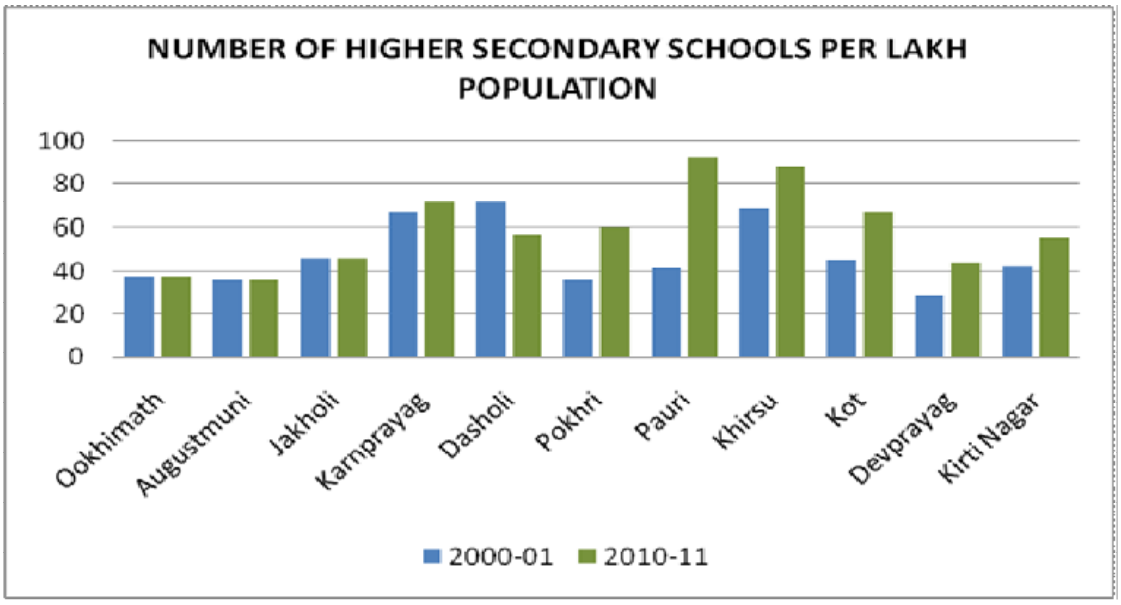


Figure 46: Number of Primary school per village (census, 01)

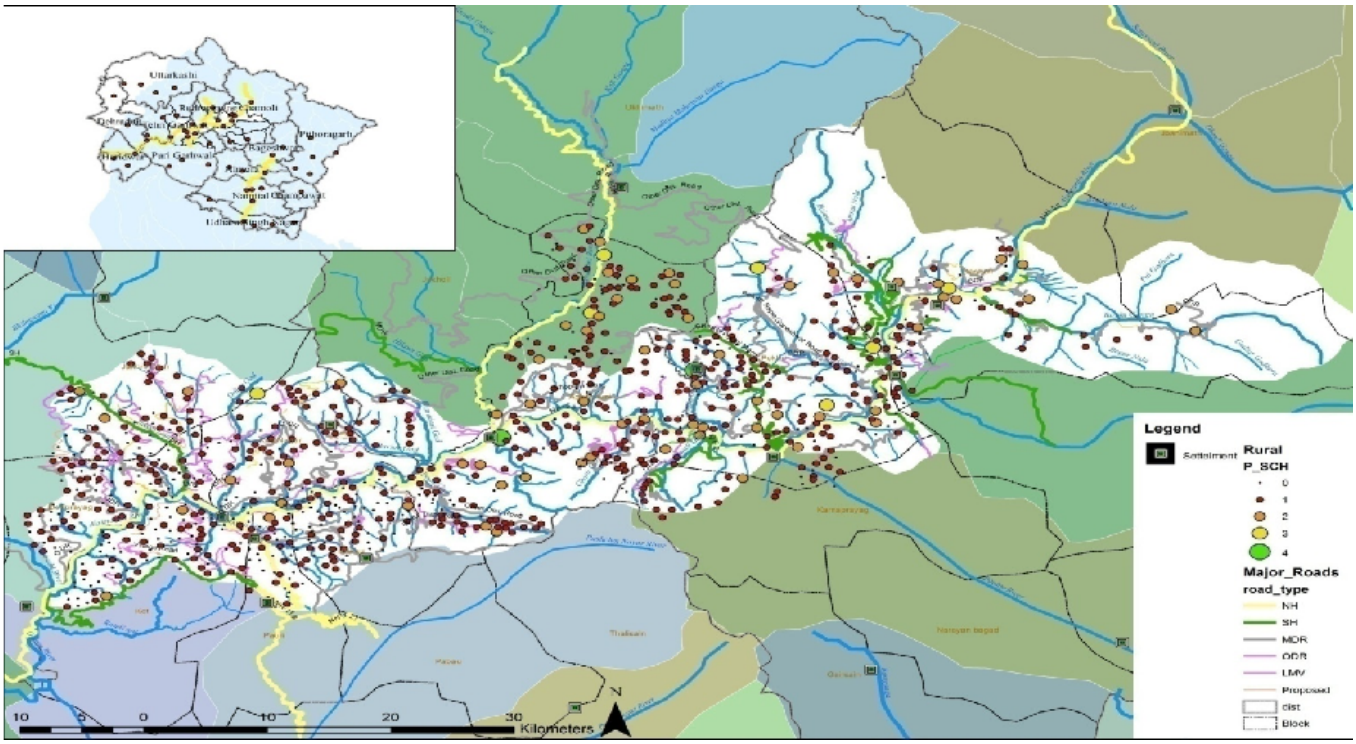



Figure 47: Euclidean distance for Primary school Range demarcation

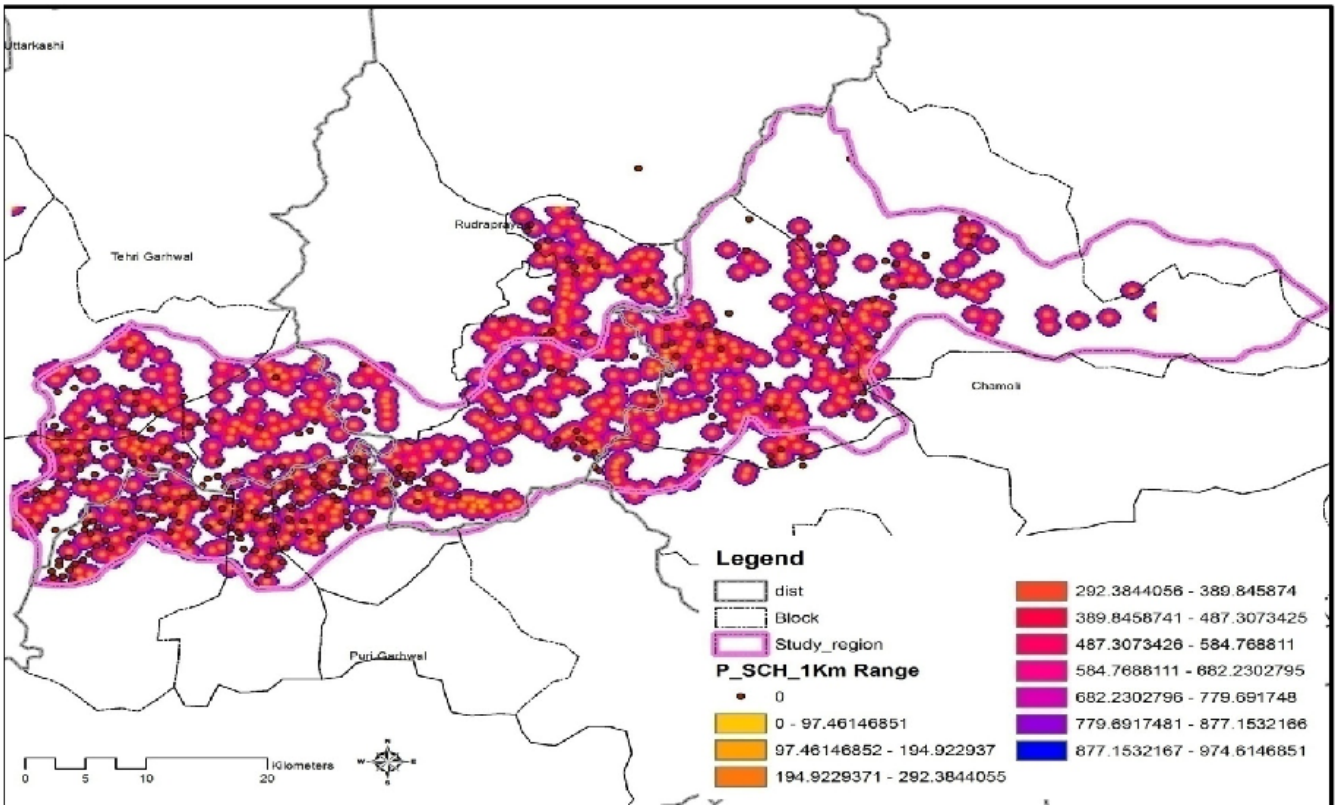


Figure 48: Number of Middle school per village

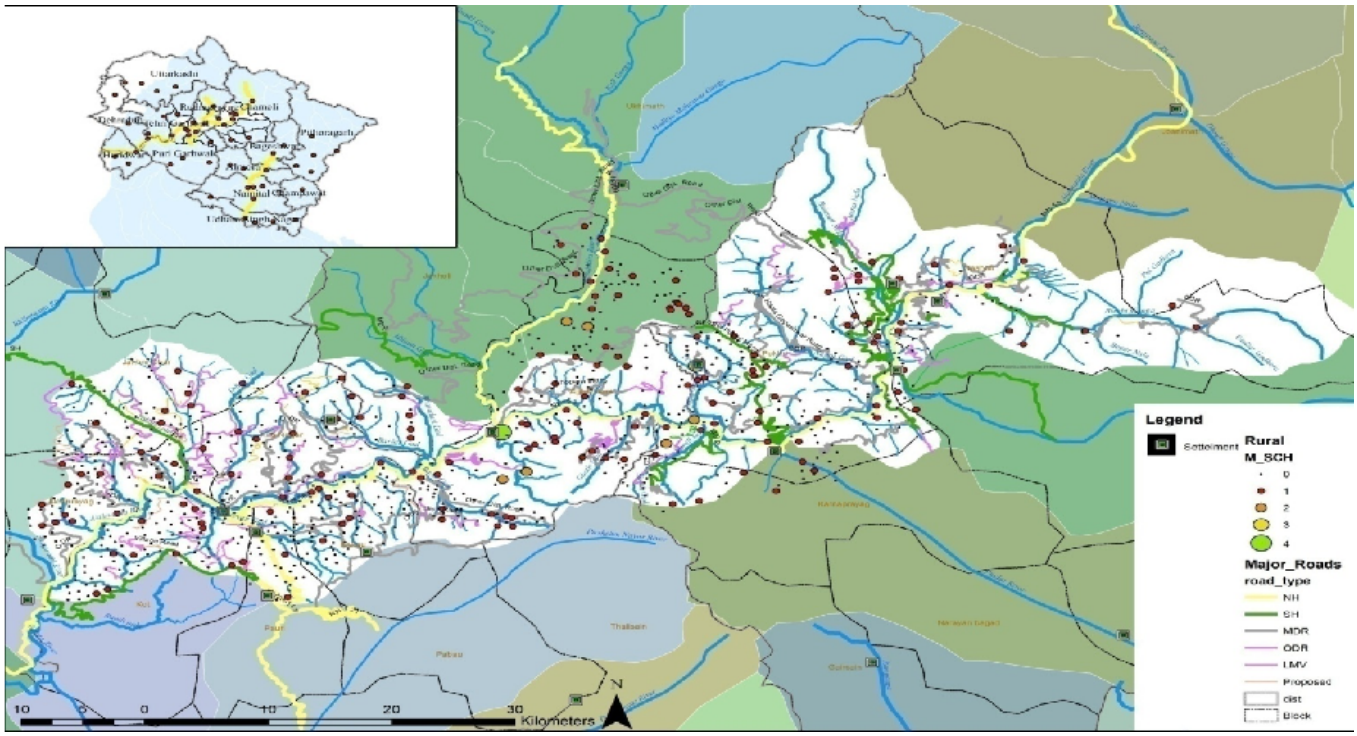
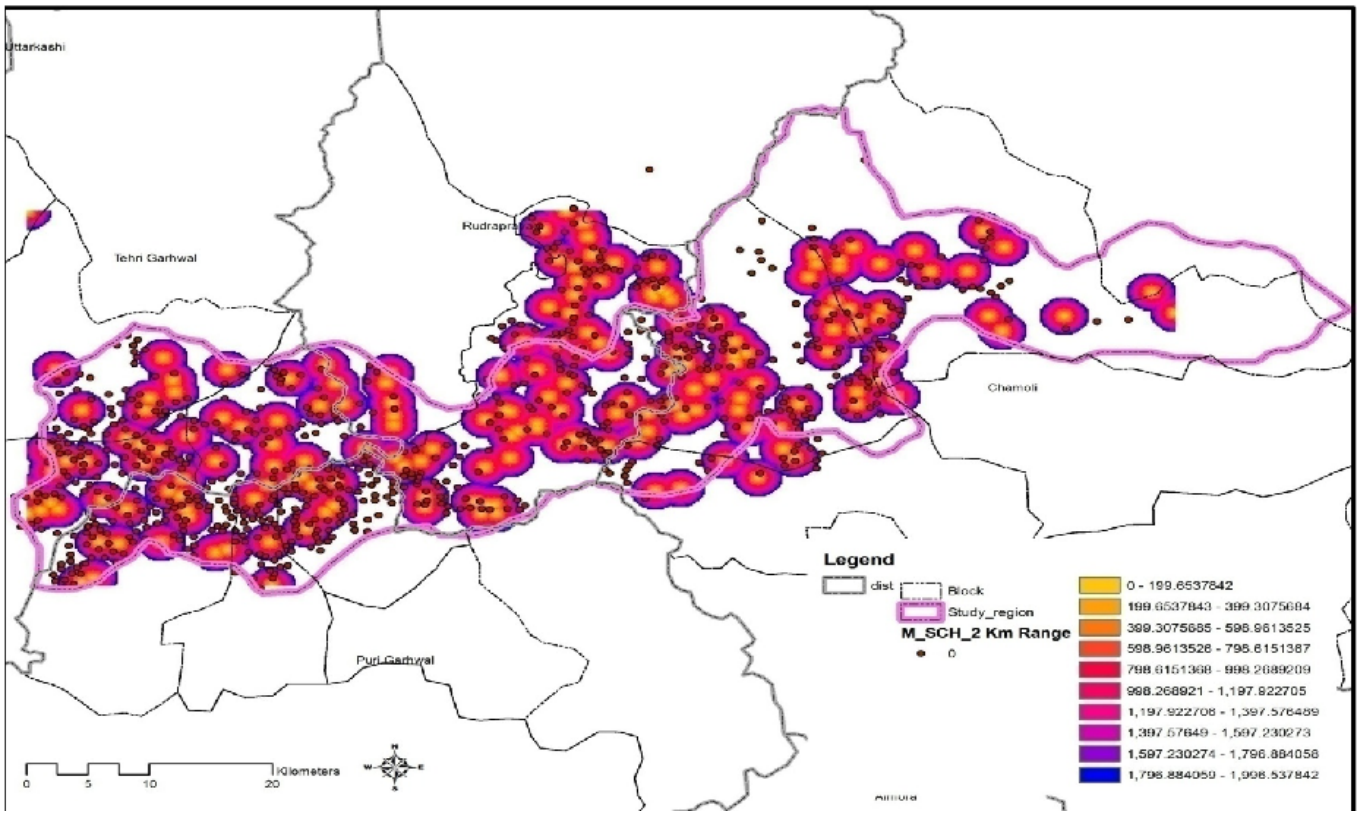



Figure 49: Euclidean distance for Middle school Range demarcation



### *5.4.1.2 Health Facilities*

The number of health facilities per lakh population has remained almost stagnant in the last decade. The number of Primary Health Centres per lakh population has increased considerably in Kirti Nagar followed by Karnprayag. The number of beds per lakh population has increased in Pokhri and Kirti Nagar. Table 25 and the figures following it give a glimpse of the number of health facilities available in the study area.

**Table 23: Health Facilities per Lakh Population in Study Area (2010-2011)**

| Development Blocks | No. of Allopathic Hospitals, Primary Health Centre and Community Health Centre per lakh Population | | No. of Primary Health Centres per lakh Population | | No. of Beds per lakh Population | |
|---|---|---|---|---|---|---|
| | 2000-01 | 2010-11 | 2000-01 | 2010-11 | 2000-01 | 2010-11 |
| Augustmuni | 14.66 | 14.66 | 2.75 | 2.75 | 87.95 | 87.95 |
| Jakholi | 9.99 | 9.99 | 4.28 | 4.28 | 82.81 | 82.81 |
| Karnprayag | 11.5 | 11.5 | 0 | 2.38 | 41.16 | 47.62 |
| Dasholi | 5.46 | 5.46 | 3.02 | 2.7 | 24.14 | 21.62 |
| Pokhri | 5.71 | 5.71 | 3.02 | 3.32 | 36.27 | 97.14 |
| Pauri | 13.12 | 13.12 | 6.3 | 6.56 | 51 | 52.49 |
| Khirsu | 20.84 | 20.84 | 4.8 | 4.17 | 97.1 | 83.35 |
| Kot | 23.46 | 23.46 | 6.9 | 7.82 | 83.4 | 93.83 |
| Devprayag | 11.38 | 11.38 | 4.05 | 1.9 | 40.54 | 87.24 |
| Kirti Nagar | 17.83 | 17.83 | 2.47 | 6.68 | 49.48 | 129.23 |

Figure 50: Health Facilities per lakh population

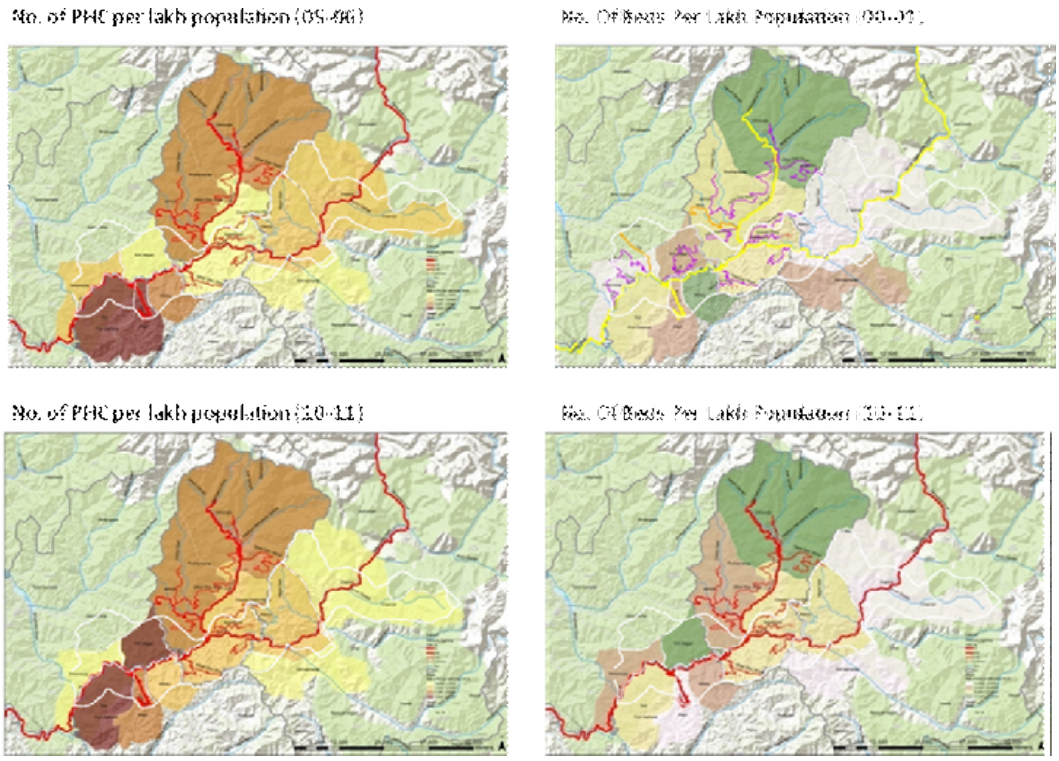


Figure 51: Coverage of available Primary Health Centers in Kms (census, 01)

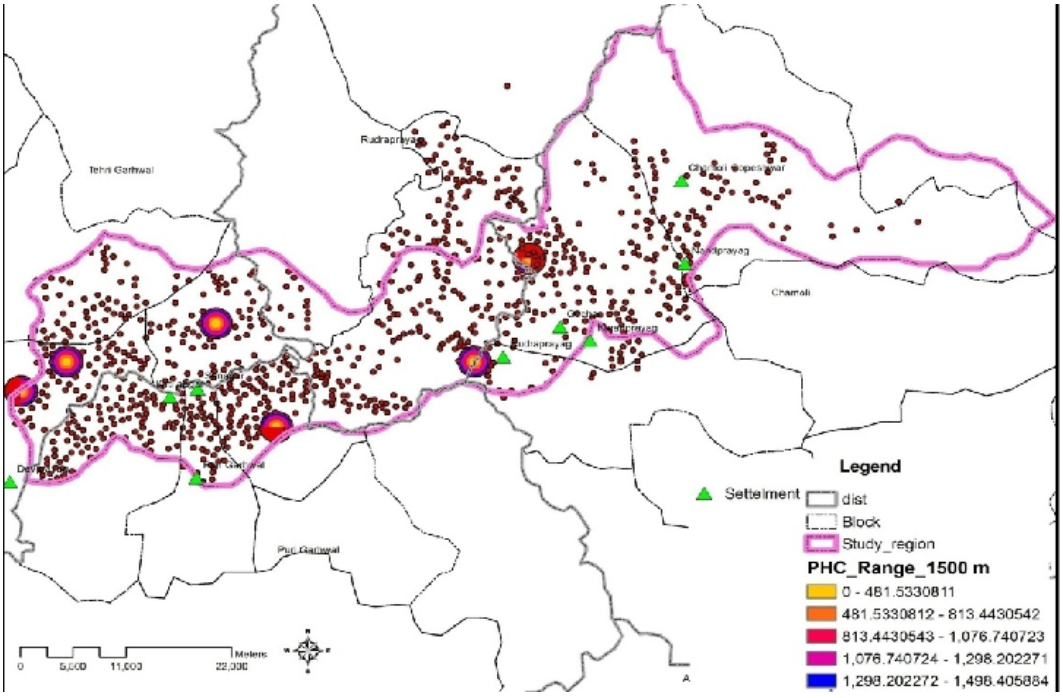
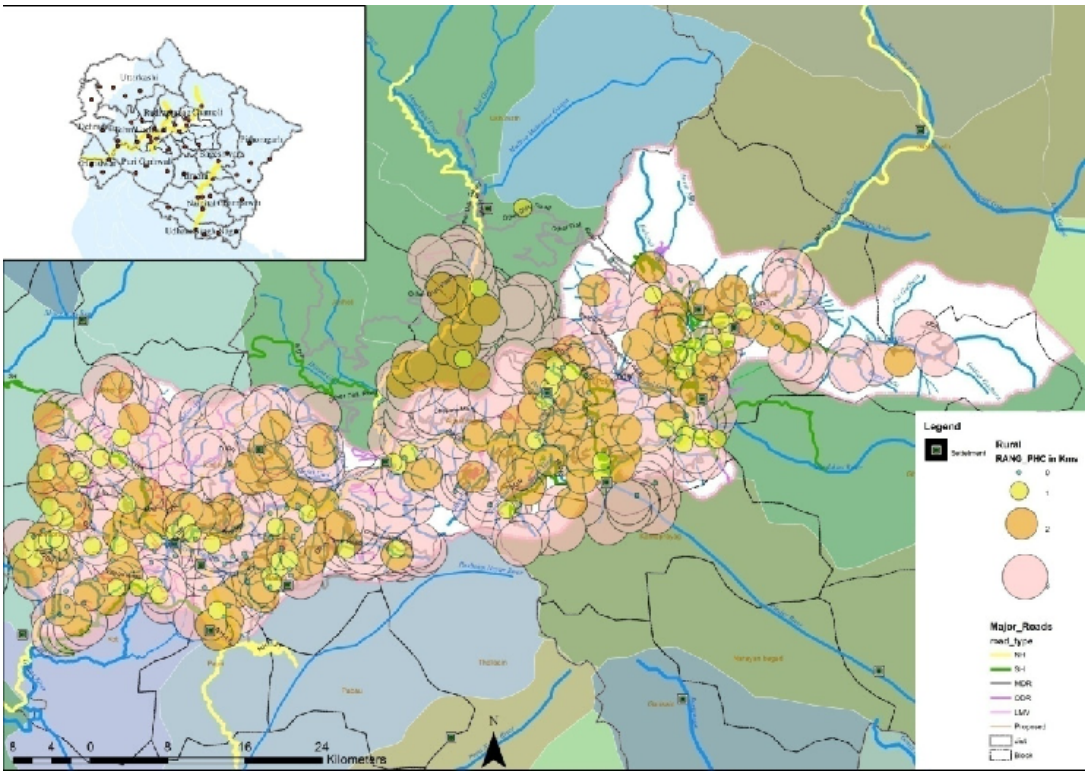


Figure 52: PHC access range for villages not having the same



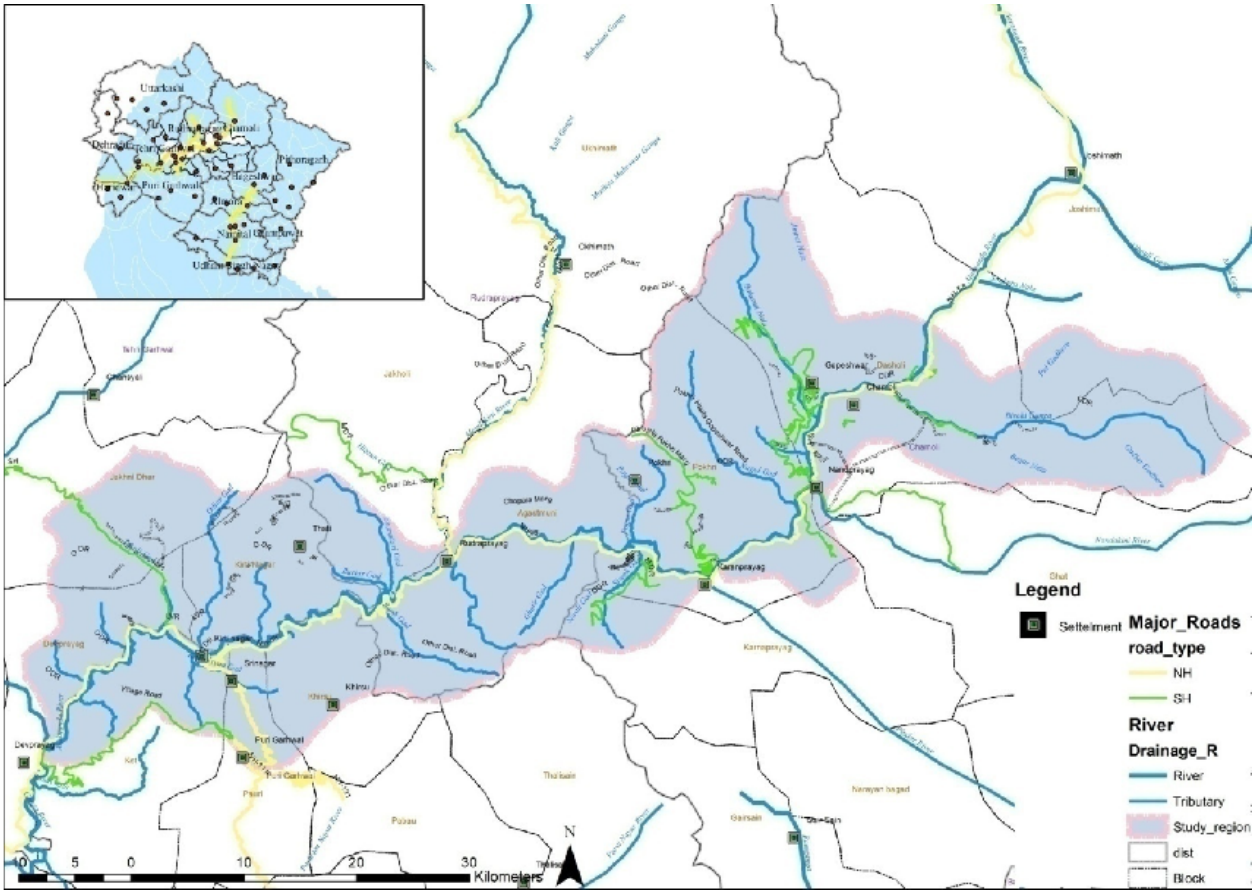
### 5.4.2 Physical Infrastructure

Physical infrastructure consists of roads, Water supply, utilities, hydro power plants, transmission lines and powerhouses.

#### *5.4.2.1 Roads*

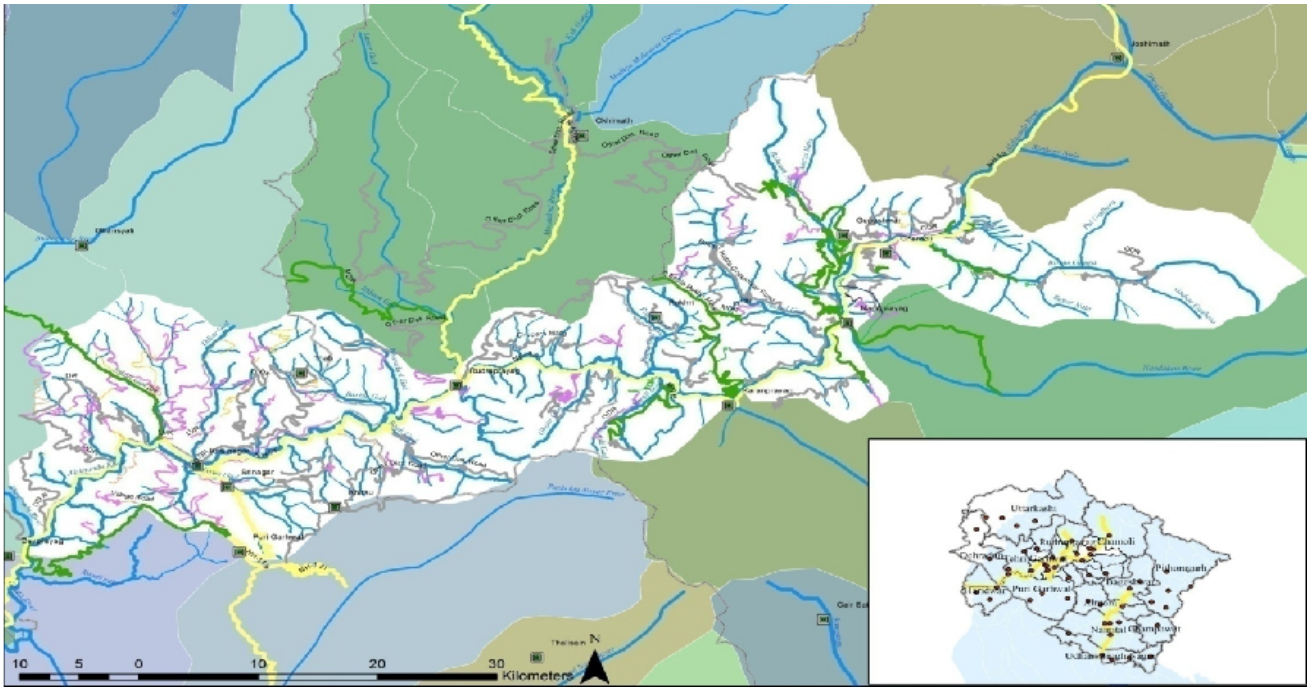
##### 5.4.2.1.1 Major Roads and its Spatial Coverage

Figure 53: Major Roads in the Study Area

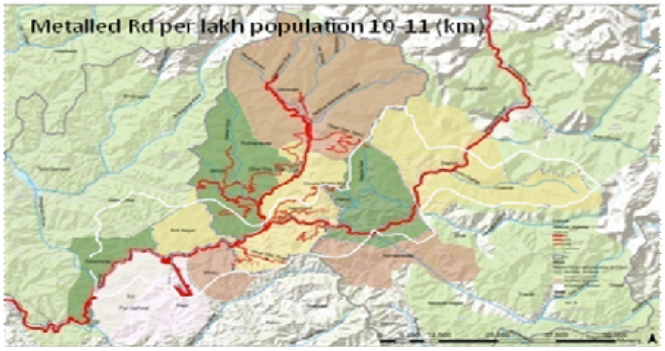


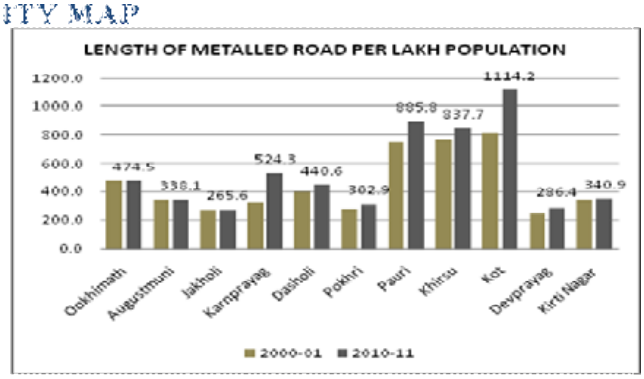

NH 58 which bifurcate the study area connects Devprayag to Mana. NH 21 starts from Kirti Nagar and towards south of the study area. NH 109 which splits from NH 58 connects to Badrinath and Kedarnath.

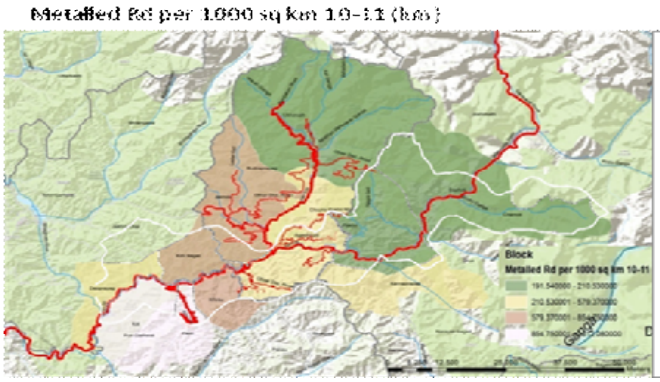
Figure 54: Road density map

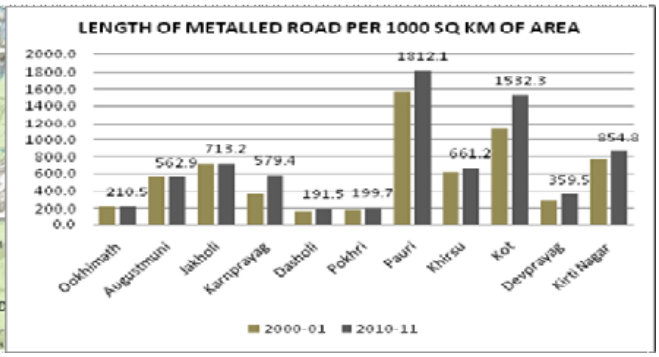



ROAD DENSITY MAP




Metalled road per lakh population and per 1000 sq km of area is more in the downstream region (southern part of the river) which includes Pauri, Khirsu and Kot.

#### 5.4.2.1.2 Roads - Issues

Roads provide accessibility to remote areas hence enhances development activities but they have proved to be the worst form of human interventions in the sense that they aggravate soil erosion and landslides. Forest clearing and blasting for road building destabilizes the slope leading to landslides. Use of heavy machinery; vibrator and blasting materials destabilizes the adjoining areas thus triggering small landslides all along the roads. Debris of the road construction is dumped into down slope area below the site; this debris causes severe erosion during monsoon resulting in destabilizing of valley slope of the area. These ill practices can be observed in remote areas where monitoring is weak and unavailability of platform to put forward local community voice.

Figure *55*: Road construction going on in study area

### *5.4.2.2 Drinking Water Source*

Physical setting of the study area gives plenty of water sources for drinkable water. Various indigenous techniques like harvesting water from forest called *naula* is found which are very sensitive and are regularly getting dried up because of human disturbance like extensive blasting and tunneling in the study area. Other water sources are also getting depleted and polluted because of excess pressure, ill management and getting diverted

Figure 56: Drinking water source access range for the villages which are not having drinking water source

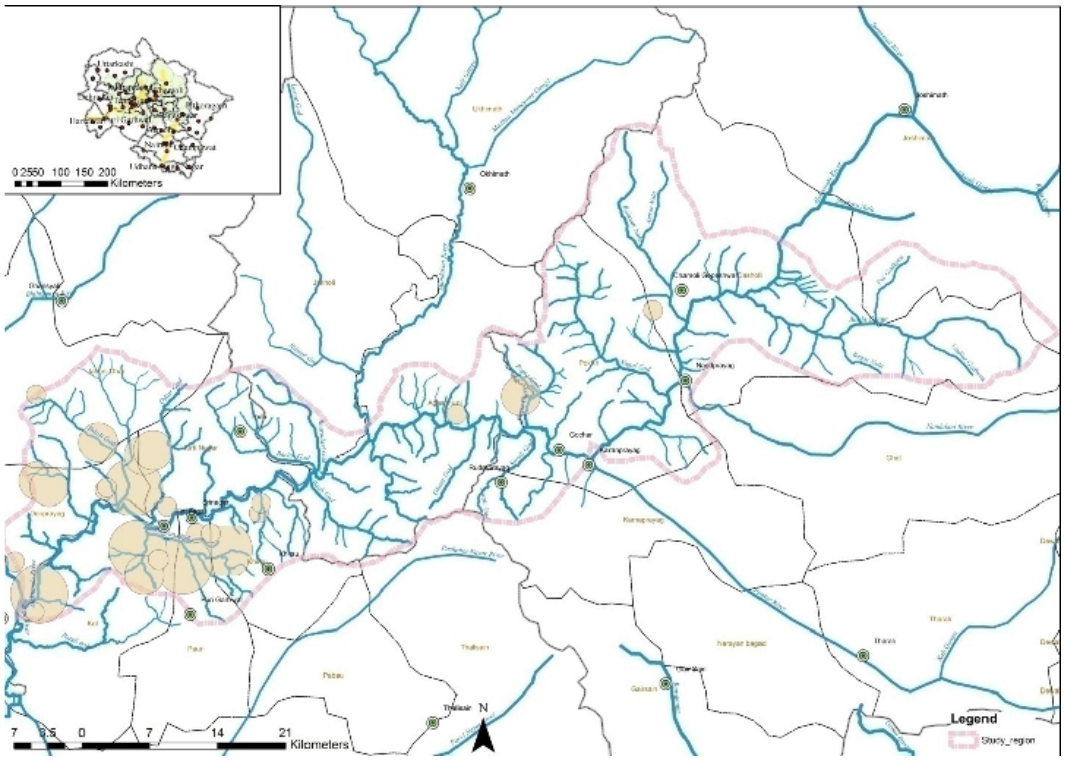
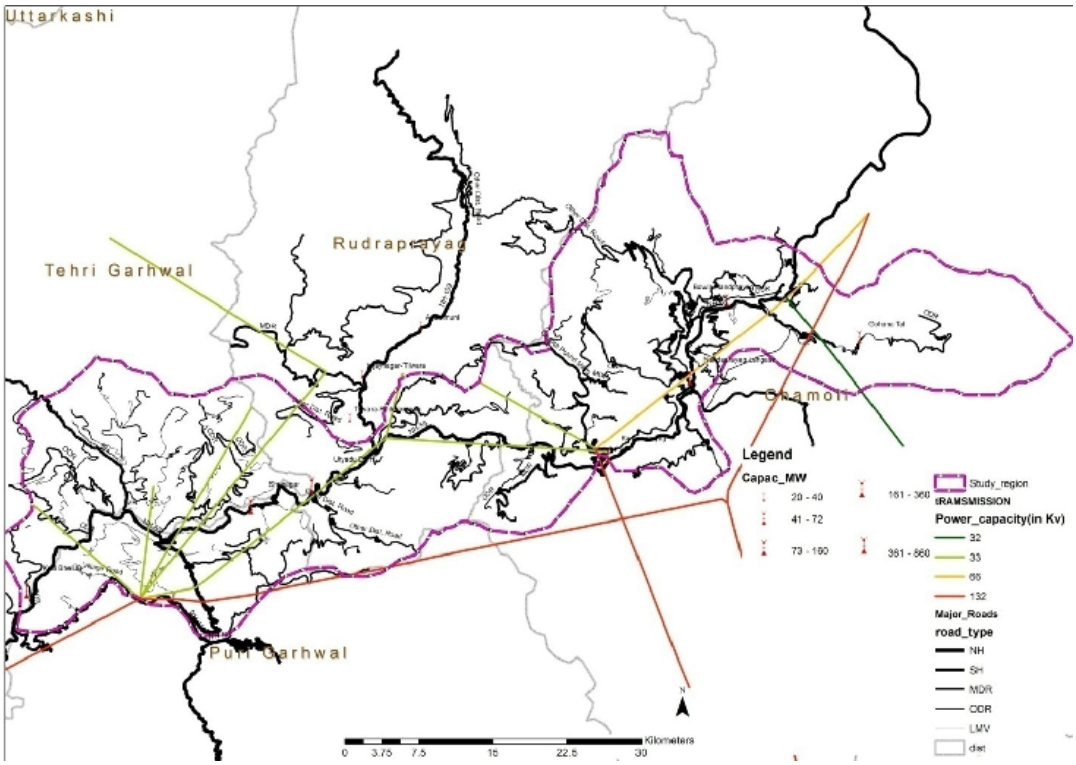



Figure 57: Map of other human intervention as such Hydro power projects, Transmission lines and roads



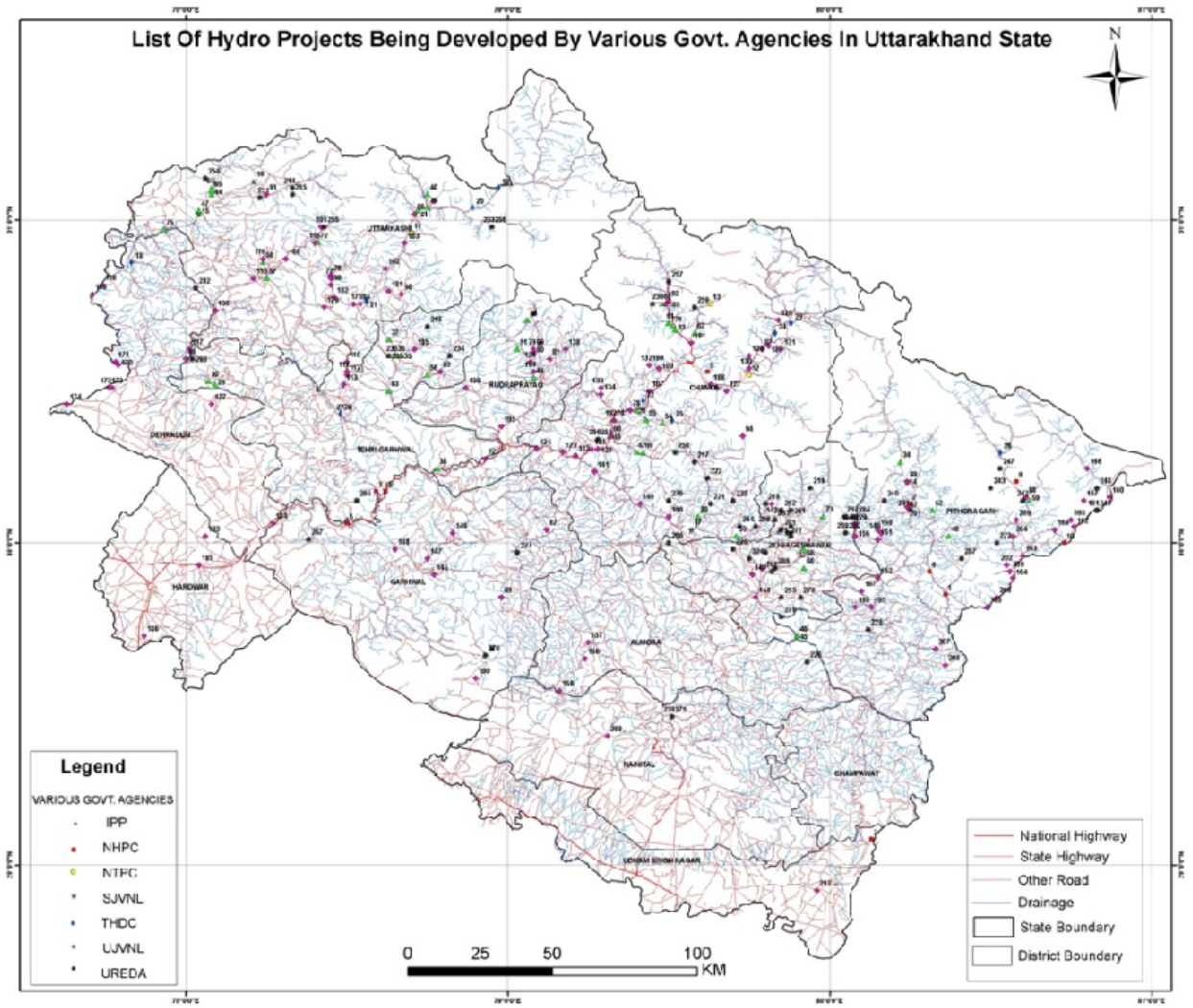
### *5.4.2.3 Hydro Power Projects*

#### 5.4.2.3.1 Distribution of Hydropower Projects in Uttarakhand

In the past years, a significant increase has been seen in the proposed number of hydro-electric projects.

There are as many as 220 such projects proposed all over Uttarakhand, of this, 52 are large size, 36 medium and 132 small scale projects with the power production targeted at 100MW per project. Apart from this, the state has 20-30000 MW generation capacities and at present 8000 capacity powerhouses are being constructed.

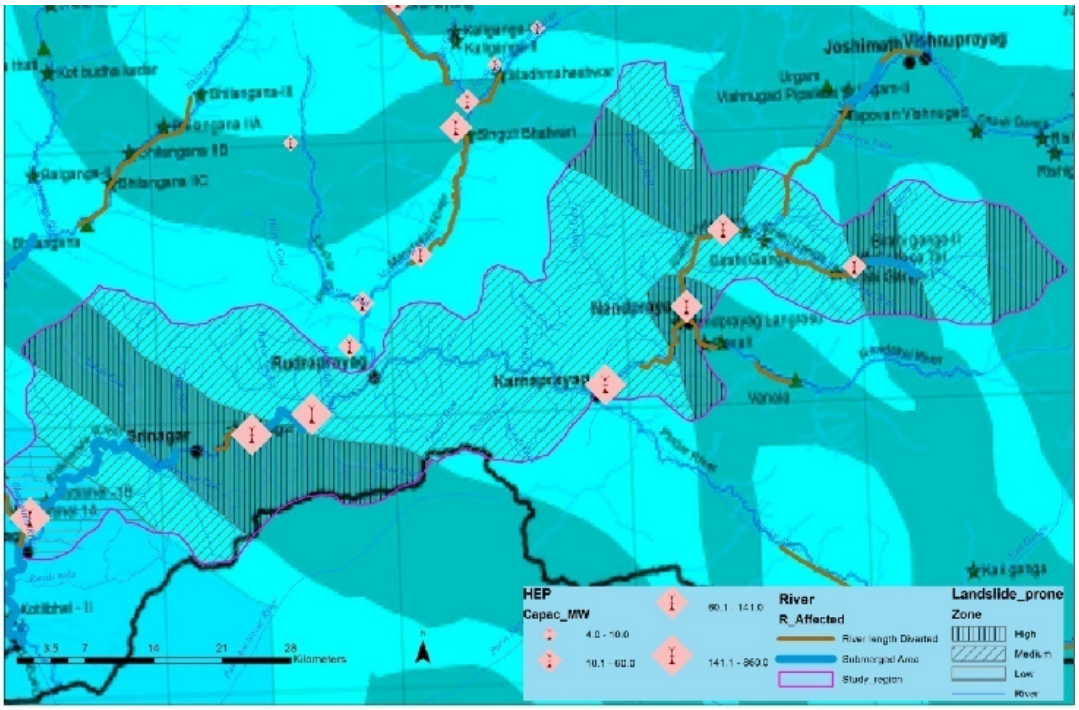
Figure 58: Distribution of Hydro projects being developed by various Government agencies in Uttarakhand State



#### 5.4.2.3.2 Number of Existing, Under Construction and Proposed Hydro Projects in Study Area

It has been observed that the 1000 unit of power is generated per meter diversion of river stretch is more in case of small hydro power projects while 336 unit of power is generated in the case of large hydro power projects that is 336 unit. Hence smaller hydropower projects are more beneficial than larger ones.

Figure 59: Capacity wise Hydel Projects Superimposed on Landslide Prone Area




The above map shows capacity wise HEPs superimposed on landslide prone zones existing in study area. Three landslide susceptibility zones are created from reference map adopted from *AHEC/2011: Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins*. Darker or vertical line shaded area in map represent high landslide susceptible zone; angular line hatch represent medium landslide susceptibility zone and horizontal line hatch symbolize low landslide susceptible zone respectively.

Figure 60: Line density and Kernel density map for River stretch affected due to dams

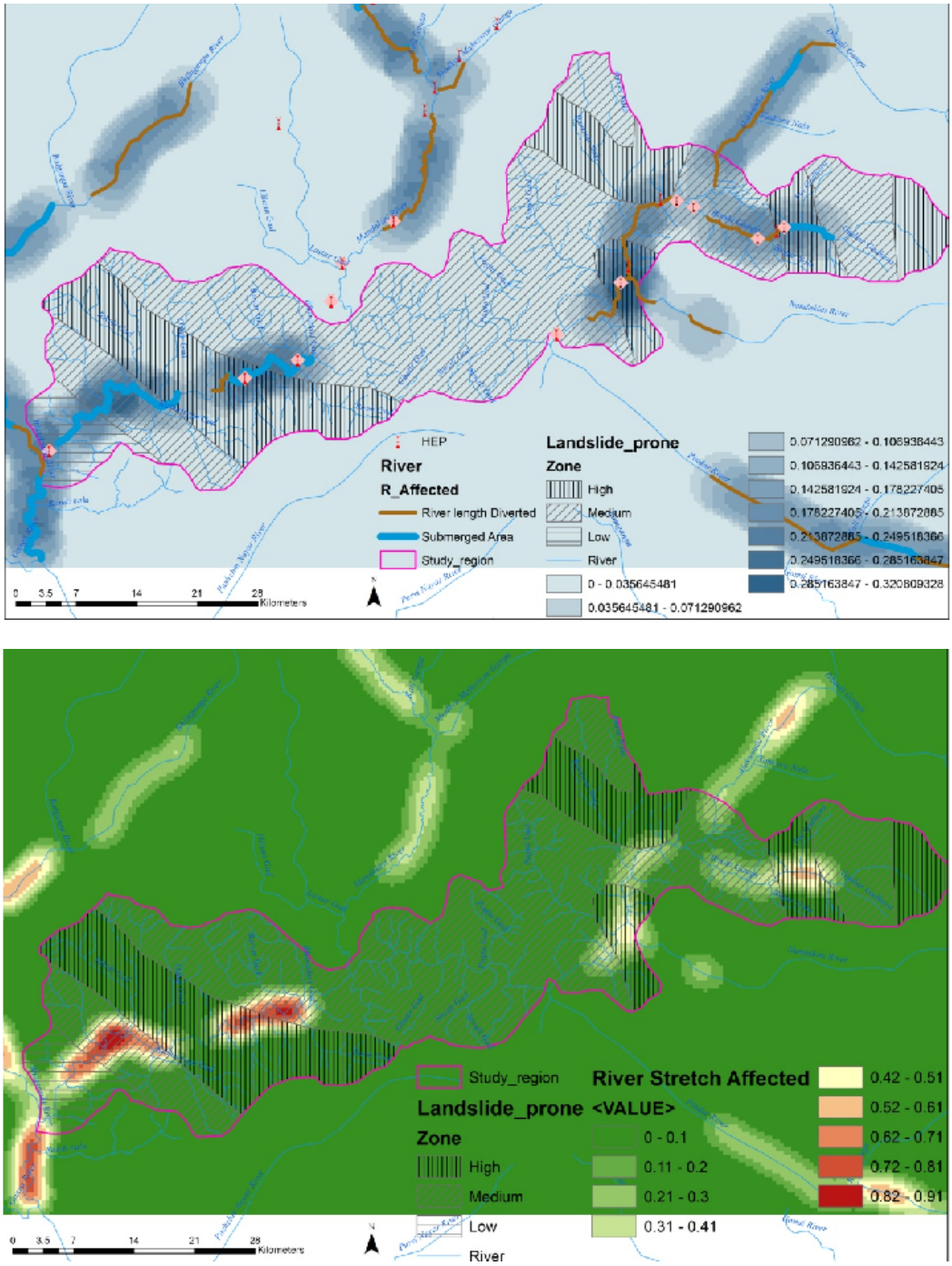
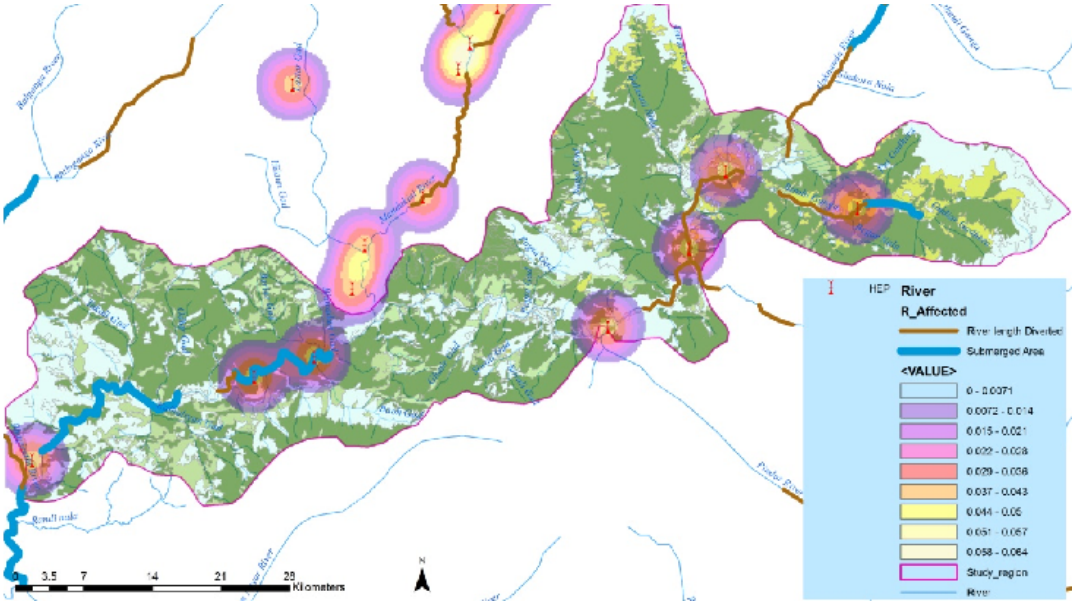
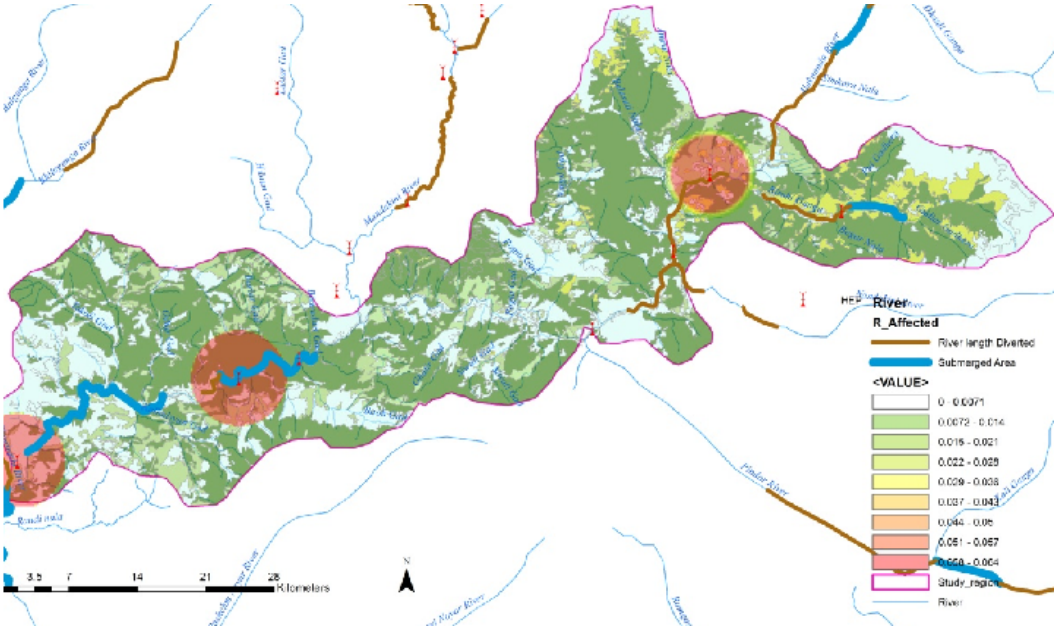



Figure 61: Forest land involved in operational Hydro power projects superimposed on different forest sub-classes




#### 5.4.2.3.3 Hydropower Projects -Issues

Hydro power projects involve forest clearance to rehabilitate villagers whose land is being taken up, forest land submerge due to reservoir formation, blasting for tunneling and diversion of river stretches through tunnels. These projects act as barrier for natural flow and affect the riverine ecosystem negatively. Presence of high capacity HEPs can be observed in high landslide

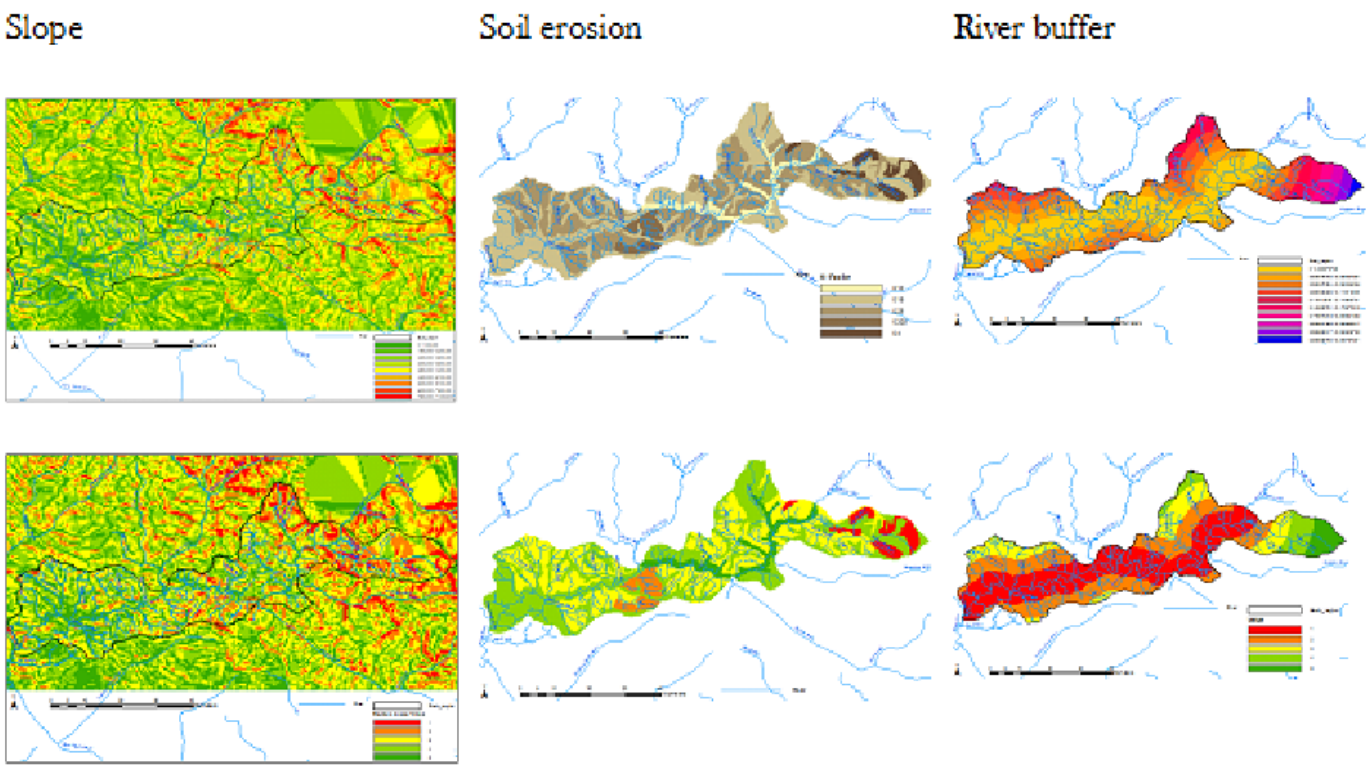
susceptible zone in the study area. The capacity of dams surely has relation with the extent of impact imposed by it and if these are located in high landslide susceptible zones than it wouldn't be a profitable or sustainable venture. Other issues include drying up of river stretches, cracks in villages and improper muck disposal.

It has been observed that the 1000 unit of power is generated per meter diversion of river stretch is more in case of small hydro power projects while 336 unit of power is generated in the case of large hydro power projects that is 336 unit. Hence smaller hydropower projects are more beneficial than larger ones.

## 5.5 Spatial analysis

### 5.5.1 Sensitivity analysis:

This analysis aims to identify land parcels which are more sensitive towards intervention by the virtue of their physical setting. Slope, Soil Erosion and River Buffer are the indicators included as an input for the sensitivity analysis.

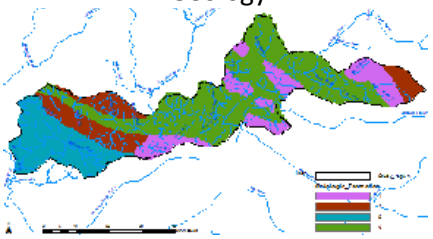



First map row of catalog above shows distribution of each input or considered criteria across study area and map of reclassified classes has been shown below which is classified in 5 different classes according to the importance of those categories or classes. These reclassified maps provide information in a similar particular (in this case red to green indicates more sensitive to less sensitive) pattern across layers.

### *5.5.1.1 Model for sensitivity*

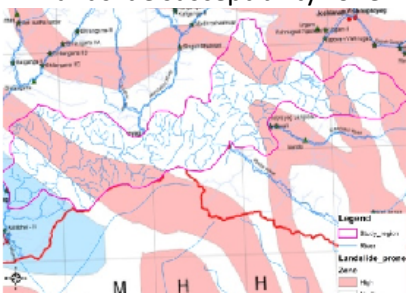
Figure 62: Catalog of indicators for land sensitivity analysis

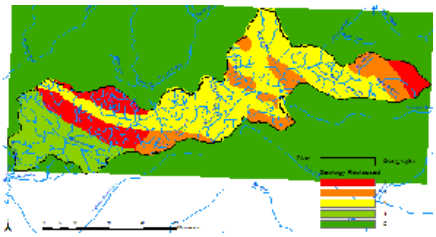
Geology

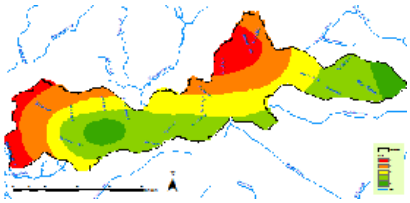


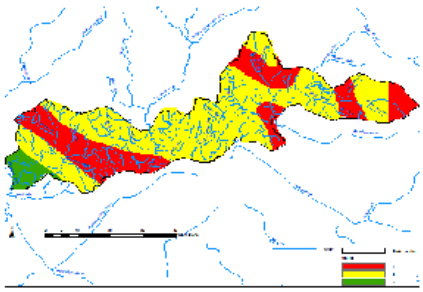
Rainfall

Landslide susceptibility zone

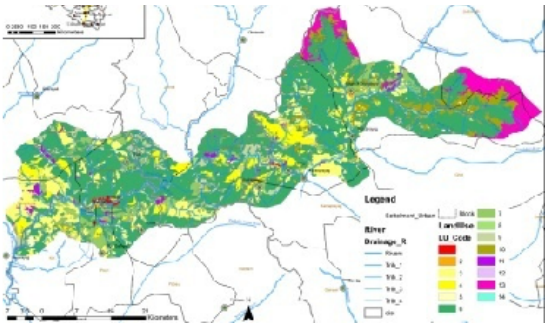


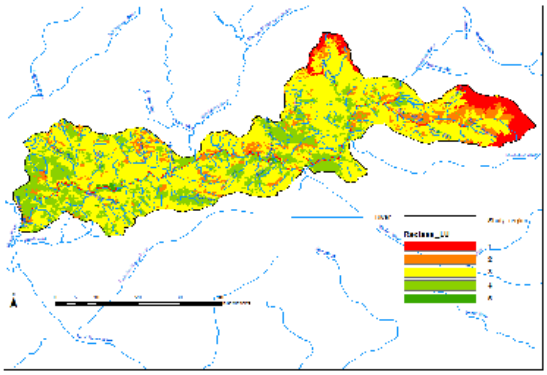





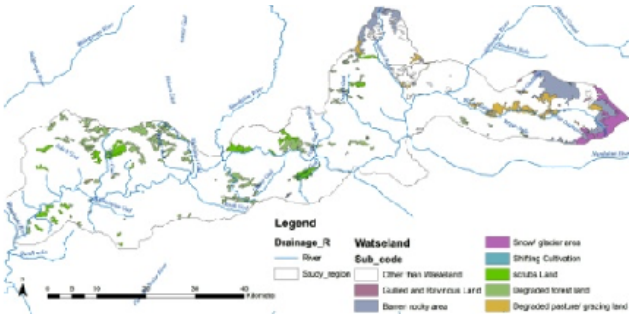


Land Utilization



Wasteland



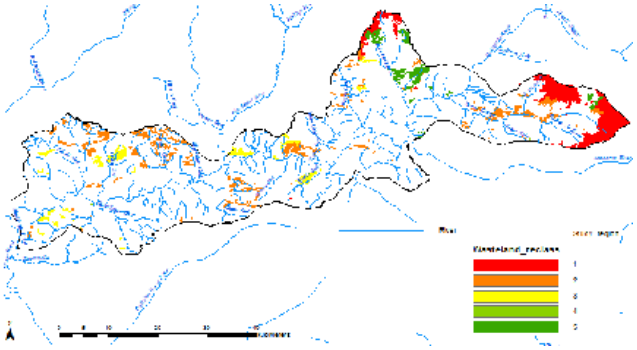
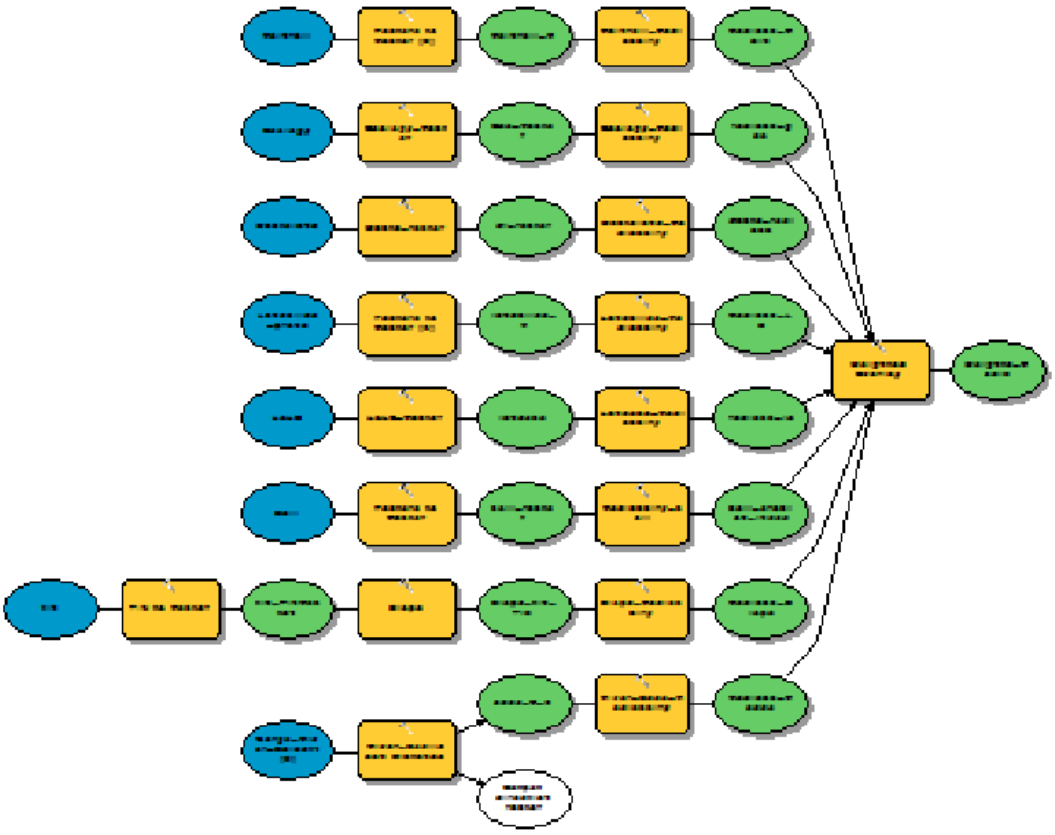



Figure 63: Model for sensitivity



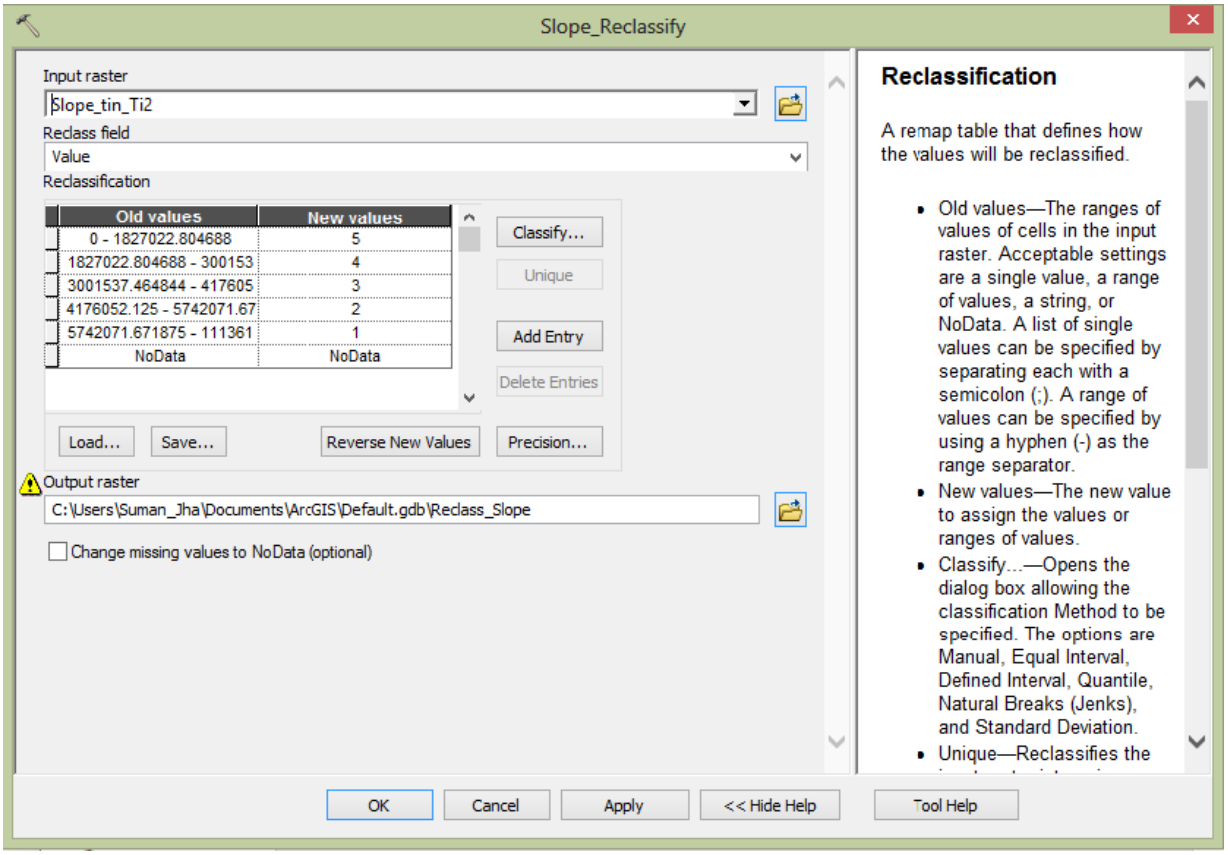
Model has been generated in Model builder available in Arc GIS. In this model, reclassification of each input followed by weighted overlay tool is done to identify cumulative sensitivity of the study area. Reclassification of inputs has been done in five classes of raster values present in each input. Number of classes is flexible to the tool and can be increased or decreased. Reclassified values ranges from 1to5 indicating more to less sensitive classes or categories. One can give similar reclassified values for similar kind of categories which are having same level of sensitivity.

To understand this, let's take an example; values for slope is first classified into 5 desired classes. Having these desired classes enables one to give values form 1-5 according to slope classes. Steep slopes have been given 1 as reclassified value and so-on. The designated values for the slope are increased with decrease in slope thus following an order of moving from worst to best case.

The method used to reclassify land utilization categories is a bit different because these are different land classes and dividing them into ranges is not possible. The same has thus been

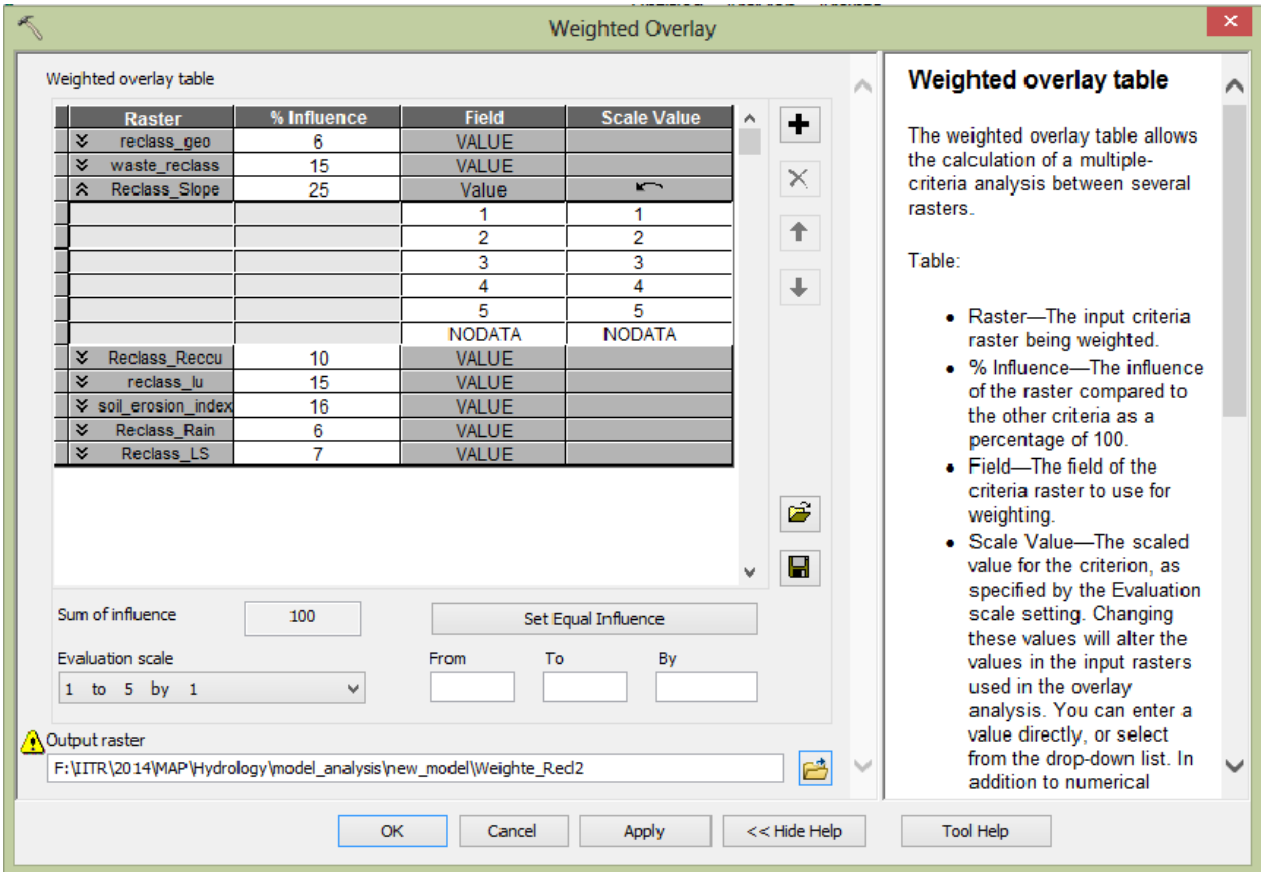
reclassified by giving same values for similar nature of LU categories. These reclassified values also range from 1-5.

Figure 64: Reclassify tool




This reclassification gives a common pattern for more to less sensitive across the inputs considered for analysis which can be viewed in catalog above. Now this reclassified patterns need to be overlaid on one platform which have common measurement scale and weights to each input in accordance to their influence factor for overall sensitivity of study area. Weighted overlay comes in a handy tool form spatial analyst toolbox in Arc GIS to perform the above analysis.

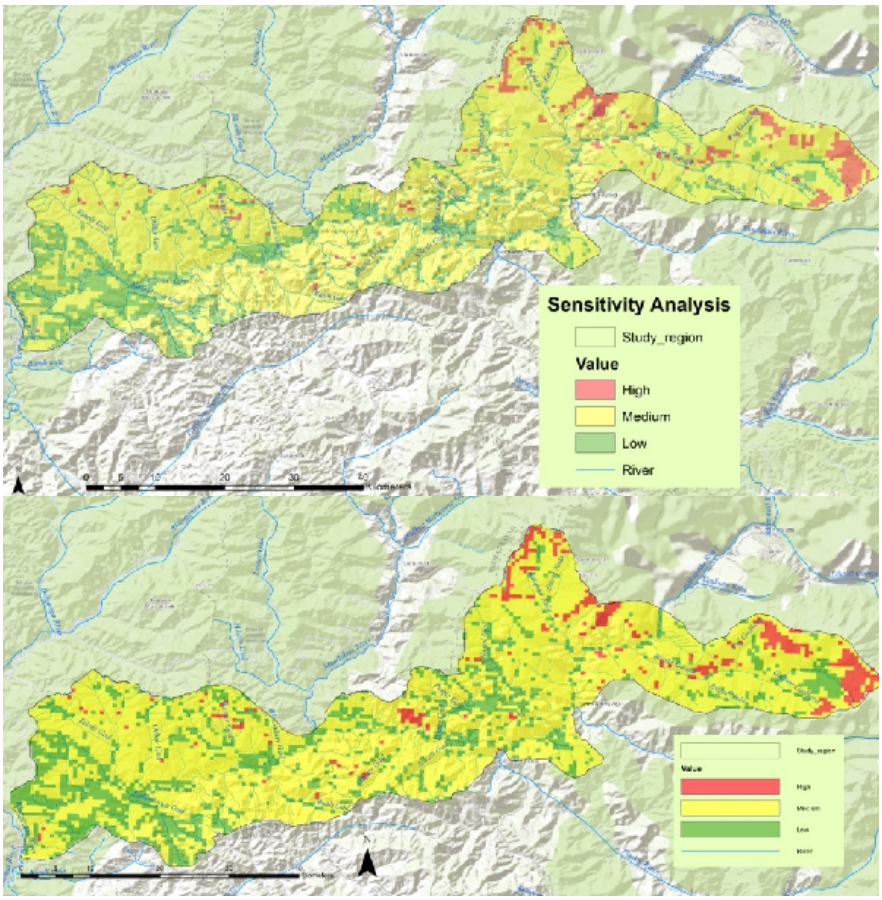
Figure 65: Weighted overlay tool




In the above figure reclassified data raster is in raster row, percentage influence of particular raster in order to determine final overlay is provided. Subsequent rows represent reclassified values of input raster and scale value assigned to the reclassified values for input within the range of evaluation scale.

Running the model gives an overall sensitivity map of the area considering that above indicators are on one common scale along with providing influence percentage to each of the input in which land parcels having high. Medium and low sensitivity index are demarcated. Output from the model has been analyzed and recalculated through calibrations in order to get more accurate output confirmative to felid reconnaissance survey observation. Table below contain some of the results obtain during model calibration process.

Table 24: Showing different results with table of influence factor for each input obtained from above model for sensitivity




| Raster | % Influence |
|---|---|
| reclass_geo | 9 |
| waste_reclass | 13 |
| Reclass_Reccu | 12 |
| reclass_lu | 12 |
| soil_erosion_index | 13 |
| Reclass_Rain | 7 |
| Reclass_LS | 9 |
| Reclass_Slope | 25 |

| Raster | % Influence |
|---|---|
| reclass_geo | 6 |
| waste_reclass | 15 |
| Reclass_Reccu | 14 |
| reclass_lu | 15 |
| soil_erosion_index | 9 |
| Reclass_Rain | 7 |
| Reclass_LS | 9 |
| Reclass_Slope | 25 |

The areas marked in red color represent high sensitive patches. It is recommended that no sort of human intervention should be permitted here except for some primary activities carried out in a regulated manner. The yellow shaded areas represent the medium sensitive zones where limited human interventions can be permitted. Green patches in the map symbolize areas which are relatively less sensitive as per the considered inputs.

In this model, discrepancy arises only in the case of river beds. River beds are highly sensitive zones but the model does not show this as the parameters fed into it include slope and soil erodability which is very less in river bed. Hence, to ensure the protection of river bed, a restricted zone along the same has been demarcated and fed into the model. Following this, the final sensitivity map has been derived. Next, a human intervention model has been generated by identifying the indicators of human intervention and assigning weightages to the same as per their

level of influence. Maximum weightage has been assigned to the parameter having maximum impact and vice versa.

### 5.5.2 Human intervention analysis

With increase in population pressure, increases the need for land as well as diversity in the type of activities. Suitable living environment encourages growth of population along the river bed and the valleys. This is evident from the spill over population and encroachments along the river bed. The other things visible along the river bed include activities like hydro power projects and construction of roads overlooking consequences of steep contour cutting. The nature of human interventions is visible in the form of littering of garbage, consumption pattern of firewood, illegal sand mining and poaching, terrace cutting and other environmental degradation activities. The extent of impact of these activities are again a result of demographic factors like average living standard of the people, main marginal ratio of working population, sex ratio, literacy (education), access to communication means and basic facilities (Health, Education and Banks) and level of awareness amongst the public. The different nature of interventions has been categorized and modeled as positive and negative.

#### *5.5.2.1 Negative human intervention*

These indicators include roads, capacity of hydro power projects, river stretch diverted and affected due to HEPs, forest land affected, un-irrigated area, rural and urban settlement point density and quality of life which includes only three parameters related to basic facility access range for the settlements i.e. drinking water source, primary school and primary health center. This analysis requires line, point and kernel density tool to determine densities of settlements, road density and river stretch affected respectively. In addition to this, buffer tool and Euclidian distance tool has been used to demarcate access range for basic facilities and multiple extent zones respectively.



Figure 66: Barren hilltop having active landslide at southern slope in pokhari (chamoli), fire set in agriculture farm to clear it up and a landslide below the road near Devprayag, Sand mining in Alaknanda river bed near Srinagar

Above images describes few activities in study area having adverse effects on environment.

Figure 67: Capacity wise Reclassification of HEPs

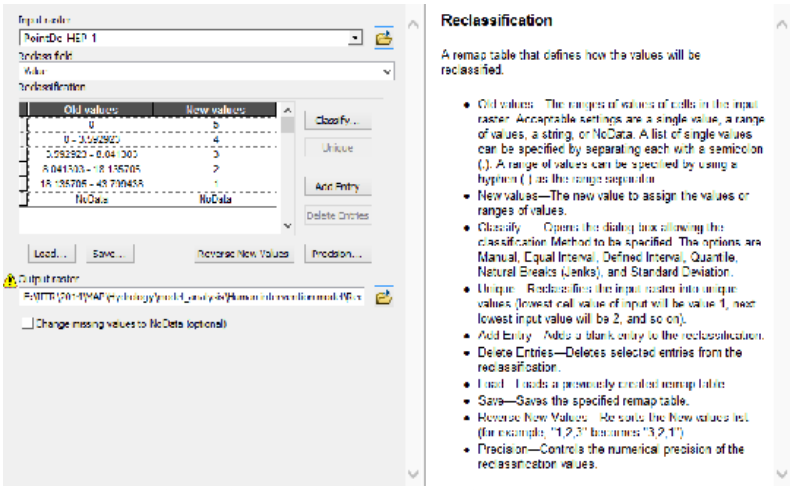



Figure 68: Model for calculating level of negative human intervention

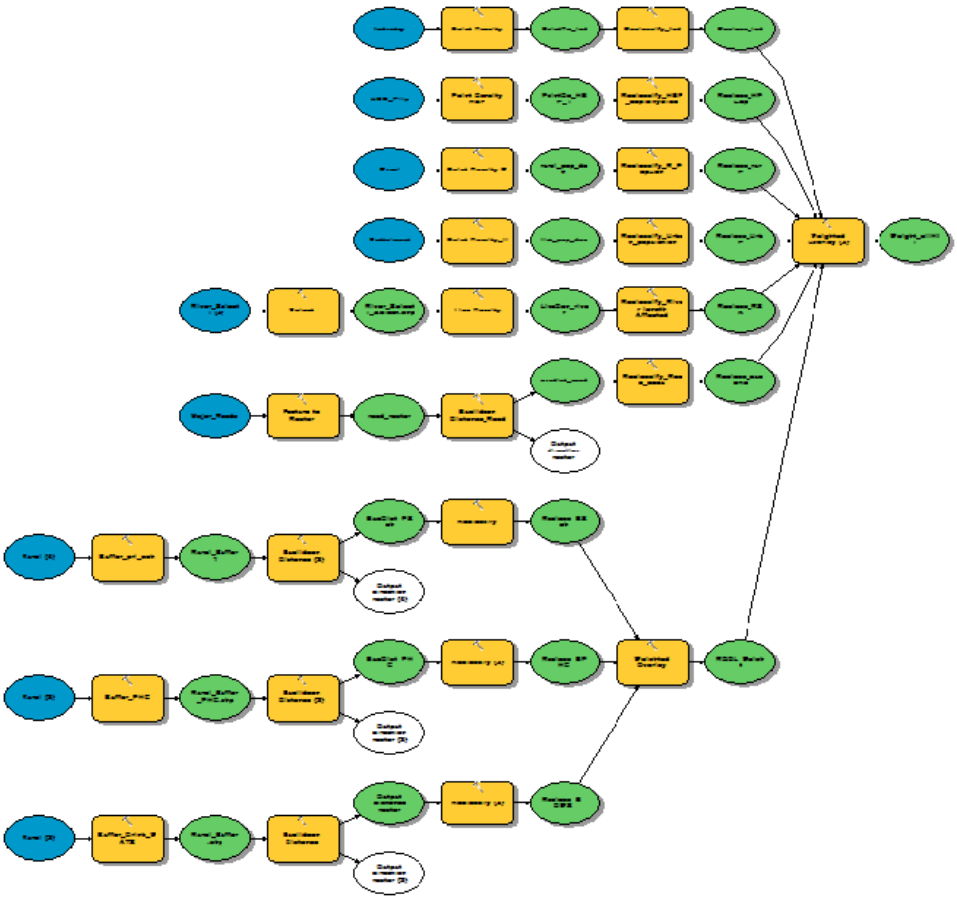


Figure 69: Overlaying reclassified raters for negative human intervention

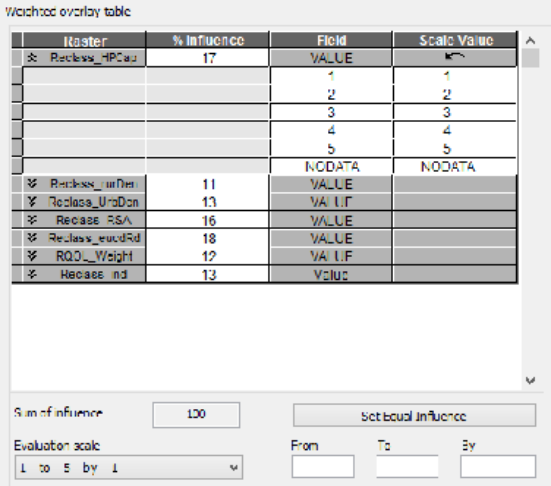



Figure 70: Overlaying reclassified raters of access range for basic facilities

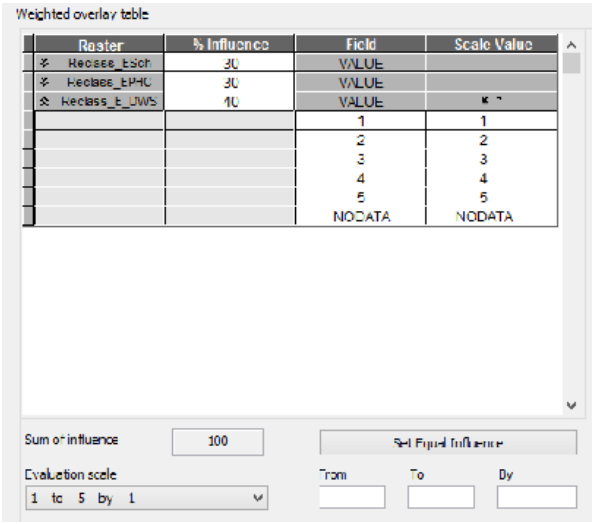
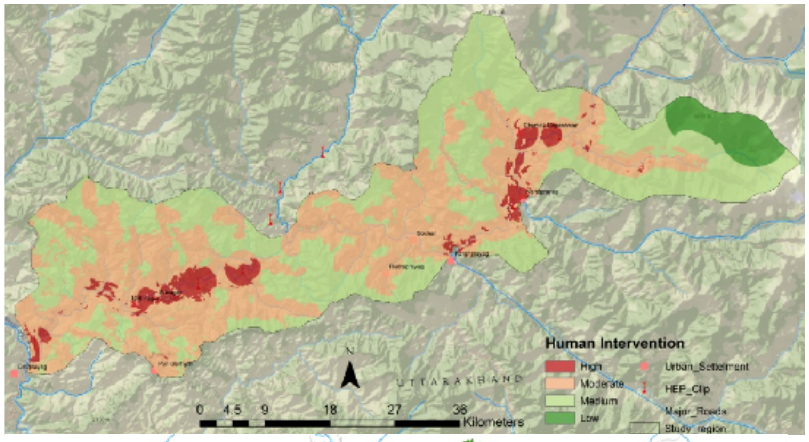
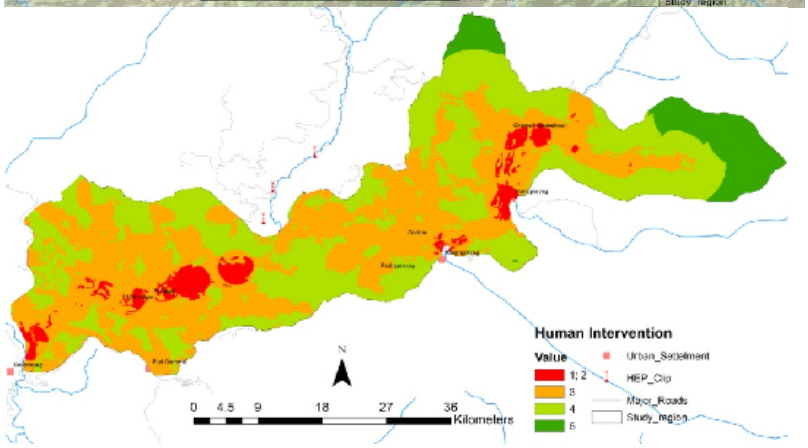



Table 25: Showing different results with table of influence factor for each input obtained from above model for Human intervention




| Raster | % Influence |
|---|---|
| Reclass_HPCap | 17 |
| Reclass_rurP | 11 |
| Reclass_UrbP | 13 |
| Reclass_RSA | 16 |
| Reclass_eucdRd | 18 |
| RQOL_Weight | 12 |
| Reclass_ind | 13 |



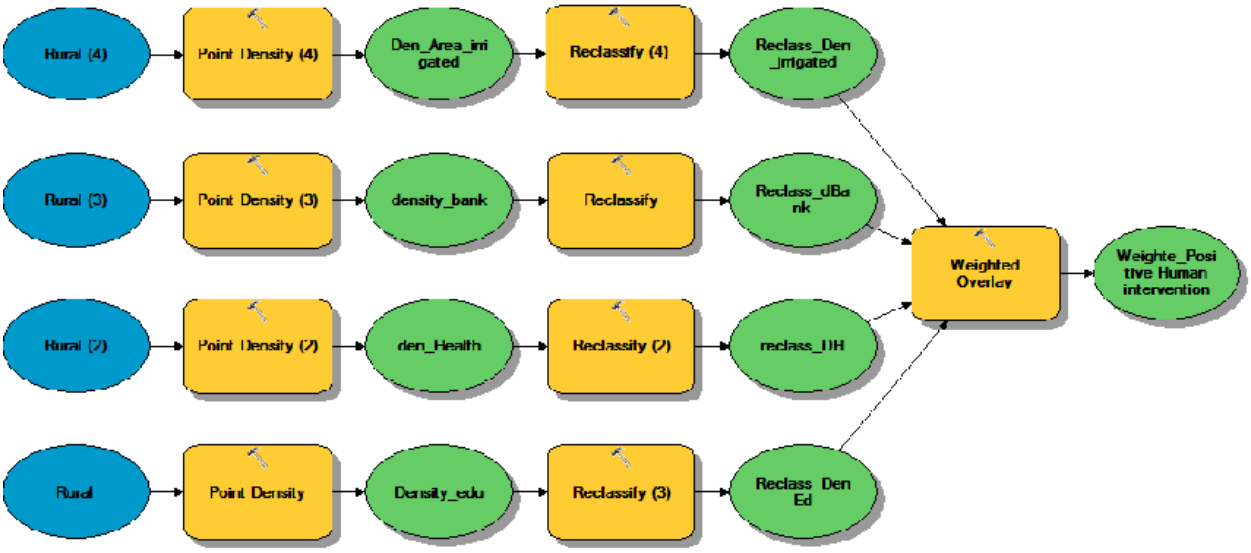

| Raster | % Influence |
|---|---|
| Reclass_HPCap | 20 |
| Reclass_rurP | 8 |
| Reclass_UrbP | 11 |
| Reclass_RSA | 16 |
| Reclass_eucdRd | 19 |
| RQOL_Weight | 15 |
| Reclass_ind | 11 |

In order to acquire best possible output various set of results has been obtained through calibrating the model by assigning different sets of weights and comparing them with ground realities.

### 5.5.2.2 Positive Human interventions

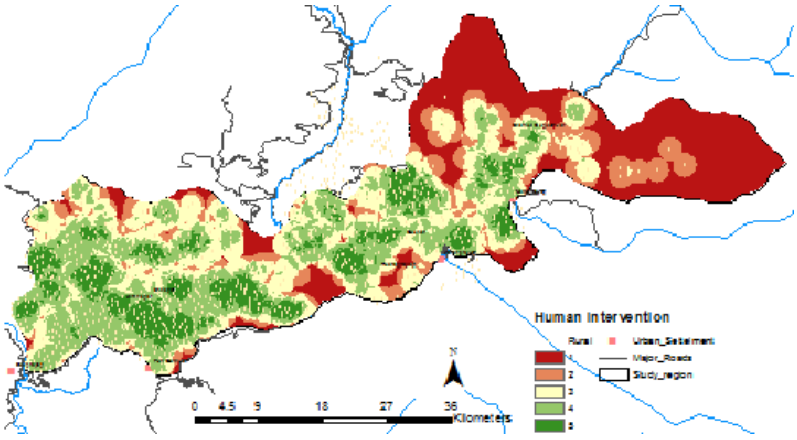
The parameters taken in this model include availability of basic facility along with workers percentages engaged in main sector and percentage of irrigated area. These parameters are responsible for the wellbeing of the people and reduce the vulnerability of the habitants.

Figure 71: Model for positive human intervention

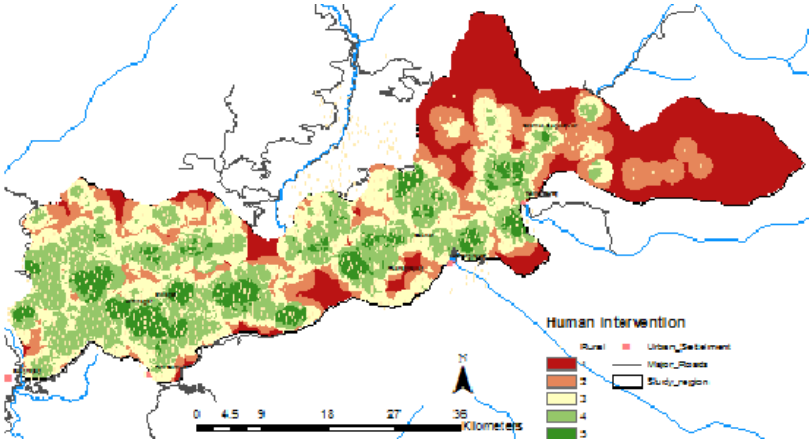



With the help of point density tool, point density for each input like number of education and health facilities and area irrigated is calculated. Each density raster has been then grouped into 5 classes in order of decreasing to increasing density i.e. values from 1 to 5.

Table 26: Showing different results with table of influence factor for each input obtained from above model for positive Human intervention (capacity)




| Raster | % Influence |
|---|---|
| Reclass_dBank | 20 |
| reclass_DH | 30 |
| Reclass_DenEd | 30 |
| Reclass_Den_irrig | 20 |




| Raster | % Influence |
|---|---|
| Reclass_dBank | 20 |
| reclass_DH | 27 |
| Reclass_DenEd | 26 |
| Reclass_Den_irrig | 27 |

The green shaded area in the map represents area under the influence of positive intervention or resilience capacity. The red shaded area are under the influence of relatively less positive intervention while the areas impacted by least human intervention is symbolized by orange colour. In the upstream area near Chamoli, pattern is changing while increasing weightages for irrigation turning parcels yellow to orange. While in downstream areas, yellow turns into orange and red because of decreasing weightages pertaining to social infrastructure. Various outputs is generated and compared with the primary survey while calibrating the model.

### 5.5.3 Vulnerability analysis

This section includes the vulnerability assessment of the study area. For this analysis, the three outputs namely positive intervention, negative intervention and sensitivity have been superimposed and the following formula has been used to calculate the vulnerability index.

Vulnerability Index = (-ve intervention – +ve Intervention) * Sensitivity

This would provide us with all land parcels which are under different states of vulnerability and help to identify parcels of vulnerable land which require immediate action for restoration or stabilization.

Figure 72: Model for calculating the above formula

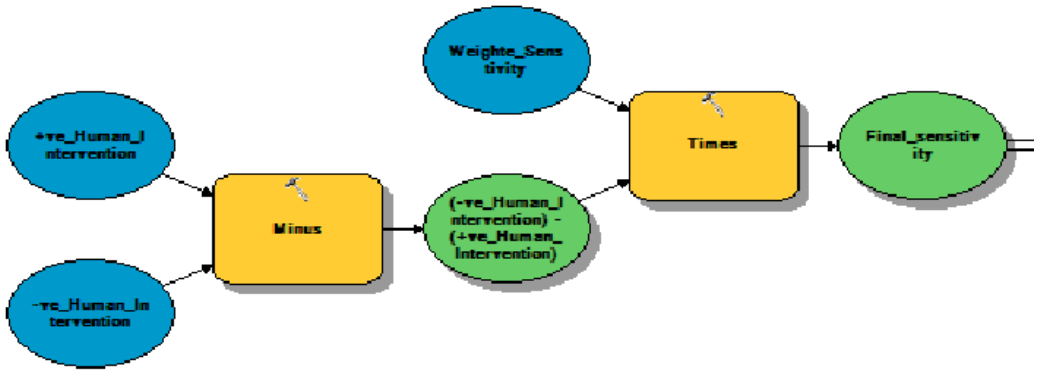



Figure 73: Vulnerability map

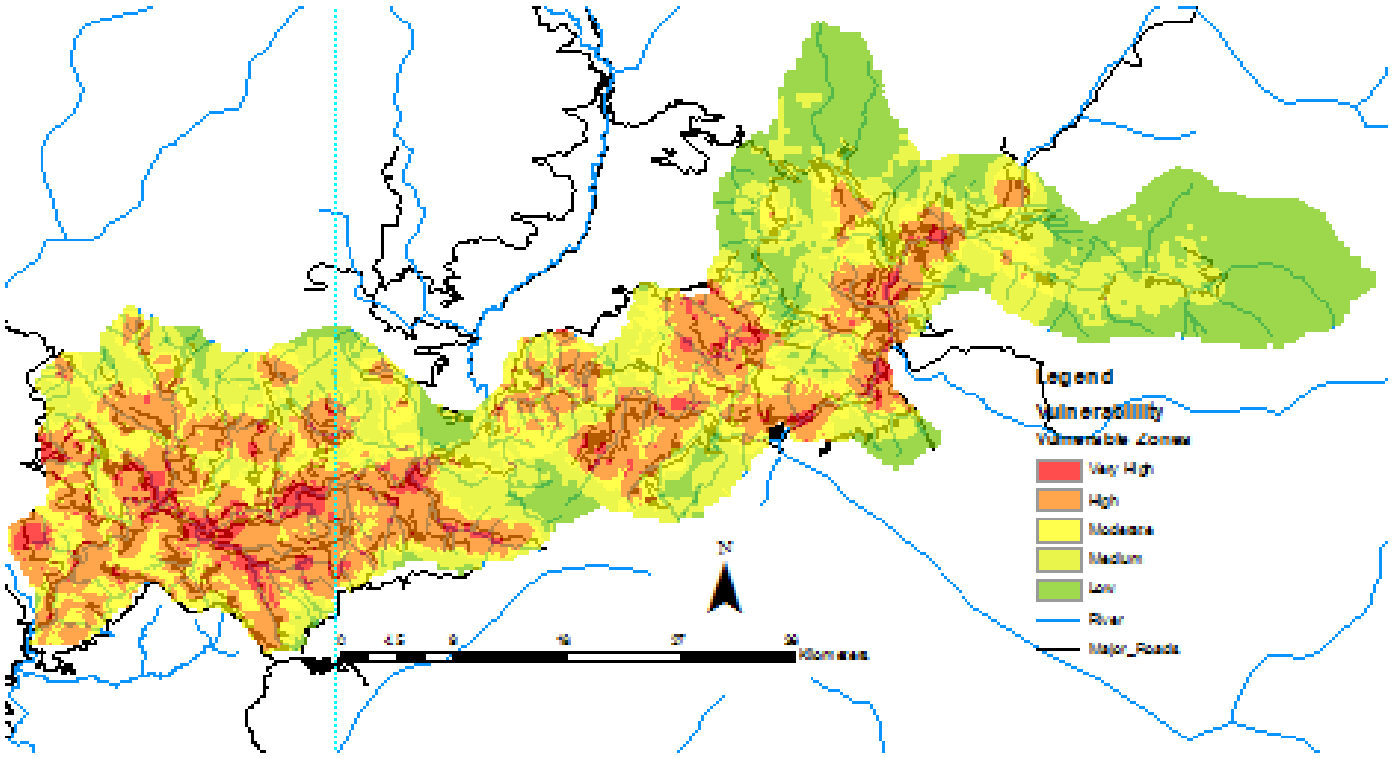


Figure 74: further modeling to obtain most vulnerable land parcels into polygon

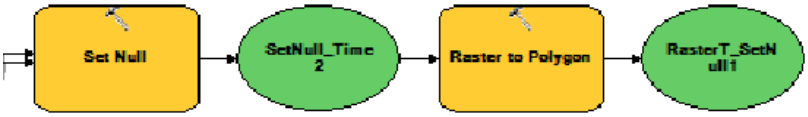



Figure 75: Map showing most vulnerable land parcels

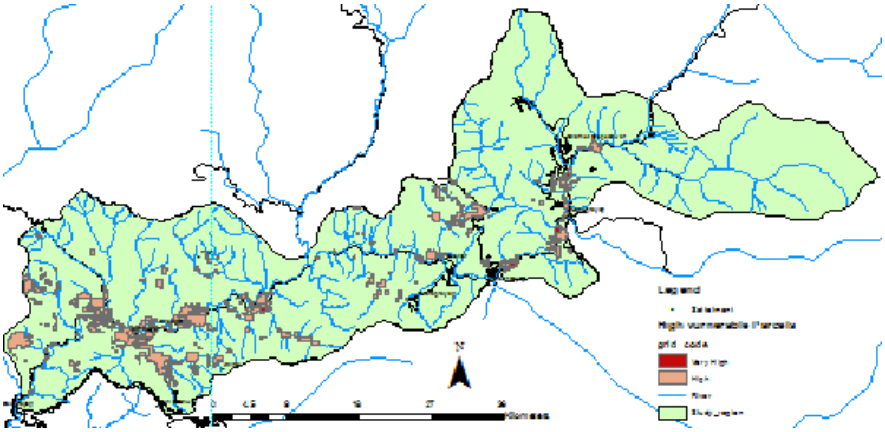


Figure 76: Further modeling to extract desired size of land parcels (< 5 Ha)

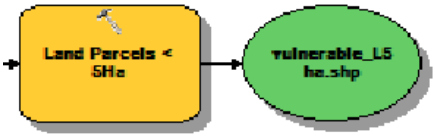



Figure 77: vulnerable land parcels above 5 ha area superimposed on most vulnerable areas

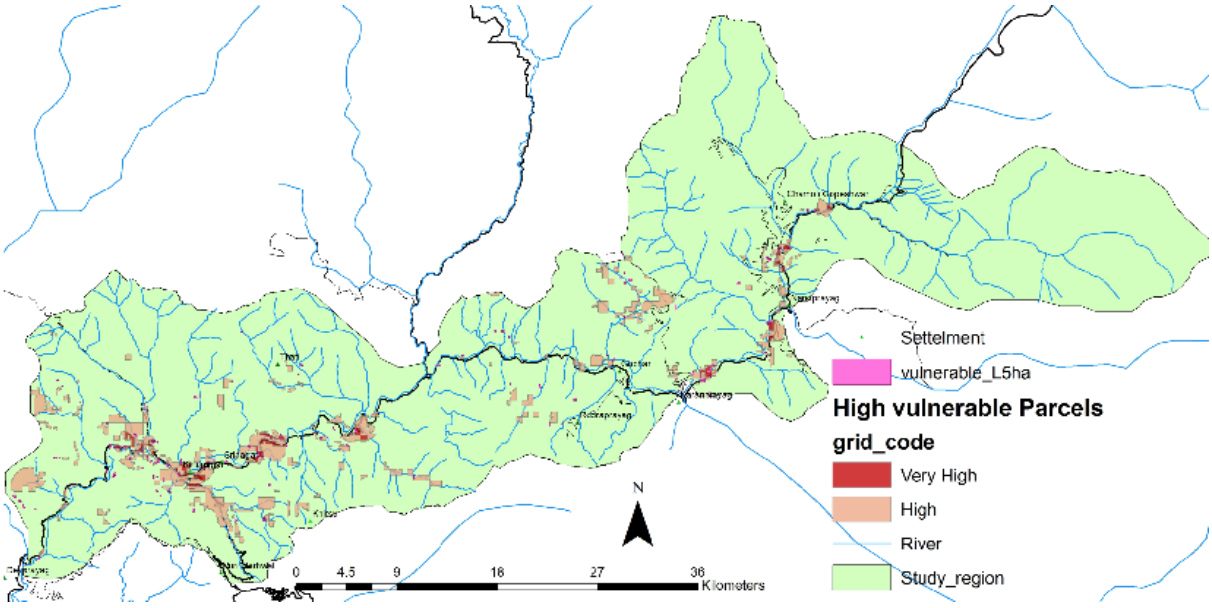
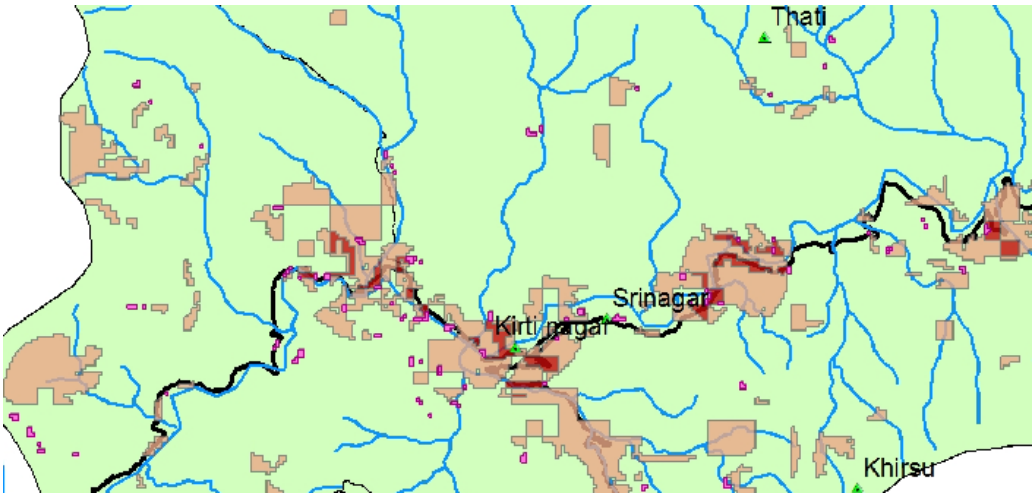


Figure 78: Identified land parcels having size less than 5 ha prioritize for restoration




Land parcels which are less than 5 ha and are isolated from bigger continuous vulnerable patches are liable to increase in size with time and may add up to the bigger degraded chunks of land. Hence, these degraded areas need immediate attention. 4.5% area of total area is coming under most vulnerable area out of which 293 ha is less than 5 ha land parcel.

### 5.5.4 Land suitability analysis for settlements

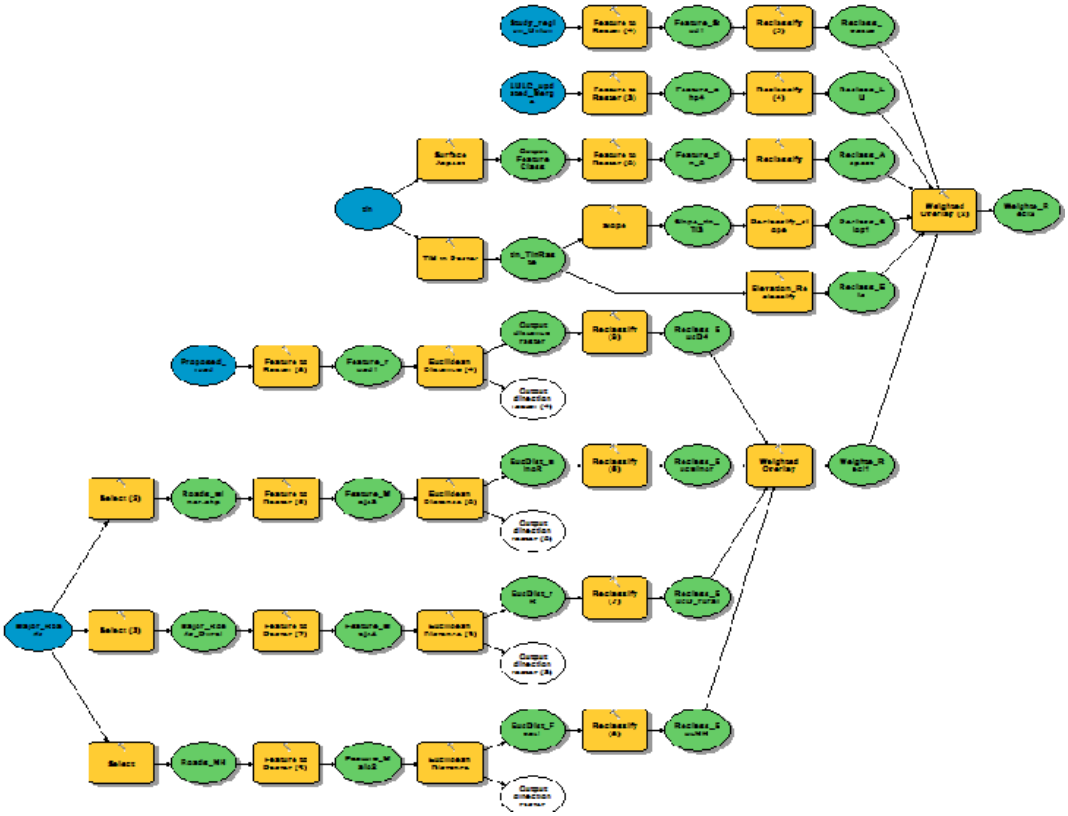
Land suitability analysis has been gone to identify the best land parcel for the settlement. Multi criteria evaluation has been used to identify suitable land parcels using equation below

$$LS = {}_{i=1}\sum^{n} w_i C_i \times {}_{j=1}\prod^{m} r_j$$

Above formula is one of the multi criteria evaluation methods named weighted linear combination which widely accepted for good for complex spatial problems.

LS are composite suitable score, C is the criteria for suitability and w is weight or importance of that criteria or input over all other inputs. "r" is the restriction or constraint for the suitability, it is like Boolean factors. "∑" is sum of weight factor and "∏" is product of all constraints.

Figure 79: Model for criteria with weightages



Above criteria model consists slope, elevation, aspect, land use, wasteland and distances from major, local and rural roads as inputs. Reclassified maps for each input have been prepared for weighted overlay analysis (WOA). Providing appropriate weights to each input along with ranking of reclassified raster value in similar order with the help of weighted overlay analysis gives us values for $\left[\sum_{i=1}^{n} W_i C_i\right]$ part of equation.

Figure 80: Reclassified value table for slope

Reclassification

| Old values | New values |
|---|---|
| 0 | 1 |
| 0 - 2741720.625 | 5 |
| 2741720.625 - 3699146.87 | 4 |
| 3699146.875 - 4787131.25 | 3 |
| 4787131.25 - 6310309.375 | 2 |
| 6310309.375 - 11140960 | 1 |
| NoData | NoData |

Figure 81: Weighted overlay analysis for different hierarchy if roads

Weighted overlay table

| Raster | % Influence | Field | Scale Value |
|---|---|---|---|
| Reclass_Euclidean | 30 | VALUE | |
| Reclass_EucD_rur | 20 | VALUE | |
| Reclass_EucNH | 40 | VALUE | |
| | | 1 | 1 |
| | | 2 | 2 |
| | | 3 | 3 |
| | | 4 | 4 |
| | | 5 | 5 |
| | | NODATA | NODATA |
| Reclass_EucTopo | 10 | VALUE | |

$$LS = (w_s C_s \cdot w_a C_a \cdot w_e C_e \cdot w_{lu} C_{lu} \cdot w_w C_w \cdot w_r C_r) \times \prod_{j=1}^{m} r_j$$

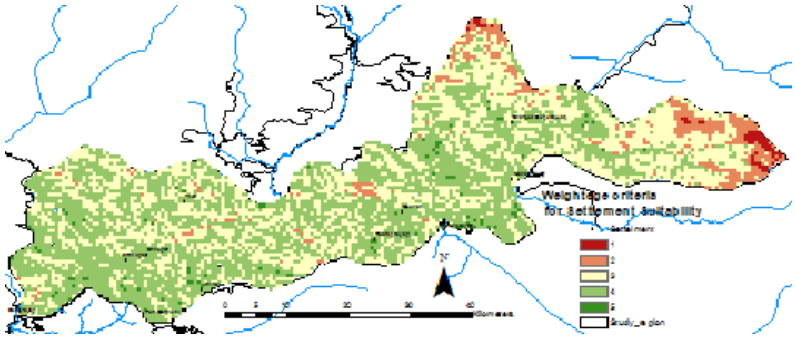
Where,

$W_s$ and $C_s$ : Weight and criteria for Slope

$W_a$ and $C_a$ : Weight and criteria for Aspect and so on for land use, wasteland and weighted overlay of distances from different hierarchy of roads.

Weights have been decided by evaluating importance factor of a particular input. These importance factors are given out of 1, comparing importance among the inputs to obtain desired result.

$$LS = (0.23C_s \cdot 0.23C_a \cdot 0.10C_e \cdot 0.15C_{lu} \cdot 0.14C_w \cdot 0.15C_r) \times \prod_{j=1}^{m} r_j$$



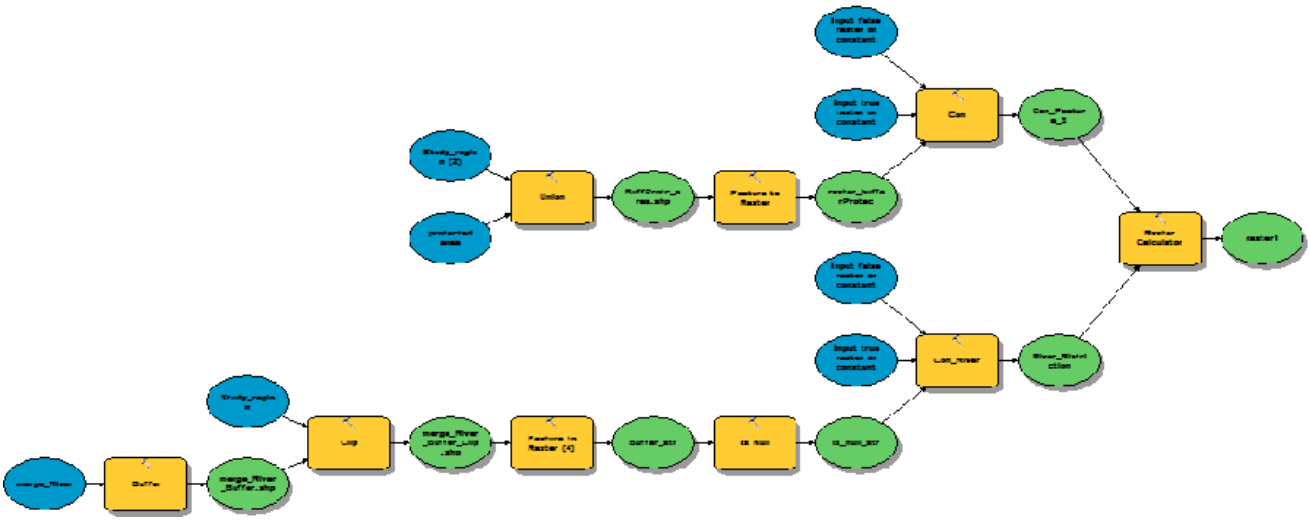

| Raster | % Influence |
|---|---|
| Reclass_Slop1 | 23 |
| Reclass_Aspect | 23 |
| Reclass_LU | 15 |
| Reclass_waste | 14 |
| Weighte_ReclRoad | 15 |
| Reclass_Ele | 10 |

In the above map land parcels having most suitable sites shown in dark green color without having any filter or restriction regarding protected area land parcel and river bed which is introduced through restriction model.

$$LS = \sum_{i=1}^{n} w_i C_i \times (r_{\text{River 200m buffer}} \cdot r_{\text{protected area}})$$

Restriction model consist various tasks requiring tools like “Is null” and “Con” to obtain Boolean raster for restricted pixel value for each input. “Is null” gives null raster contains only restricted land parcels while no data for rest of the pixels but “Con” gives conditional raster using null raster by defining true and false raster values. Conditional raster has been calculated in raster calculator from map algebra toolbox. By multiplying both conditional raster in raster calculator overall restricted area has been obtained.

Figure 82: restriction model



End result of this model is Boolean raster (it contains only two values0 and 1 for true and false pixels respectively) that represent the restriction to develop any new settlement into that true pixel land parcels.

Figure 83: restriction map for the suitability analysis

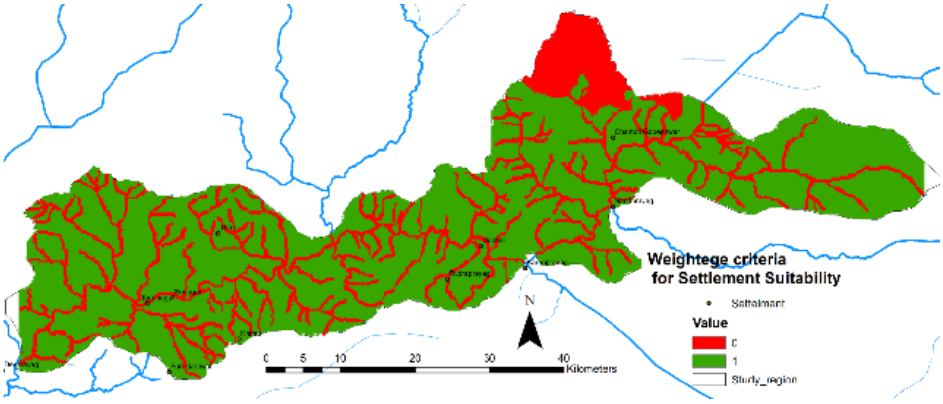
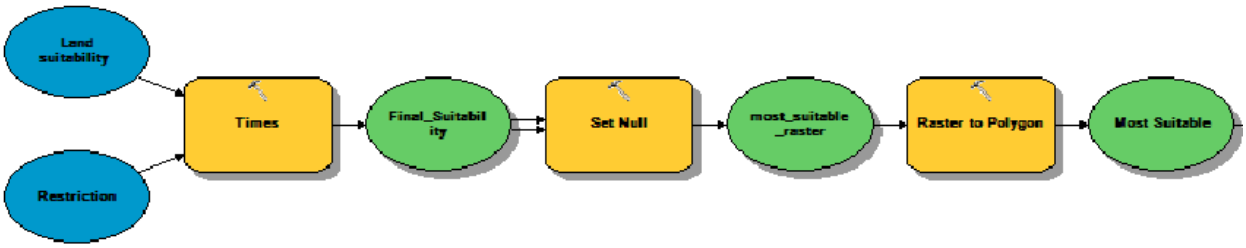


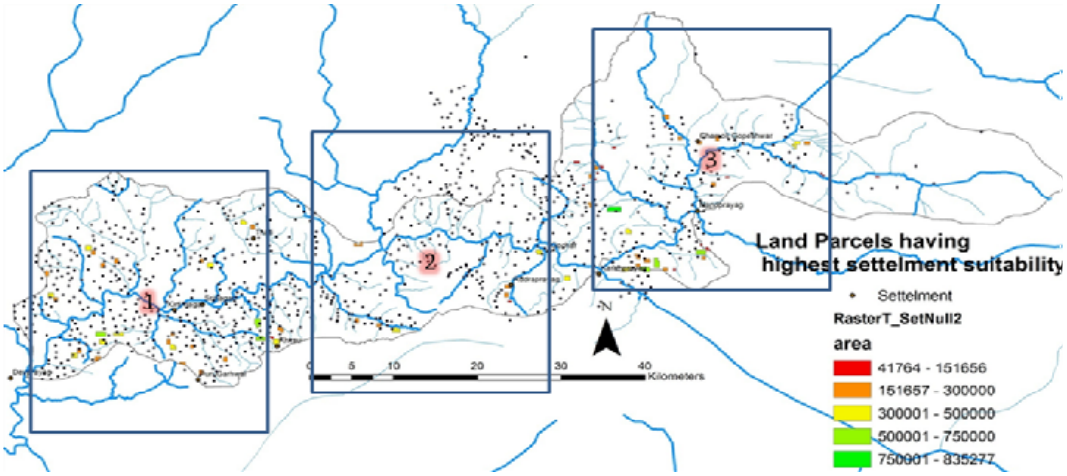

Figure 84: Final suitability model for settlement



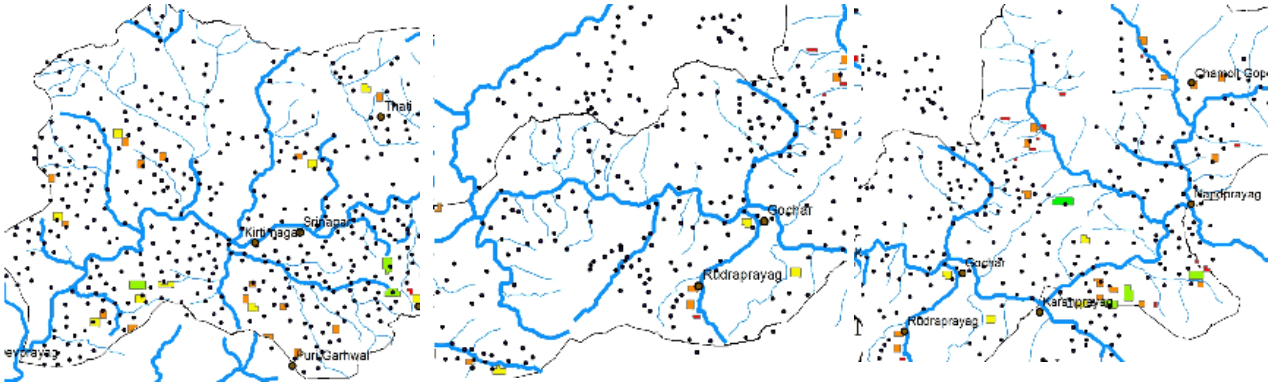

Times function gives an output map indicating areas having suitability rank 1 to 5 with 0 values indicating restricted area. Study seeks to identify most suitable sites for settlements. To fulfill above

"Is Null" function have been used for extracting pixels having highest suitable pixel value i.e. 5. These land parcels have been converted into polygon for further area analysis.

Figure 85: Map showing most suitable area wise land parcels superimposed by existing settlement layer



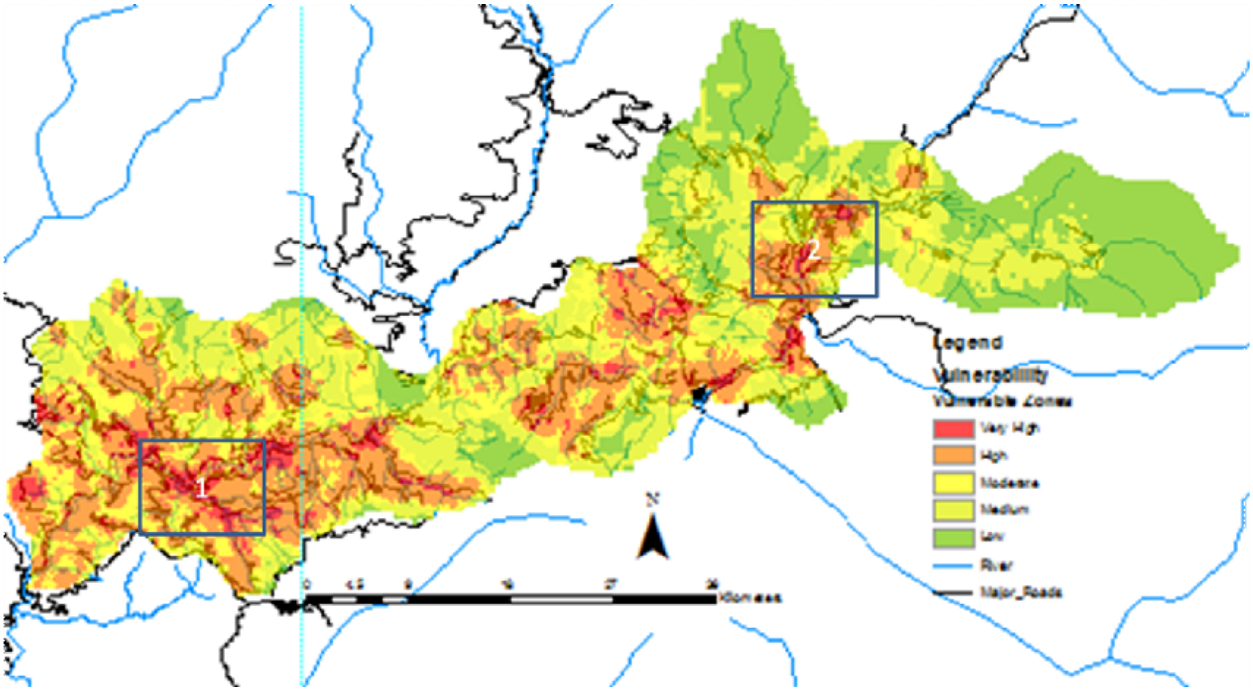

Map showing most suitable area classification wise land parcels superimposed by existing settlement layer. Parcels in red having area less than 1.5 ha while next one is orange having area between 1.5 to 3 Ha. Other ranges are 3 to 5 Ha, 5 to 7.5Ha and up to 8.3Ha. These all land parcels are suitable for settlement and color code is showing area wise classification.

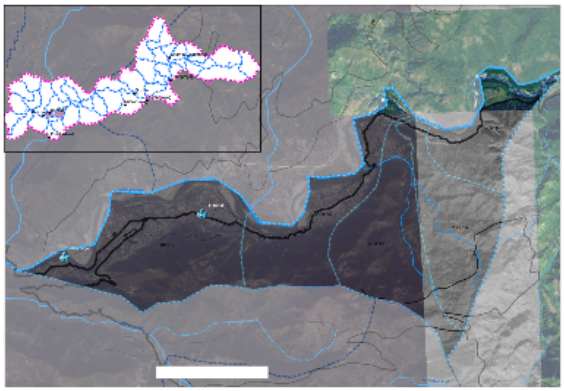


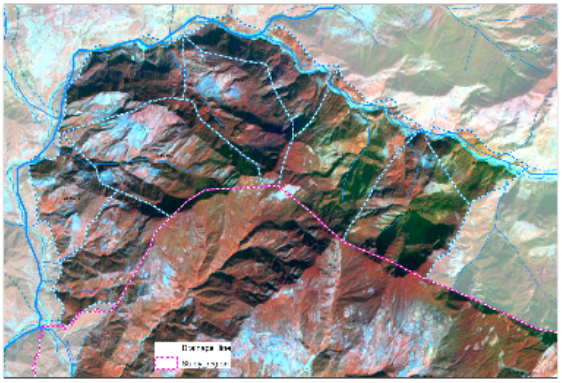

It is observed that most of the suitable land parcels is already acquired by existing settlements in the area which also kind of confirmation to the analysis. But map also contains potential parcels where settlement can come up in order to fulfill needs of the future population. In upstream area near Chamoli, vacant suitable parcels having less than 3 Ha area are present which could be develop as new rural settlement. While between Karanprayag and Nandprayag two medium size vacant suitable parcels is more suitable for small size towns.

## 5.6 Identified micro watershed for immediate attention

Two sub-watersheds falling into very high vulnerability zone has been identified for more detail analysis, demarcation of degraded land parcels and suggesting restoration measures for the same.





This sub watershed is situated in downstream area consisting Kirti nagar and Srinagar which is considered to be large urban centers of the region. NH- 58 is passing through the area.

Figure 86: Map showing micro-watershed base map super imposed by most vulnerable land parcels

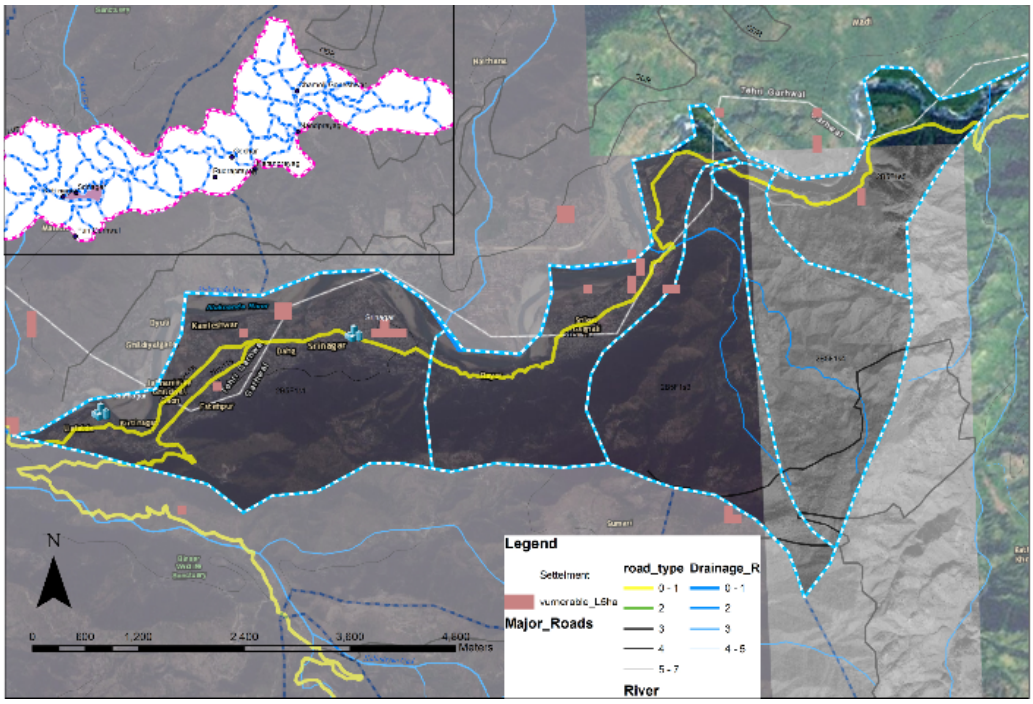



Figure 87: Micro-watershed having larger area of vulnerable parcels

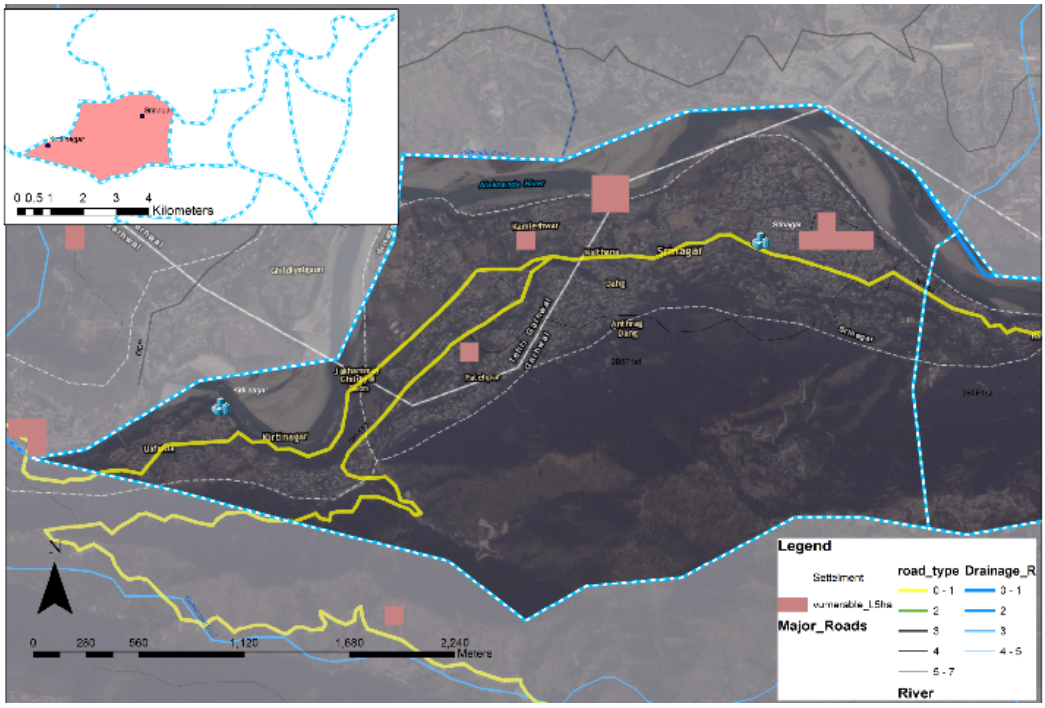


Figure 88: current land use map prepared through NDVI image

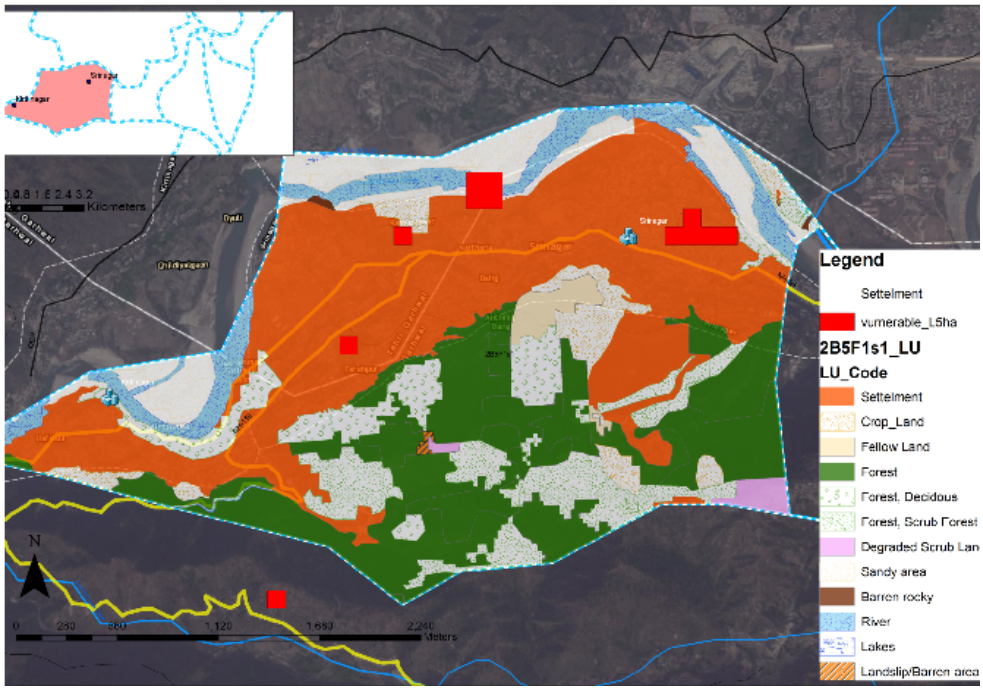
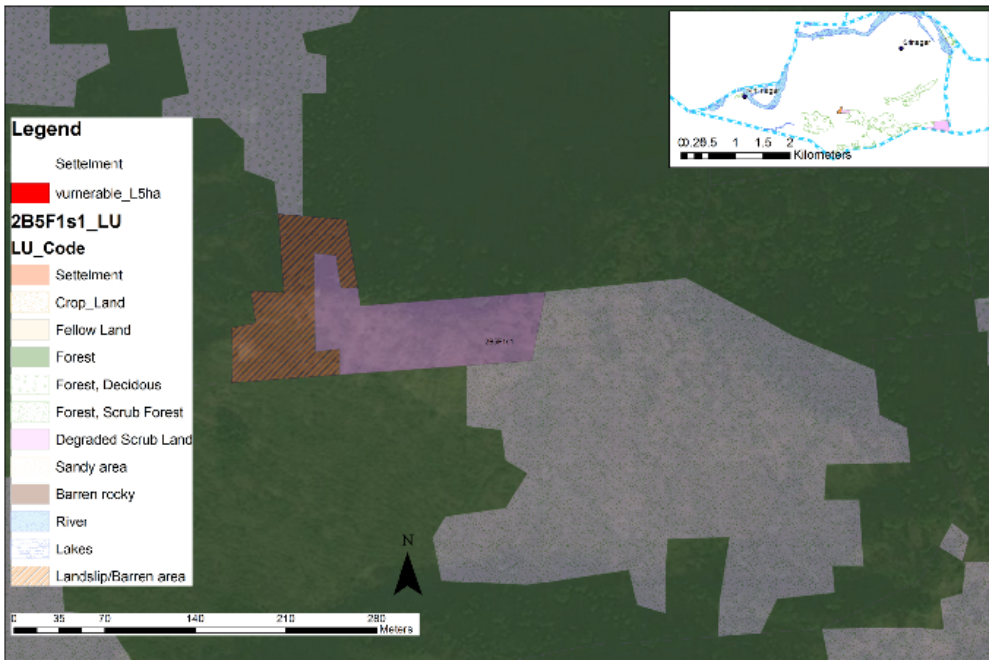



Figure 89: Degraded land parcel identified for restoration




Three categories of degraded land have been demarcated for respective restoration measures discussed in chapter 6. Brown color indicates landslide/landslip area, pink represents degraded scrub land and light green is degraded scrub forest.

# Chapter 6

## 6 Recommendation and proposal

### 6.1 Recommendations

#### 6.1.1 Activity zoning as per physiographic zones

- The northern and eastern most parts of the study area are the snow covered region where no development can take place. These areas are the most sensitive and ecologically fragile area and hence any type of intervening by human should be prohibited here.

- The existing practice of growing seasonal crops and using the land for pasture should be encouraged in the Alpines during the non winter season. Care should be taken that the same patches of pasture land should be used in alternate seasons so that the regeneration capacity of the land can be retained.

- The region most affected by human activities is the Middle Himalayas and the river valleys. The region within Alaknanda river bed is most exploited along with the hills along it through which the NH passes. The relatively low altitude and plain areas in the downstream area; comfortable climatic condition; and lack of suitable land in the uphill region encourage the growth of human settlements here. With increase in population, increases the need of resources resulting in increased burden on the nature.

  Hence the development activities carried by human in these areas need to be regulated and restricted. The type of activities and the extent till which they can be carried out in these regions need to be defined properly.

#### 6.1.2 Soil

Very severe soil erosion takes place in the extreme eastern part of the region that is in the Dasholi region. Severe erosion takes place almost in 50% of the area under concern. These soils are shallow and are dominant along the side slopes. The entire area is prone to landslides except the western most part in the downstream region.

As has already been stated both natural and manmade erosion are dominant in the region. Climatic erosion is a natural process and hence cannot be regulated. What can be regulated are the causes of erosion due to human activities.

- One of the major causes for soil erosion is deforestation for non-forest purposes like HEP projects and rehabilitation of displaced population which has to be strictly prohibited. In case there is no other option other than use of forest land in some cases, afforestation has to be taken up in some nearby degraded areas to balance the loss of the former.

- Clearing of forests and blasting for road building destabilizes the slope leading to landslides. Proper environmental impact assessment needs to be taken for the road projects.

- During field survey, local residents have raised concern regarding use of heavy machinery; vibrator and blasting materials which destabilises the adjoining areas thus triggering small landslides all along the roads. Debris of the road construction is dumped into downslope area below the site; this debris causes severe erosion during monsoon resulting in destabilising of valley slope of the area. Road building techniques and toolkit need to be develop taking various factors into consideration like formulating yardsticks for contour cutting for road building in different zones; providing alternate options for access like lifts or ropeways; lesser use of blasting material; and devising methods for proper debris management and disposal.

- Large hydro power projects submerge huge extracts of forest land, hence small hydro power projects should be encouraged so that the negative impact on environment is reduced.

- Horticulture and tea plantation should be encouraged to prevent soil erosion.

### 6.1.3 Wasteland

The various types of wasteland in the study area include scrub land, waste land due to shifting cultivation, degraded forest, degraded pastures, sandy area and barren rocky area. Around 7% of the study area is under wasteland.

- Scrub land can be retained as they help in soil erosion.

- Shifting agriculture involves clearing of forests. Cultivation is done in these areas for 2 to 3 years following which it is left abandoned due to reduction in soil fertility. This can be minimized by introducing irrigation and use of organic fertilizers.

- Degraded forest includes those forests which has lost its structure and productivity. Degraded forests need to be rehabilitated and forest plantation should be encouraged.

- Degraded pastures can be minimized by controlling over grazing and avoiding the use of each pasture same land in consecutive seasons. The pasture land used in one season should left free in the next season to retain its regenerative capacity.

- Sand mining should be regulated in scientific manner. Illegal mining has to be curbed. Sand mining in sediment accumulation zone of river reduces sediment availability in river bed which increases carrying capacity of river in the downstream area leading to aggravated soil erosion and changing sediment deposition pattern.

  Excessive sand mining in downstream areas increases the slope of channel and flow velocity of water which results in aggravated soil erosion in upstream area.

### 6.1.4 Water resource

- Receding forest area increases the surface run off thus resulting in recurring floods. Hence forest should be conserved.

- Large hydro power projects dries up long stretches of river. Hence they should be prohibited and micro hydro power projects should be promoted.

- The waste generated by the combined population of local residents and tourists pollutes the water bodies. Tourism should be encouraged in a regulated manner and providing facilities like water supply, sewage treatment plants, garbage bins and washrooms, especially in the valley region.

- No new construction activities should be taken up along river beds within 200 m from the bank.
- Disposal of waste of any form into the river must be prohibited.
- Sand mining need to be regulated.
- Building regulation norms like FSI, FAR, ground coverage, setback, height of building, structure and building materials should be specified for taking up any new construction beyond 200 m from the bank.

### 6.1.5 Forest resource

- Oak and pine trees are cut to meet the need for fodder and firewood. Oak and pine forest in the upstream areas should be conserved as they help in retaining water in the soil.
- Alternate source of energy like wind energy, solar energy and water energy should be encouraged to reduce use of firewood.
- The plantation of native wild edibles and preparing products like fruit juice, squash, pickles and jam from them should be encouraged.
- Deliberate forest fire, for better growth of fodder grass, protection of crops from animals and extraction of honey or gum should be prohibited.
- As already mentioned, deforestation should be strictly controlled. Aromatic and medicinal herbs native to the area should be promoted.

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### 6.1.6 Agriculture

- Mixed cropping pattern should be encouraged. Both subsistence crops and cash crops should be cultivated but in a planned manner taking into consideration the suitability of climate and the soil.

- The different crops that are suitable for the concerned area include subsistence crops like rice, wheat, barley, maize, mandua, pulses and soyabean while cash crops include potato, onion, tomato, pumpkin, cucumber, beans, radish, carrot, coriander and green leaves.

- Provision of irrigation facilities through rain water harvesting and check dams and use of organic fertilizer should be taken up to enhance the regenerative capacity of agriculture land thus reducing the impact of shifting agriculture. Increase in net irrigated area would lead to increase in agricultural productivity.

- Contour farming should be taken up. Bund should be provided along the edges of the agricultural field located between two contours. The slope of the terrace farms should be adjusted as per the soil and water condition there. If the slope of the terraces is much inclined outwards, it would aggravate soil erosion. While if they are inclined inwards, water logging may occur. Agricultural fields can be leveled by cut and fill to achieve bigger fields for cultivation. Narrow trenches filled with water and pebbles can be made to direct surface water runoff.

- Cold storage should be established.

- Agriculture is carried on small parcels of land (less than 1 ha). These lands should be combined into one wherever possible and cultivated together. This would improve the economy of scale.

- Proper marketing strategies have to be formed for the agricultural products.

### 6.1.7 Industry

The various types of industries that can be promoted include:

- Agro Based Industry

- Food processing industry

- Horticulture based units

- Pharmaceutical units

- Handloom
- Khadi and Village industries

Polluting industries should be prohibited in the region. Industrial norms pertaining to environment protection should be followed.

### 6.1.8 Tourism

The main issues with respect to tourism include poor road condition, lack of infrastructural facilities, land degradation, increased use of firewood in dhabas, and garbage problems.

- The flow of tourist has to be controlled and regulated. The carrying capacity of the site to support tourism activities needs to be calculated.
- Tourist circuit has to be identified for the area.
- Facilities like washrooms, drinking water sources, eating joints and rest areas should be provided.
- Sewage treatment plant, sites for disposal of wastes, and dustbins has to be provided.
- Cottages in nearby villages can be used for tourists to reside rather than building hotels or lodges on the river bed.

### 6.1.9 Hydropower Projects

The main issues with respect to hydro power projects are clearing of forests for the project itself and to rehabilitate the affected population, submerging of vast tracts of forest land, diversion of river stretches, drying up of water sources, cracks in villages and muck disposal.

- Proper environmental impact assessment has to be carried out before the implementation of large hydropower projects.
- Projects affecting huge tracts of forest land and water resources should be prohibited.

- Micro hydropower projects should be encouraged. Water mills locally called *gharat* at local levels can be promoted.

- Proper disposal of muck need to be carried out.

- Afforestation has to be taken up to balance the loss of forest land affected by these projects.

## 6.2 Proposal

Demarcation of vulnerable pockets to restore the degrade patches. Case specific restoration measures for degraded forest, scrub land and landslide patches can be apply from recommendation part separately.

Figure 90: Degraded land parcel purposed for restoration

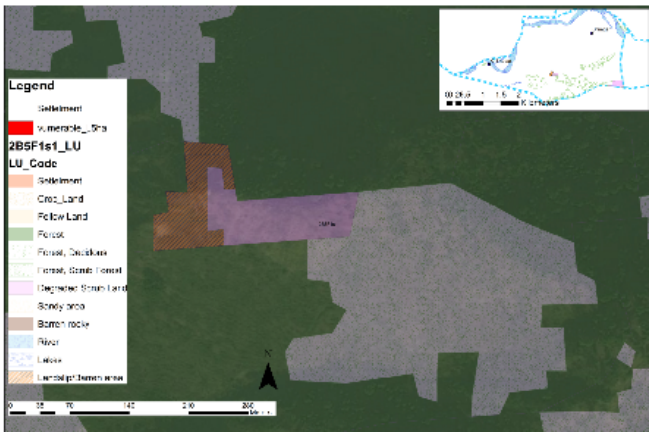
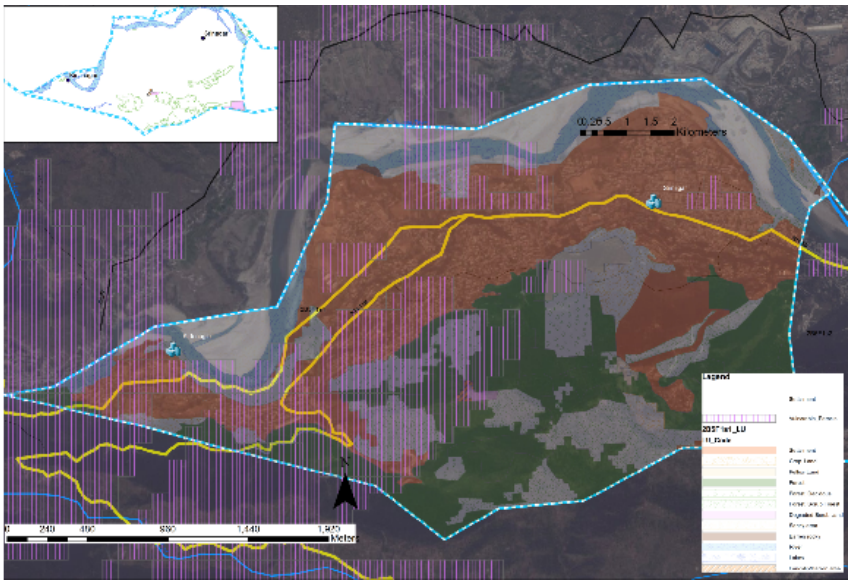



Figure 91: Map showing most vulnerable area in micro watershed



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