LAND CHANGE DYNAMICS AND ASSESSMENT OF DETERMINANTS OF CHANGE: A CASE STUDY OF BHAGIRATHI BASIN IN UTTARAKHAND

Dissertation submitted to Jawaharlal Nehru University

For the partial fulfillment of the degree of

MASTER OF PHILOSOPHY

NISHA

CENTRE FOR THE STUDY OF REGIONAL DEVELOPMENT

SCHOOL OF SOCIAL SCIENCES

JAWAHARLAL NEHRU UNIVERSITY

NEW DELHI 110067

INDIA

2013

जवाहरलाल नेहरू विश्वविद्यालय
JAWAHARLAL NEHRU UNIVERSITY
Centre for the Study of Regional Development
School of Social Sciences
New Delhi-110067

DECLARATION

Certified that the dissertation entitled **"LAND CHANGE DYNAMICS AND ASSESSMENT OF DETERMINANTS OF CHANGE: A CASE STUDY OF BHAGIRATHI BASIN IN UTTARAKHAND"**, is submitted by **"Nisha"** in the partial fulfillment of the award of Master of Philosophy of Jawaharlal Nehru University is a bonafied and original work to the best of our knowledge and may be placed before the examiners for evaluation. This dissertation has not been submitted for the award of any degree of this university or of any other university.

Nisha

Nisha

CERTIFICATE

We recommended that the dissertation be placed before the examiners for evaluation.

Prof. MILAP PUNIA

(Supervisor)

Centre for the Study of Reg. Dev.
School of Social Sciences
Jawaharlal Nehru University
New Delhi - 110067

Prof. P. M. KULKARNI

(Chairperson)

Chairperson
Centre of the Study of Reg. Dev.
School of Social Sciences
Jawaharlal Nehru University
New Delhi-110067

DEDICATED TO

My Loving Parents

ACKNOWLEDGEMENT

It is my humble duty to express my indebtedness and gratitude to my supervisor Prof. Milap Punia for his constant guidance, stimulating suggestions and encouragement enabling me to grasp the complexity and subtlety in the execution of this work. I feel grateful for his comments on chapter drafts and organization of thought has been immensely productive. Without numerous invaluable discussions with him, this research work would not have been completed. He has frequently instilled me with confidence enabling me to work to the utmost of my ability and hence complete this assignment. I personally feel that my gratitude to him is not expressible as a simple acknowledgement.

I am highly thankful to the Central library staff of JNU, Documentation unit of CSRD for the cooperation in this regard. The most importantly my gratitude towards the entire Faculty member of the Centre for the their invaluable suggestions and advices times and bound right from the MA days have directed me towards the holy grail of idea of researching in this field and has instilled the courage that has enabled me to consider and reconsider my thoughts and to channelized it in the given direction. I would also like to thank my teachers for providing me every kind of help during my studies.

I am short of words to express my sincere and respectful thanks to my family members, who have been constant support to me. I feel thankful to my friends who with their tireless enthusiastic motivation and lovable company made the research itself and writing the dissertation worthy a memorable process of learning. The note of gratitude would have been completed without the special mention of my friends and seniors whose supports during the critical times in the whole process are noteworthy. Neha, Nayan, Sandhya, KiranDi, Shivesh, Vivek Dhankar Sir,Sandeep, Varun, Dhiren, Stanzin, Surabhi Jigmat, Nitin and Arvind.

And finally I am grateful to that Almighty who has embedded in me the hope to finish this task with zeal genuinely.

21st July, 2013 *Nisha*

CONTENTS

Abbreviations

1	GIS	Geographic Information Systems
2	IPCC	Intergovernmental Panel on Climate Change
3	IGBP	International Geosphere-Biosphere Programme
4	LULCC	Land Use and land Cover Change
5	IHDP	Human Dimensions Programme on Global Environmental Change
6	NRSC	National remote sensing Centre
7	AWiFS	Advanced Wide Field Sensor
8	MODIS	Moderate Resolution Imaging Spectroradiometer
9	SRTM	Shuttle Radar Topography Mission
10	IMD	Indian Metrological Department
11	OLS DMSP	Operational Linescan System and Defence Meteorological Satellite Program
12	LCM	Land Change Modeler
13	PCA	Principal Component Analysis
14	SoVI	Social Vulnerability Index
15	GLOF	Glacial Lake Outburst Flood
16	ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
17	DEM	Digital Elevation Model
18	ICIMOD	International Centre for Integrated Mountain Development
19	UTM	Universal Transverse Mercator
20	MLP	Maximum Likelihood Parameter
21	PMGSY	Pradhan Mantri Gramin Sadak Yojna

LIST OF MAPS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

1.1 INTRODUCTION

Land use and land cover information extracted from remote sensing systems purvey us with the quantitative values for all possible applications/functions performed by human and environment respectively over various scales, particularly at synoptic scale. Remote sensing-both data and image processing and analysis through geographic information systems (GIS) are increasingly affecting the research agendas on global environmental change, as evidenced by various reports of the Intergovernmental Panel on Climate Change (IPCC) and the International Geosphere-Biosphere Programme (IGBP), as well as a number of initiatives by institutions and organizations that fund research on global change. Remote sensing and GIS playing a big role and in future has to play big in sphere of research, particularly environmental research. The impacts of remote sensing and GIS to date have been greatest within the environmental and policy arenas because space-based and other imagery is used primarily to determine the physical properties of the biosphere and the lithospheric surface, such as forest cover or changes in built up—information that is needed in spatially explicit form by various stakeholders and decision makers. Till now, indirect linkages between information embedded within spatial imagery and the core themes of the social sciences has been emphasized under the human dimensions of global change. These human dimension encompasses assessments of the proximate causes of land-use and land-cover change (e.g., shifting cultivation, clear-cutting of timber, illegal construction on steep slopes and on river bed), environmental constraints/ opportunities associated with human activities[1].

[1] Jacqueline Geoghegan, Lowell Pritchard, Jr.,Yelena Ogneva-Himmelberger, Rinku Roy Chowdhury, Steven Sanderson, and B.L. Turner II (1998), "Socializing the Pixel" and" Pixelizing the Social" in Land-Use and Land-Cover Change, People and Pixels Linking Remote Sensing and Social Science, National Academy Press, Washington, D.C.

There has been many attempts to generate knowledge out of global land use and land cover initiatives and such opportunity is represented by the core research project on Land-Use/Cover Change (LUCC) of the IGBP and the International Human Dimensions Programme on Global Environmental Change (IHDP)[2].This project (or project framework) is prepared to improve understanding of the human and biophysical forces that design land-use/cover change through three measures of assessment: (1) ground-based studies of use-cover dynamics, focused on the land manager; (2) space-based observation of the land- cover consequences; and (3) integrative models of these dynamics at various scales of analysis. The objectives of the LUCC project include making remote sensing in general (but especially that involving satellite imagery) more relevant to the social, political, and economic problems and theories pertinent to land-use and land-cover change which we euphemistically call "socializing the pixel" and "pixelizing the social[3]." This objective incorporates methodological tools, such as GIS, that are relevant to analysis of spatial imagery and "gridded" data in general. efforts to achieve this objective must attend issues of scalar dynamics—interpreting, merging, and analyzing the data and analysis across spatial, temporal, and hierarchical scales. National remote sensing Centre (NRSC), ISRO-Department of Space is preparing ,a repository of land use land cover information extracted from AWiFS sensor (on board IRS-P6) of 56 meters every from 2004-05 at national level[4].

Land-use and land-cover change are layman terms for the human modification of Earth's terrestrial surface. Land use and land cover are two different terminologies that are very often used as a substitute for each other. 'Land cover refers to the physical materials on the surface of a given parcel of land, while land use refers to the human activities that takes place on or make use of land e.g. residential, commercial, industrial etc.' Through centuries, humans have been modifying land to obtain food and other essentials for socio-

---

[2] Turner, M., G.J. Arthaud, R.T. Engstrom, S.J. Hejl, J. Liu, S. Loeb, and K. McKelvey, (1995) Usefulness of spatially explicit population models in land management. *Ecological Applications* 5:12-16.

[3] Jacqueline Geoghegan, Lowell Pritchard, Jr.,Yelena Ogneva-Himmelberger, Rinku Roy Chowdhury, Steven Sanderson, and B.L. Turner II (1998), "Socializing the Pixel" and" Pixelizing the Social" in Land-Use and Land-Cover Change, People and Pixels Linking Remote Sensing and Social Science, National Academy Press, Washington, D.C.

[4] National Remote Sensing Agency, (2006), National Land Use Land Cover Mapping using multi-temporal AWiFS data: project report 2004-05, Department of Space, Govt. of India, Hyderabad, pp. 9-18.

economic purposes. Currently, the rate, extent and intensity of land use and land cover change far exceeds the usage in past, driving unprecedented changes in ecosystems and environmental processes at the local, regional and global scales. These changes encompass the greatest environmental concerns of human population today, which includes the increasing climate change, biodiversity loss and the pollution of water, soil and air.

Land use effects land cover and changes in land cover affect land use. The land use and land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization as well as exploitation by men through time and space. The research reveals that the intense and rampant land use in mountain environments is leading gradually towards a regional-scale degradation of land. Steady population growth, immigration, improved access to the healthcare facilities, often necessitates the development of infrastructures such as better roads, buildings, agricultural/horticulture, timber extraction, and grazing activity. The resulting impact of such development inevitably leads to changes associated with climatic variables. The LULC change affects surface temperature because it changes the way that available energy is partitioned between sensible and latent heat. This in turn changes the efficiency of turbulent transfer and affects the amount of available energy via a change in albedo resulting in variations in temperature.

LULC change study is significant, since today's world is surrounded by plethora of changes in LULC, which are ultimately going to affect everybody's life at a micro level scale as well as synoptic scale. LULC changes are one of the elementary changes in the physical space of a region, which have huge potential of alteration through its backward and forward linkages with other elements, be it physical realm or social realm elements.

Remote sensing technology is one proven strategy to better document, characterize and quantify land use land cover. This information is vital input for various developmental, environmental and resource planning applications, and regional as well as global scale process models. These kinds of databases are also important for national accounting of natural resources and planning at regular intervals. Thus, in this study attempt has been made to harness the potential of remote sensing datasets, techniques and analysis of information for land use and land cover change and assessment of possible determinates of change. This study adopted both spatial and socio-economic analysis with help of remote sensing and socio-economic data from census of India.

1.2 STATEMENT OF PROBLEM

The presence of snow on Earth is a significant presence over a wide range of spatial and temporal scales. Locally and regionally, the interaction of cryosphere with the human and natural environment occurs in both, the positive and the negative ways. On the global scale, the cryosphere represents an important part of the Earth's climate system. Snow and ice are generally highly reflective of the incident solar radiation, as they provide a feedback mechanism to the system. Their presence, and annual and long-term variations, modifies the distribution and flow of water. The seasonal snow cover is responsible for the largest annual and inter-annual variations in land surface albedo and contributes towards an important feedback mechanism to the global climate system[5]. Area under snow has direct impact on regional climate, it affects amount of solar incoming radiation and thus local albedo. An albedo is generally understood to be the ratio of incoming to outgoing solar radiation. The snow albedo feedback is a positive feedback mechanism which in layman term means that, if the snow-covered area warms, snow tends to melt, lowering the albedo, and therefore resulting in further melting of snow. Physical properties of snow such as grain size, density, wetness or moisture content are also important for the transfer of heat and water and it also alters the reflectivity. Thus, seasonal snow cover alters the albedo, resulting in the alteration of the regional climate.

The largest snow cover areas are located in Antarctica and Greenland and in many other smaller masses located in high mountains. The large ice sheets are immensely important in the global climate system, occupying about 11% of the Earth's land surface. The presence of a very high albedo (which can exceed 90%) makes them brightest naturally occurring objects on Earth. This also results in making them an important component of

[5] Rees, W. Gareth (2006), Remote Sensing of Snow and Ice, CRC Press, Taylor & Francis Group, Cambridge University England.

the albedo feedback mechanism of the global climate system. Their low temperature contributes to the global temperature gradient that drives the atmospheric circulation system and their size and position profoundly affects the detail of this circulation. In addition to that, they are also the major repositories of fresh water[6].

The Himalayas are the youngest and the highest mountains of the world, having the largest concentration of glaciers outside the polar caps. Their glacier coverage estimates around 33,000 square kilometers. The region is aptly called the 'water tower of Asia' as it provides around 8.6 x 106 m^3 of water annually[7]. The melt water from the extensive snow cover and glaciers in the Himalayas drains into the perennial Himalayan river systems. This function is extremely vital for the millions of lives inhabiting the mountain slopes and plains in the south. But with time, an increased ablation recently observed in the Himalayas due to climate change is leading towards changes in the hydrology of the region[8]. These changes are likely to cause a temporary increase in annual flow of the melt water followed by a reduction of Himalayan river flows in the long run. This reduction in turn is likely to have a significant negative impact on the everyday life, economy of the people residing in the highlands and the downstream regions.

The environmental problems concerned with the change in a snow covered area and its impact on climate will directly have an effect on the economy of a region.[9] People inhabiting the mountains have lived with and survived great hazards such as flash floods, avalanches, and droughts for millennia. Kulkarni's (2012) research shows that in Baspa glacier, snow line was visible at 4,900 meter in 1976. It went up to 5,200 meter in 2006. This change shows that there has been a shift in the snow line. Similarly, Singh et al[10] (2012) study confirms that there is an upward shift of vegetation in the alpine zone of the

[6] Bindschadler, R. (1998), Monitoring ice sheet behavior from space. *Reviews of Geophysics*, Vol. 36(1) pp 79-104.

[7] Dyurgerov, M.B. and Meier, M.F., (1997). Mass balance of mountain and sub polar glaciers: a new global assessment for 1961–1990. *Arctic and Alpine Research*, vol. 29 (4), 379–391.

[8] IPCC, 2007.

[9] ICIMOD (2010) 'Climate Change Impact and Vulnerability in the Eastern Himalayas' – Synthesis Report. MacAurthur Foundation.

[10] Singh, C.P.,Panigrahy.,S.,Thapliyal., A., Kimothi., M.M., Soni., P. and Parihar, J.S., (2012), Monitoring the alpine treeline shift in parts of the Indian Himalayas using remote sensing, *Current Science*, 102(4), 559-562.

Himalayas. Bolch et al [11](2012) reviews that most of the Himalayan glaciers are losing mass at a rate alarmingly similar to the glaciers elsewhere, except for an emerging indication of a mass gain in the Karakoram. These prior researches have allowed this study to be directed more towards the impact of land use/land cover changes on the regional climate. In this dissertation, focus would be on how such changes modulate the altitudinal wise change in the basin.

The greater geodiversity in mountains than in most other landscapes provides to it a special status. Mountain stratigraphic system cannot be claimed as the extraordinarily fragile but a greater range of vulnerability to disturbance than many landscape, in the physical space leading to disturbance in social space, makes it special eco-sensitive zone with greater degree of fragility. Being high and steep, mountain system transmit the disturbance, occurring when natural hazards, whether seismic, volcanic, mass movements or floods takes place, is rapidly transmitted through the stratigraphic system. When inappropriate land use changes are made, vegetation soil are rapidly removed, because of the steep terrain, low temperature and relatively less developed soils, the recovery of the mountain stratigraphic system from disturbance is generally slow and sometimes falters entirely.

Moreover, remote sensing data is in particular useful for land cover mapping in mountainous regions such as the Himalayas, since these areas are generally inaccessible due to the higher altitudes and the ruggedness of the terrain. Over the years, a number of studies to map land cover using remote sensing data in the higher mountain areas have been reported with varying degrees of accuracy. This may be due to a large number of factors that influence the remote sensing process. These include the presence of shadows due to the high altitude of the terrain, the cloud cover, deep narrow valleys and ravines, low sun angles, steep slopes and differential vegetation cover. Therefore, due to changes in the environmental conditions, spectral characteristics also change from one region to the other (Arora and Mathur, 2001). Hence, classification only on the basis of spectral data from a remote sensing sensor alone may not be sufficient to gather effective land

[11] Tobias Bolch, Anil Kulkarni, Andreas Kääb, Christian Huggel, Frank Paul, Graham Cogley, Holger Frey, Jeffrey S. Kargel, Koji Fujita, Marlene Scheel, Markus Stoffel, Samjwal Bajracharya, (2012), The state and fate of Himalayan Glaciers, *Science*, vol. 336, 310-314.

cover information. A classification approach that incorporates data from other sources may therefore be more effective than one that is based solely upon the multispectral data from a single remote sensing sensor.

1.3 STUDY AREA

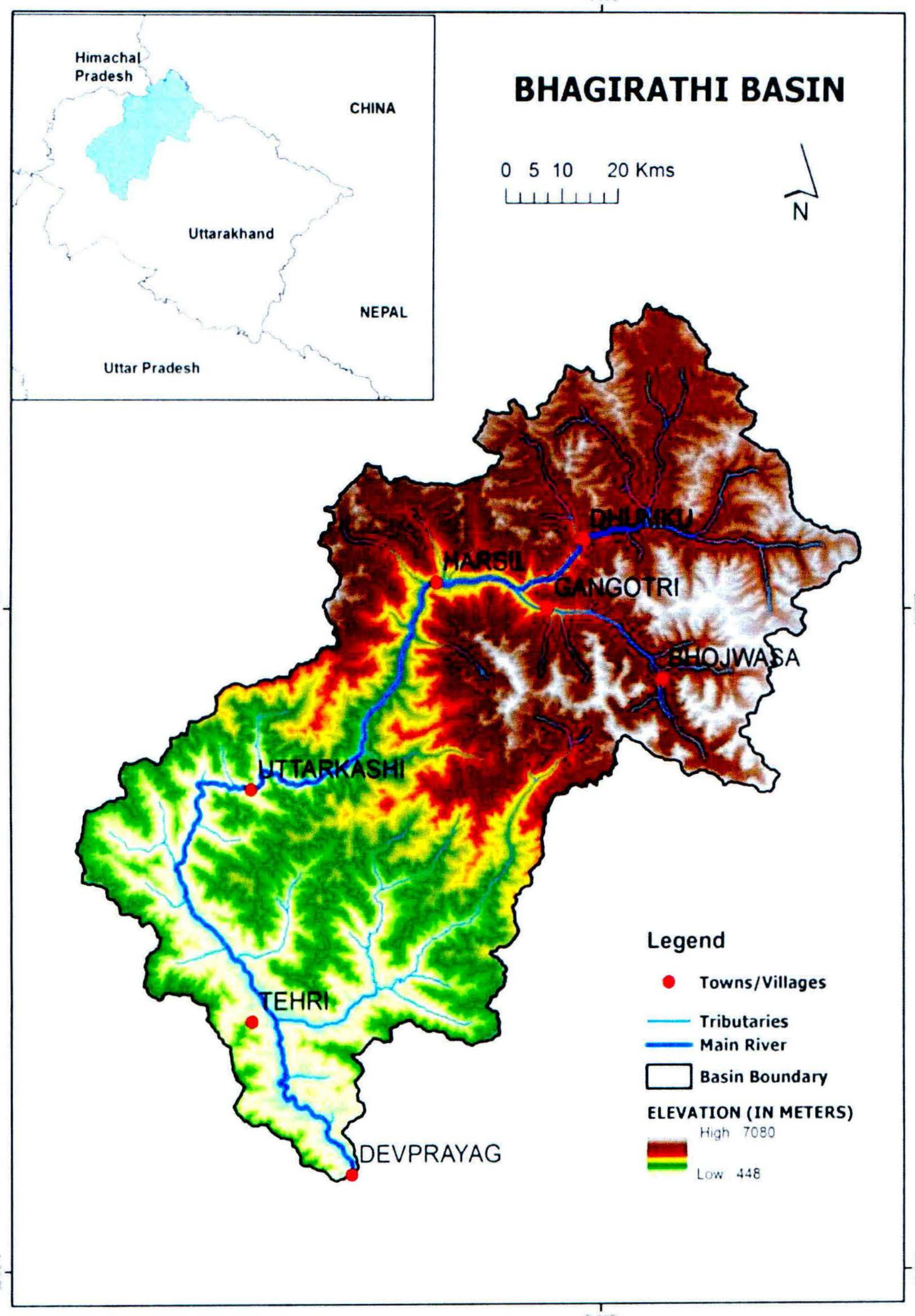
1.3.1 Location of study Area

Selected study area is located between the latitude 31° 30' 00" N to 30° 06' 00" N and longitude 78° 06' 00" E to 79° 30' 00" E in Garhwal Himalayas. The basin is defined in the north by the international boundary, and by the water dived between Satluj and Bhagirathi basin. In the south, Devprayag (the confluence of Alaknanda River and Bhagirathi River) marks the limit of the basin. The basin limits are marked by the water divide between Bhilangna Ganga (a tributary of Bhagirathi River) and Mandakini River (tributary of Alaknanda River) on the east, and water divide with the Yamuna basin on the west (Sangewar and Shukla, 2009)[12]. Bhagirathi basin covers an area of 7,502 squares kilometer. Out of which 755 squares kilometers (10.06 %) is glacier covered. 238 glaciers have been identified in this basin (Singh et al., 2008)[13].

[12] Sangewar, C.V. and Shukla, S.P., 2009. 'An inventory of Himalayan Glaciers', Special Publication No.34, *Geological Survey of India*. 588pp.

[13] Singh, R.k., Srivastava, D. and Sangewar, C.V., 2008. 'Glacier Inventory-basin wise classification of the glaciers and Data cards'. In: Raina, V.K. and Srivastava , D. (Eds), *Glacier Atlas of India. Geological Society of India.* Bangalore, 65-185.

Map 1.1 Study Area



1.3.2 General introduction of the Study Area

The Bhagirathi River emerging from the Gangotri glacier at Gomukh is considered to be the source of the Ganga River (Spate, 1957)[14]. It is situated in the Uttarkashi district of Uttarkhand State. The name of the state Uttarakhand come into existence in year 1999 as a 27 State of the Republic of India, earlier this state was part of another state, Uttar Pradesh. Uttarakhand is surrounded by Tibet in the north and Nepal in the east. The whole state is a hilly terrain incorporating the Trans, Higher, Lesser and sub-Himalaya part along with the great Indo-Gangetic Plain falling in the Haridwar and Udham Singh Nagar Districts.

Bhagirathi river basin is not a single valley glacier, but a combination of several other glaciers which are fed to it forming a huge mass of ice. Bhagirathi peaks are a group of peaks, each with a height above 6400m. The three peaks Bhagirathi I, II, and III stand at and dominate the end of the valley leading up to Gaumukh. These peaks form a part of the Himalayan ranges in the Gharwal region. The glacier flows at a gentle slope except for a few ice walls and crevices developed in the upper regions of the glacier whereas in the lower part (above the snout), the glacier is covered with debris which imparts a muddy appearance to its surface. It is a combination of the large number of glaciers that form the huge mass of ice. The total catchment area of Bhagirathi River is 8846.64 sq. km and lies in Uttarkashi and Tehri Garhwal districts. The catchment can be subdivided into the watershed of the Bhagirathi, Bhilangana, Kaldi, Pilang, Jalandhri and Jahnvi Ganga.[15]

The Ganga River bed up to Gangotri is filled up with debris left behind due to the recession of glaciers. Further downstream of Gangotri, the evidence of broad U shaped valley of glacial origin is seen only at the higher elevation and the river has cut a narrow V- shaped fluvial valley at the lower elevation up to Kharali. The bed slope is steep in the upper reaches and is of the order of 50m to 30m per kmm from Gangotri to Loharinag Dingad. It decreases to 20m per km in its descent from Loharinag to Tehri. The total

[14] O.H.K, Spate., (1957) India and Pakistan: A General and Regional Geography.
[15] Selvan, M.T and Kodi, Malar P. (2012), 'Application of Remote Sensing techniques to study Hydro-Meteorological changes on the dynamics of glaciers, Bhagirathi basin, Garhwal Himalaya', *ARPN Journal of Engineering and Applied Sciences* Vol.7 No.3 March.

catchment area of Bhagirathi River is 8846.64 sq km and lies in Uttarkashi and Tehri Garhwal districts. Their catchment can be sub-divided into the watershed of the Bhagirathi, Bhilangana and Asi Ganga River.

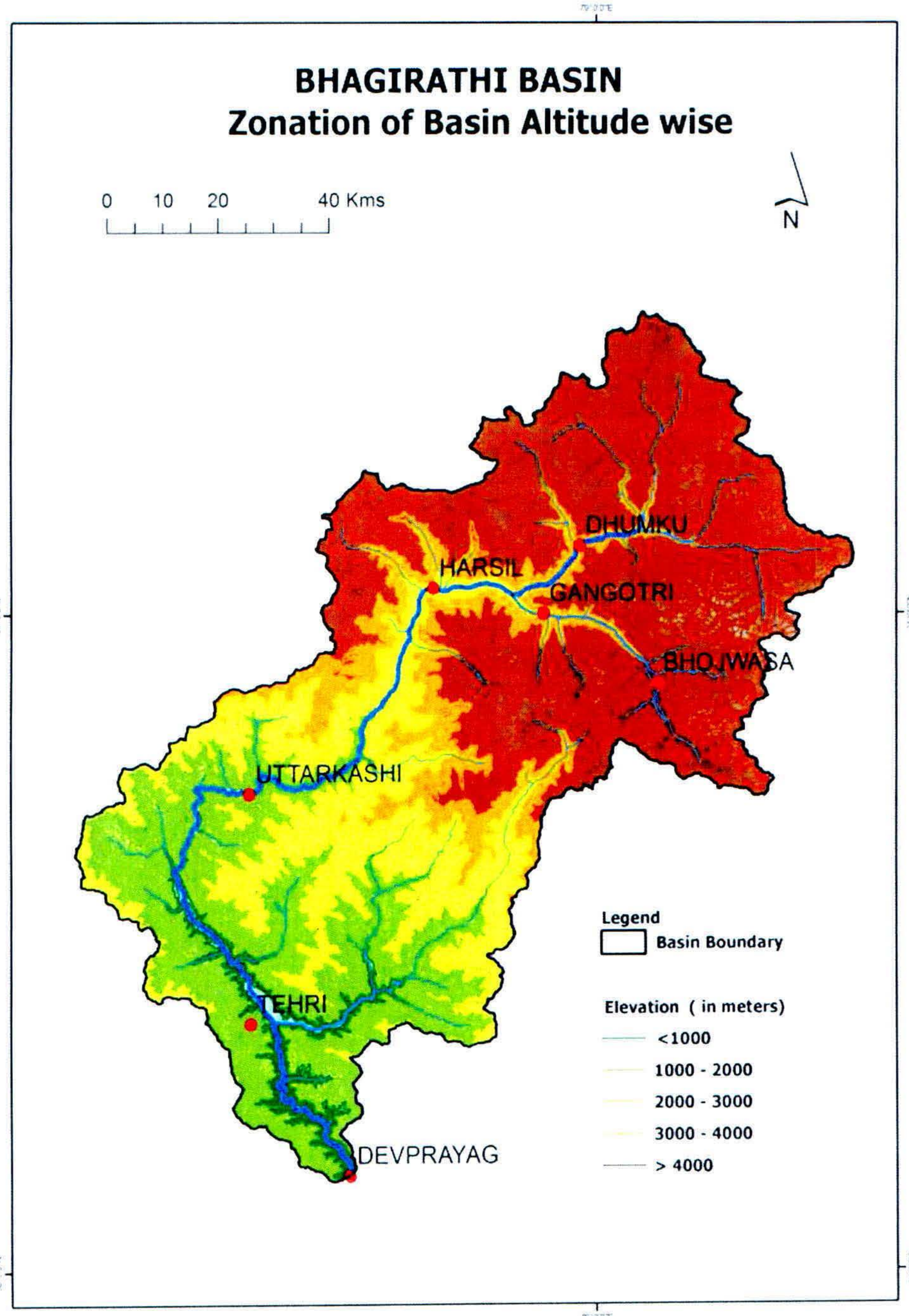
1.3.3 Altitudinal division of Bhagirathi Basin

Physically, the study region rises from the sub-Siwalik Bhabar to a magnificent series of glacier-garlanded peaks: Kedarnath, Badrinath group (6710-7010 metres.) of peculiar sanctity as feeding the Bhagirathi and Alaknanda headwaters of Ganga; Kamet (7756 meter.) across the Alaknanda; the farther east Trisul, Nanda devi, the last (7817 meter.) being the highest peak in India outside Kashmir. Superimposed, as it were, on the recently mobile and highly complex base are the effects of intense contemporary physiographic activity. Much of the area below 380 meters is forested, largely on the northern slopes with their less direct but more effective precipitation (Spate, 1957).

In the Bhagirathi sub-basin, the highest and the most fascinating zone, is located above 4000m elevation. Most of the region is snowbound. This zone is the principal source of water and major tributaries of Ganga River emanates from this zone. No vegetation grows in this area. Also, this zone lacks habitable human population. Occasionally, shepherds visit with their flocks for grazing purposes. Between 4000 m and 3000 m elevation, the valleys and amphitheaters are filled with glacial debris that is being slowly removed by rivers. This zone has plenty of alpine meadows which provide pastures for semi- nomadic tribes. This zone supports sub- alpine type trees. Between elevation of 3000 m and 2000 m, tremendous gorges are found. Truncated spurs rise steeply to dizzy heights. Over them water falls descend from the hanging valleys. This zone is also sparsely populated. The habitation and communication lie along valley bottom. The area is extremely rugged. This zone has some of rich temperate forests and generally good vegetation can be found. It has reasonable concentration of trees. The fields are generally scattered, small and in steps. Between elevation 2000 m and 1000 m, the river terraces are quite common. The valleys are open. Terraces provide fertile land for intensive cultivation. This zone has comparatively high density of population. This zone also supports sub-tropical Chir forests. Most of the project area falls between the slope 33 %

to 100 %. This reflects their vulnerability to soil erosion and emphasizes the need to protect the area against it[16]. (Map 1.2).

Map 1.2 Bhagirathi Basin, Altitude wise zones



Source: *From SRTM Satellite Data*

[16] AHEC/2011: Assessment Of Cumulative Impact Of Hydropower Projects in Alaknanda and Bhagirathi Basins.

Bhilangana and Asiganga are the major tributaries of Bhagirathi River. Asiganga joins Bhagirathi River upstream of Uttarkashi. Bhilangana River originates from Khatling glacier and joins Bhagirathi River at Tehri. It has its own sub- tributaries, namely Balganga and Dharni Ganga.

1.3.4 Glaciers

A large number of glaciers exist above the snow line. The factors controlling the glacierization of an area includes the height of ridges, the orientation of slopes and the amount and type of precipitation in the area. The Gangotri system is a cluster of glaciers comprising the main Gangotri glacier as a trunk part of the system. The other major glaciers of the system are: Raktvarn (55.30 sq km), Chaturangi (67.70 sq km), Kirti (33.14 sq km), Swachand (16.71 sq km), Ghanohim (12.97 sq km), and few others (13 sq km). Depth of the glacier is about 200 m and the elevation varies from 4,000-7,000 m. Satopanth and Bhagirath Kharak glaciers in upper Alaknanda basin originates from the peaks of Chaukhamba and Badrinath range. These glaciers are 13 and 18 km long respectively with snouts at an altitude of 3800 m.Owing to the large size of Gangotri glacier, and its melt water stream, the Bhagirathi River is a full-fledged river even though it emerges from the sub-glacial tunnel at the glacier terminus of the Gaumukh (Cow's mouth)[17].

1.3.5 Rainfall

The basic pattern of Indian climate is governed by the summer and winter monsoon systems of Asia. The winter rains are brought by the 'Western disturbances' and the summer rains by the summer monsoon winds. The seasonal regularity of monsoon winds and rainfall affecting local climates varies. Sometimes, the rains may come at the expected time and at others, rainfall over an entire monsoon season may be considerably diminished. By contrast, there are times when the rainfall is unusually heavy leading

[17] ibid

often to disastrous floods. In the interior region of catchment, rainfall is very low. Annual rainfall is about 1500 – 2000 mm.

The maximum rainfall is observed during the monsoon months due to south west monsoon which normally strikes the Garhwal Himalayas towards the end of June and withdraws from the region towards the end of September. The precipitation is due to the passage of depressions of cyclonic storms from the Bay of Bengal over the region. After originating from the Bay of Bengal, the monsoon winds move in North West direction disturbances advancing towards Afghanistan and West Pakistan.

1.3.6 Temperature

Temperature varies greatly from place to place and from month to month. Maximum temperature ranges from 30° C to 36° C while minimum between 0° C to 6° C. For every 1000 m rise in elevation, the mean temperature falls by approximately 6° C.

1.3.7 Wind

The wind pattern in the area is extremely complicated. The general direction of the flow over the mountains in winter is from North-East to North- west. Over mountains the actual wind may show considerable deviation due to local influences. At higher levels, the winds are westerly of about 120 km per hour reaching 160 km per hour or more. At low levels they are about 50-60 km per hour.

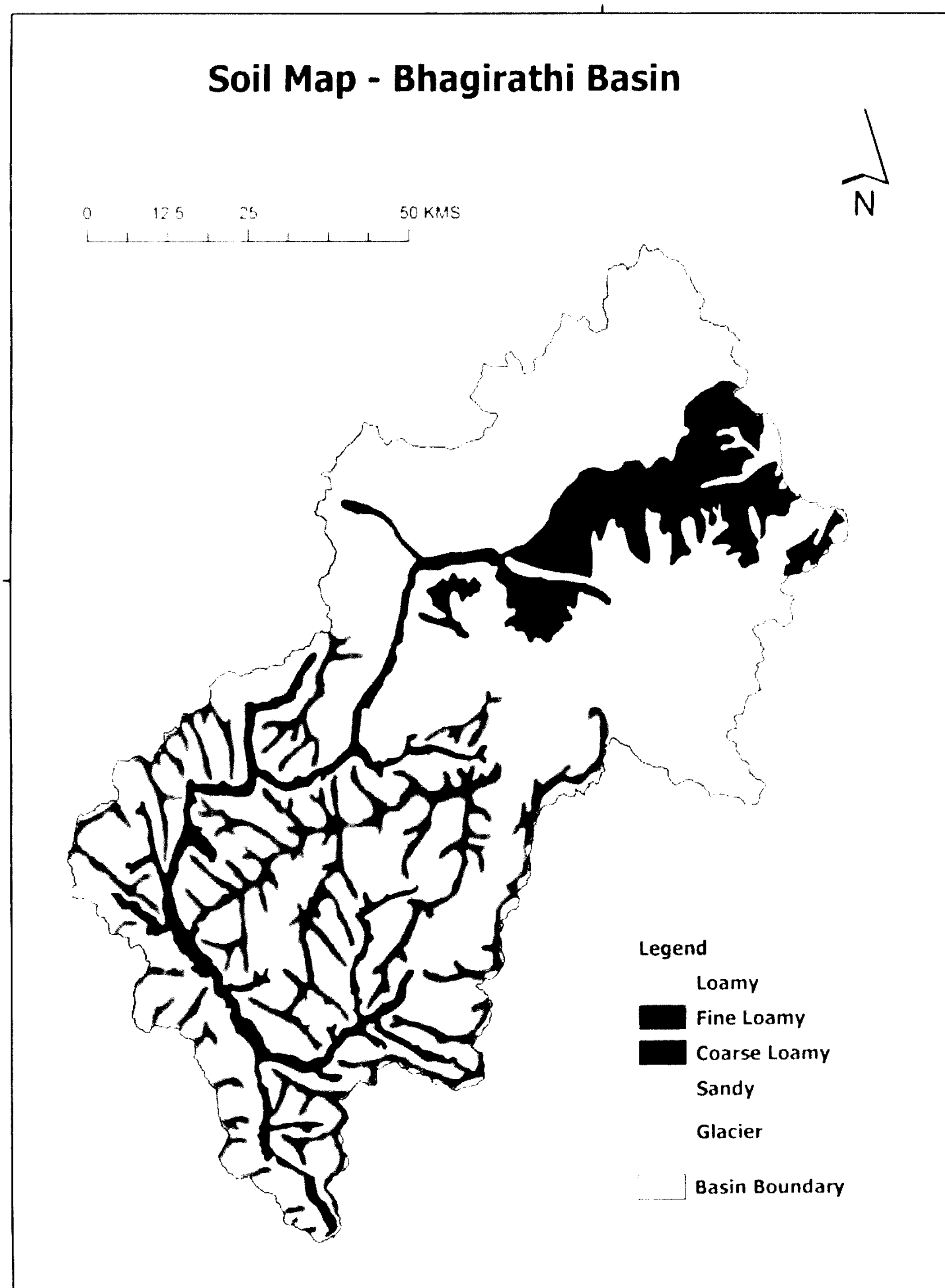
1.3.8 Soil

The soil is generally shallow and moderate with less than 50 cm thickness on a steep slope area exception being the cultivated areas on moderate slope where the thickness of the soil is relatively more and mainly comprises of the fine soil[18]. The flat areas and inter-mountain valleys contain thicker soil cover. The piedmont zones in the area contain variable thickness of the soil types. It can be noticed in the entire study area that the characteristic of the soil changes with the changing altitude and the geomorphic situations.

---

[18] NRSA, 2001.

Map 1.3 Soil Map of Basin



1.3.9 Land Cover

The major land cover patterns in the study area are Snow cover, Glacial Debris, forest, scrubs, barren land, agriculture land, Fallow land, Settlements and the water bodies. The agricultural land is mainly present in the hill cut terraces and near the river terraces. The major settlements in the study area are along the national highway that runs close to the Bhagirathi River. Some other isolated settlements are also present in a scattered form in the area.

1.3.10 Vegetation

It can be observed that in the entire study area comprising of both the high and low altitude regions, the dominant plants are Deodar, Pinus, Rhododendron, Betulautilus, Cesrus, Piceasp with beautiful pastures and grass land. The moderate and the low altitude slopes are generally used for step cultivation to grow vegetables and crops. The dominant natural vegetation over these slopes is mainly Pinus, Dalbegia sisoo and Shores Robusta.

1.3.11 Drainage

The study area is drained by one of the holiest river in India, named Ganga, also known as Bhagirathi in the upper riches. It originates from the Gangotri Glacier in Tethys Himalaya and forms a U- Shaped valley in the upper course near Jhala. It forms V-shaped gorges during the course of greater Himalaya and lesser Himalaya. The dendritic drainage pattern is predominant over the entire region of the study area. The parallel and the sub-parallel pattern can also be observed along the hill slopes.

1.3.12 Geology and Geomorphology

The study area mainly consists of two geological stratigraphic units from south to north namely: Garhwal group and the central crystalline. The Chail thrust separates the Garhwal group from the Central crystalline[19]. The dominant rock types found in this Garhwal group are mainly quartzite and metabasic with intercalation of phillite and

---

[19] Islam. R. and Thakur, V. C., 1988. Geology of the Bhilangana Valley, Garhwal Himalaya. Geoscience Journal, 9: 143-152.

chlorite schist, while the central crystalline group mainly consists of Sheared granite gneisses, porphyritic gneiss, talk schist, mica schist, mylonites and quartz – feldspathic schist[20].

The area is transversed by numerous thrust and faults trending in east-west. Geomorphology of the area can be described as highly dissected structural hills of Pre-Cambrian metamorphic/meta-sedimentary rocks with an active denudational processes leading to rugged topography. The major land-forms in the area are glacial, fluvial, structural and denudational in origin. The general geomorphic features are cliffs, rocky slopes, waterfalls, major and minor ridges and quaternary deposits along the river valley and hill slope. The structural and lithological control on the development of landforms is evident in the area by the fact that the metamorphic rocks which are dominant in the area are more resistant to the weathering process.

1.3.13 Livelihood Options and People

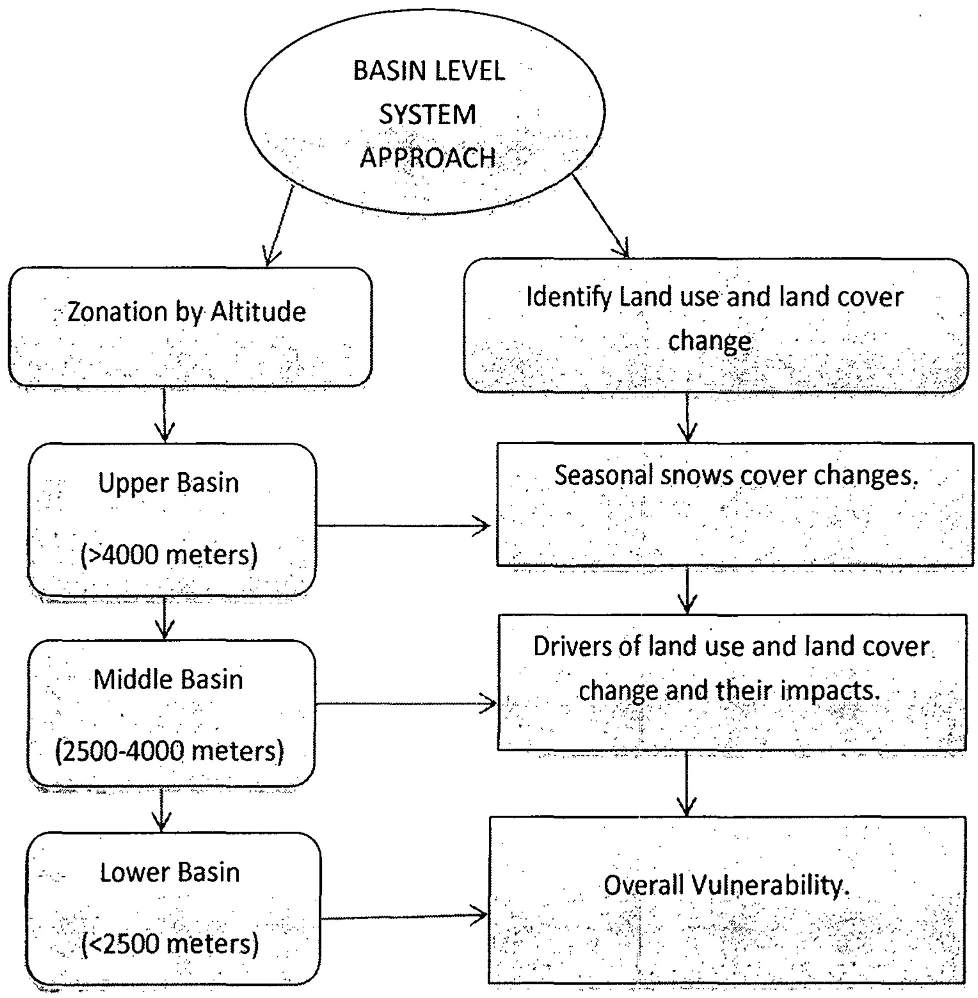
In the region as a whole pastoralism and various trading activities are of less significance than agriculture, but in the higher north they may be said to predominate. Lower down the forest play an intimate part in the life of the people. At the highest level live the Bhotiya, among whom pastoralism and trading are more important than agriculture. Their alpine pasture lie at 3050-4270 mtr. in valleys with little rain but much winter snow. Fields are too small and irregular for ploughs to be used, and hoe culture is far more common. Madua, Wheat, Barley are the chief crops, often irrigated by primary methods on little outwash cones. Life of Bhotiyas is mobile. During the long absence of the menfolk of woman weave fine woolen. The main baggage animals are sheep and goats. A notable contrast with rest of Kumaun is provided by the higher and more independent status of the Bhotiya women (Spate, 1997).

---

[20] Choubey, V.M. and Ramola, R.C., 1997. Correlation between geology and radon levels in groundwa-ter, soil and indoor air in Bhilangana Valley, Garhwal Himalaya, India. Environmental Geology, 32: 258-262.

1.4 PURPOSE OF THE STUDY

Figure No. 1: Basin Level System Approach



Flow chart: Interlinkages between different levels of basin

Flow chart illustrates how in an altitude based zones of river basin a sequence of changes, which are interlinked, in one zone leads to changes on the other zones and finally leads to impact on the vulnerability map of the down basin region.

1.5 OBJECTIVES

This study is based on basin level system approach. The main aim of the study is to focus on the changes that have occurred in higher altitudes in the basin, linkages between the upper basin region and lower basin region and how changes in upper basin or stream region affects socio economic vulnerability profile of down basin or stream region having adverse impact on the livelihood options of the residents of the downstream region. The research objectives of the study are as follows:

1. To investigate and assess land use and land cover change in Bhagirathi basin.
2. To identify and analyze the drivers of land use land cover change and its impacts.
3. To assess the variability in snow cover area and its impacts.
4. To analyze the overall vulnerability in the region due to anthropogenic interventions/ climate change.

1.6 RESEARCH QUESTIONS

To understand the basin level system approach in context of altitudinal wise LULC change and its impact on downstream, the following key questions need to be answered:

1. Where LULC changes have taken place in the past?
2. What are the drivers or determinants of land-use change?
3. How information on these drivers can be used to project future LULC patterns?
4. What will be the consequences of change in LULC and regional climate?
5. How land use change leads to the social environmental vulnerability

1.7 DATA BASE

The present research used various datasets from remote sensing data to geoenvironmental data in the Bhagirathi basin for the study. The brief details of datasets used in the present research are summarized in table 1.1

Table 1.1 Overview of the source, purpose and description of the data sets used in present study

S.No.	Data Source	Year/Time period	Purpose and Description
1	Multitemporal Landsat images	MSS, TM	To analyse the land use and land cover change in the basin.
2	MODIS Since 2000	Tera 2000 to 2002, 8 day and daily snow over images Aqua,2002 to 2012, , 8 day and daily snow over images	To assess the spatial and temporal variability in snow cover area in thre Bhagirathi basin.
4	SRTM	2000	To analyse the topography of the present study area.
5	OLS DMSP	2009	To detect the Built-up area in the study region.
6	Indian Metrological department Rainfall & Temperatute	1957 to 2005, 2009-2010, 1979-2004	To analyse the temperature and rainfall pattern in the study region
7	District Censes Handbook	1961,1971,1981 and 1991	To study the demographic changes observed in the study areas
8	Primary Census Abstract	1991 and 2001	To analyse the social vulnerability in the region .

1.8 RESEARCH METHODOLOGY

1. For the objective of investigation and assessment of land use and land cover changes in the Bhagirathi basin, the deployed research method is LULCC modeling which includes LCM Model by using IDRISI Selva. Arc GIS and Erdas Imagine software were used to device land use/cover classification in a multi-temporal approach. The IDRISI 17.0 Selva version has been used for the analysis of image. Land Change Modeler for ecological sustainability applied to find out the future change of LULCC in the study area. The land-use information for the year 2020 is predicated in Bhagirathi basin.

2. To analyze the overall vulnerability in the region due to anthropogenic interventions/ climate change the methodology which has been used is Principal Component Analysis to arrive at the Social Vulnerability Index. A set of 19 indicators has been employed on basis of their representativeness to derive social index, economic index and infrastructural index. After sorting out data the following steps were performed on MS excel and SPSS.

- Based on whether the indicator is positive or negative it is normalized. Upon receiving normalized values, the weights in the computation were determined by using factor loadings and Eigen Values from Principal Component Analysis.
  Then the best and worst values are identified in an indicator, which will depend on the nature of the indicator. In case of a positive indicator, the HIGHEST value will be treated as the BEST value and the LOWEST, will be considered as the WORST value; and vice versa.

$$NVij = 1 - \left[\frac{\{Best\ Xi - Observed\ Xij\}}{\{Best\ Xi - Worst\ Xi\}}\right] \quad \text{.......equation 1.1}$$

- Weights are determined after finding eigen values.
- The following formula is used to determine the SoVI by calculating the index as shown below-

$$I = \frac{\sum_{i=1}^{n} Xi\left(\sum_{j=1}^{n} \left|Lij\right| .Ej\right)}{\sum_{i=1}^{n}\left(\sum_{j=1}^{n} \left|Lij\right| .Ej\right)} \quad \text{.......equation 1.2}$$

Where I is the Index, Xi is the ith Indicator; Lij is the factor loading value of the ith variable on the jth factor; Ej is the Eigen value of the jth factor

Based on the SoVI, assign RANK in ascending order. The Highest Index with RANK ONE will be treated as the BEST means low Social vulnerability and the LOWEST Index, with last rank will be treated as the WORST means high level of social vulnerability among the villages of Bhagirathi Basin, used in computation of SoVI.

3. To assess the variability in snow cover area and its impacts, Snow Cover Area assessment in the upper basin region has been done using binary method. And representation of snow cover changes through graphs and trend lines.

4. To find the drivers of LULCC in the basin, simple bar graphs, classified land use and land cover maps (1979 to 2010) have been used. Growth rate of population has been calculated by this formula:

$$\text{Growth rate (\%)} = \left[\frac{N1-N0}{\{N0\}}\right] * 100$$

where, N1 is population in the final year and N0 is population in the base year.

5. Map of road development of the basin prepared by Google earth images with the help of ARC GIS.

6. Qualitative method including literature survey has been deployed to arrive to a suitable land use policies in the study region.

1.9 ORGANIZATION OF THE STUDY

The whole study is divided into seven separate chapters. These are as follows-

Chapter 1: This chapter includes the introduction of the study, description of the study area, statement of problem, objectives, research questions, data source, and methodology, organization of the study and limitations of the study.

Chapter 2: This chapter includes review of literature in detailed way for the understanding of the research problem.

Chapter 3: This chapter includes the land use and land cover dynamics in the basin, change detection by using LCM modeling, prediction of 2020 land use/land cover scenario.

Chapter 4: This chapter presents the assessment of overall vulnerability in the region by calculating social development index, economic development index, infrastructure development index and social vulnerability index.

Chapter 5: This chapter analyzes the drivers of land use land cover change in the entire basin including snow cover changes in upper basin in particular and their impacts in the Basin. In addition to this, the chapter is also an attempt to give details of the Uttarakhand calamity that had occurred on 16th to 17th june 2013 in Bhagirathi basin, its affected areas and impacts.

Chapter 6: This chapter includes the summary of the whole study and conclusions emanated from the study.

CHAPTER 2

LITERATURE REVIEW

2. Introduction

To get insight into the understanding of basin level study in context to the land use and land cover change and its impacts, altitudinal variation in basin related to LULCC and for studying socio- environmental vulnerability, a literature review has been undertaken. It has given the scope to understand the basin level system approach in a more prescribed way. For doing this review, it has been divided into four sections and sub sections.

1. Spectral properties of Snow
2. Variability in Snow and its impacts
3. Land Use and Land Cover change and its impacts
4. Socio- environmental vulnerability

2.1 Spectral properties of snow

Snow is a mixture of ice crystals, liquid water, and air. The ice crystals are deposited on the Earth's surface as a result of atmospheric precipitation along with wind or mechanical deposition. Snow is also defined as falling or deposited ice particles formed mainly by sublimation (UNESCO/WMO 1970). Roughly 5% of the global precipitation that reaches the Earth's surface does so in the form of snow (*Hoinkes,* 1967).

A spectral property of snow implies the snow-albedo feedback mechanism. Snow is highly reflective in that part of spectrum with albedo values generally ranging from 0.80 to 0.98 μm. The snow albedo mechanism is looked upon as a positive feedback that occurs when warmer temperatures reduce the snow-covered areas, revealing a darker substance and promoting increase in radiation heating (*Nolin and Stroeve,* 1997).

The global albedo is a function of the reflectivity of three basic components of the atmospheric system: clouds, surfaces and scattering by the atmosphere itself. There is a considerable variability in albedo over space and time. Diurnal albedo variation results mainly from changing sun angle, with minimum albedo occurring at midday. Seasonal variation occurs as the surface characteristics and cloudiness changes during the year (*Henderson-Sellers and Hughes,* 1982).

Physical properties of a snowpack such as grain size, crystal structure, density, surface geometry and liquid water content are also important for transfers of heat and water. The most basic intensive physical parameter that describes a snow pack is its density. Densities lie typically in the range 0.2–0.6Mg m^{-3} unless the snow has fallen very recently in very cold conditions, when it can be as low as 0.01Mg m^{-3} .A typical value for freshly fallen snow (fresh snow or new snow) is about 0.1Mg m^{-3}. As the snow pack ages, its density increases as a result of compaction by wind and gravity, and through thermal metamorphism. The most important parameter describing the internal structure of a snow pack is the grain size (or crystal size), often simply defined as the mean radius or equivalent radius of the ice crystals, although some characterizations also take into account the form and orientation of the crystals. Typical grain sizes range between 0.1 and 3 mm, although values as low as 0.01mm have been reported in the new low-density snow. The surface geometry of a snow pack can play an important role in the interaction of electromagnetic radiation with the pack. Geometric properties can be referred to as surface roughness at small length scales and as surface topography at larger scales (Rees,2006).

Variation in the earth's atmospheric temperature are generally governed by the amount of incoming solar radiation (terrestrial), volcanic activity (geothermal) and combustion of fossil fuel (human activity). If the earth's surface receives less solar radiation during the summer months, snow deposited during the previous winter does not melt completely. When snow accumulates year after year, glaciers advance. The increase in albedo of snow and ice, results in the more intense solar radiation reflection back into the space, causing a negative feedback to the solar thermal input cycle. Temperature would drop even further, and eventually another ice age would occur. When the earth's surface receives more solar energy, the planet warms up due to a positive feedback mechanism, snow melts and glaciers retreat. The rise and fall in the amounts of solar energy affecting the Earth's surface is a major driving mechanism behind climate change.

This seasonal variation in snow cover is an important feature of the climate because the unique properties of snow significantly affect interactions between the land surface and the atmosphere. A snowpack increases the surface albedo, insulates the ground from the atmosphere, stores water, and changes the roughness of the surface.

Aoki et al (2007) investigates various types of snow conditions at four locations - in eastern Hokkaido, Japan and Barrow, Alaska- from 2001 to 2005 to validate ADEOS-II (Advanced Earth Observing Satellite) /GLI (Global Imager) snow/ice products. These products are snow surface temperature mass fraction of soot contained in the snow, and two types of snow grain sizes retrieved from different channels.

Similarly, *Painter et al* (2009) describe and validate a model that retrieves fractional snow-covered area and the grain size and albedo of that snow from surface reflectance data (product MOD09GA) acquired by NASA's Moderate Resolution Imaging Spectroradiometer (MODIS). The model analyzes the MODIS visible, near infrared, and shortwave infrared bands with multiple endmember spectral mixtures from a library of snow, vegetation, rock, and soil. Also, it validates the model with fractional snow cover estimates from Landsat Thematic Mapper data, at 30 m resolution, for the Sierra Nevada, Rocky Mountains, high plains of Colorado, and Himalaya.

Rittger, Painter and Dozier (2012), assess the methods for mapping snow cover from MODIS. They examine three widely used MODIS snow products: the ''binary'' (i.e., snow yes/no) global snow maps that were among the initial MODIS standard products; a more recent standard MODIS fractional snow product; and another fractional snow product, MODSCAG, based on spectral mixture analysis. Evaluation shows that the extant observations for the science of the Earth System could be substantially improved. Characterizing snow cover by spectral mixing is more accurate than the empirical methods that are based on the normalized difference snow index, both for identifying snow-covered and snow-free areas and for estimating the fractional snow cover within a sensor's instantaneous field-of-view. Retrieving that fractional value is particularly important in mountainous terrain and during spring and summer melt to give an accurate picture of the snow's location and extent. Spectral mixing maintains its performance over all land cover and throughout a large range of topography.

2.2 Variability in Snow and its impacts

Glaciers are the visible indicator of climate change. Glacier mass balance, length and snow-melt runoff are some of the glacier parameters directly related to the climate. Remote sensing based regional studies provide an overview of recent changes in the Himalayan glaciers.

Richard (1997) discusses seasonal snow cover in both, the current and the future climates. Climate warming in a simulation with an increased concentration of carbon dioxide and sulphate aerosols is found leading to a larger reduction in snow. He also suggests that climate warming will lead to a larger reduction in snow cover over North America and Europe than over Asia. Satellite observations show a general decrease in Northern Hemisphere snow cover over recent years, but the decrease is greater for Eurasia.

Singh et al (2006) in his analysis of effect of climate change on runoff of a glacierized Himalayan basin shows that runoff increased linearly with increase in temperature and rainfall but the influence of the temperature change was greater than the rainfall change. The increased rate of melting under a warmer climate has resulted in the retreating of glaciers. On the long-term scale, greater melting of glaciers during the coming years could lead to the depletion of available water resources and its influence on water flows in rivers. The water resources of the Himalayan region may also be highly vulnerable to such climate changes, because more than 50% of the water resources of India are located in the various tributaries of the Ganges, Indus and the Brahmaputra river system, which are highly dependent on snow and glacier runoff.

Bajracharya et al (2007) investigates the impact of climate change on glaciers and glacial lakes in the Himalayas based on empirical evidence and time-series data and information. The result shows that the valley glaciers and small glaciers are retreating fast. The Imja glacier retreated at an average rate of 42m per year in the period from 1962 to 2000. The retreat rate increased to 74m per year during 2001 and 2006, when it became one of the fastest-retreating glaciers in the Himalayas. Some of the smaller glaciers in Bhutan have completely disappeared; they could not be found on the satellite images of 2000–2001. In the Bhutan Himalaya the average retreat rate of glaciers was around 30m per year between 1963 and 1993. Some of the glaciers in the Lunana region of the Pho Chu sub-basin were retreating as fast as 57m per year in 2001, with an increase in retreat rate as high as 800% since 1970. The study also looked at methodologies for carrying out vulnerability and hazard assessment, and discussed possible early warning systems and suitable mitigation measures to reduce the adverse impacts of a GLOF (Glacial Lake Outburst Flood).

Bhambri et al (2011), examine the glacier changes in the Garhwal Himalaya from 1968 to 2006 based on corona, aster and landsat TM satellite data. Study provides a comprehensive multi-temporal glacier fluctuation record for the upper Bhagirathi and Saraswati/Alaknanda basins. Glacier area decreased from 1968 to 2006, i.e. 2.8% and more recently, recession rate have increased. The number of glaciers increased from 82 in 1968 to 88 in 2006 due to fragmentation of glaciers. This indicates that the average shrinkage rate is influenced by glacier size. Overall, south- and southwest facing glaciers shrank at higher rates. Debris covered area has increased.

Bhambri et al (2011) presents a semi-automated mapping method for the debris-covered glaciers of the Garhwal Himalayas based on an Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) digital elevation model (DEM) and thermal data. Morphometric parameters such as slope, plan curvature and profile curvature were computed by means of the ASTER DEM and organized in similar surface groups using cluster analysis.

Selvan and Kodi (2012) evaluates the de-glaciation pattern of the Bhagirathi basin from 1980-2006. Study found that there was a less fast retreat in the year 1980-90 compared to the 2000-2006. The glacier smaller in size is under a major threat. 30% area has been vacated by glaciers. The large glaciers have shown a reduction in areal extent, whereas smaller glaciers have increased in number. Thus, smaller glaciers are more prone to threat due to the changes in the climatic conditions and larger glaciers are susceptible to the fragmentation.

2.3 Land Use and Land Cover Change

Human Beings are dependent on land, not only for variety of needs but also for survival and existence, either directly or indirectly. Land is regarded as one of the most basic and fundamental resource available to men. Man uses land to fulfill his various requirements resulting in manifestation of certain changes. Landscape of a particular area is the surface manifestation of the way it has been used. Landscape feature of any area changes with time which is reflected in unique land use pattern of the area.

With time, increased human needs and aspirations along with the increase in the technological capabilities resulted in a major change with respect to the land cover and the use of land as a resource. The pace, magnitude and the spatial reach of human alteration of the Earth's land surface are unprecedented.

Land use and land cover are two different terminologies that are very often used as a substitute for each other. 'Land cover refers to the physical materials on the surface of a given parcel of land, while land use refers to the human activities that takes place on or make use of land e.g. residential, commercial, industrial etc.' Land use and land cover change have been recognized as significant drivers of global environment change.

Virginia H. Dale (1997) dealing with relationship between land-use change and climate change made some important observations. Study shows that in recent years, land-use change have had much greater effect on ecological variables than climate change. The change in land use, and especially land management, to adjust to climate change resulted in certain adaptations leading to ecological effects. Therefore, study assesses an understanding of the non-climatic causes of land-use change (e.g., socioeconomics and politics) which are necessary to manage ecological functions effectively on regional and global scales.

Lambin et al (2001) focuses on the major myths on driving forces of land cover change and proposes alternative pathways of change. It concludes that neither population nor poverty alone constitutes the sole and major underlying causes of land cover change worldwide. Rather, it is people's response to the economic opportunities, as mediated by institutional factors that drive land cover change. Opportunities and constraints for new land uses are created by local as well as national market policies. Global forces become the main determinants of land-use change, as they amplify or attenuate local factors.

Eugenia Kalnay & Ming Cai (2003) examines the impact of urbanization and other land uses on climate change by comparing trends observed by surface stations with surface temperatures derived from the NCEP-NCAR 50-year Reanalysis (NNR). They use the difference between trends in observed surface temperatures in the continental United States and the corresponding trends in a reconstruction of surface temperatures determined from a reanalysis of global weather over the past 50 years, which is insensitive to surface observations. To estimate the impact of land-use changes on surface warming and results shows that that half of the observed decrease in diurnal temperature range is due to urban and other land-use changes. The effect of agricultural development, increasing evaporation during the day, would also tend to decrease the maximum temperature: irrigation would increase the heat capacity of the soil, thus increasing the minimum temperature. Therefore, both urbanization and agriculture effects could be consistent with the general increase in the minimum temperature and slight decrease in the maximum temperature, and contribute to the reduction in the diurnal temperature range.

Tegen, M.et al (2004) assessed the relative importance of climate and land use in determining present and future global soil dust emission. As the current consensus that up to half of the modern atmospheric dust load originates from anthropogenic ally disturbed soils , here they evaluated that dust from agricultural areas contributes $<10\%$ to the global dust load. Analyses of future changes in dust emissions under several climate and land-use scenarios suggest dust emissions may increase or decrease, but either way the effect of climate change will dominate dust emissions.

Pitman and Narisma (2005) compiled a study on the role of land surface processes in regional climate change and found that the cooling effect of reforestation over Western Australia is caused primarily by the increase in leaf area index that lead to corresponding increase in the latent heat flux. There are two different mechanisms that explain the change in rainfall and temperature: Rainfall decline related to a change in moisture convergence and vertical velocities over the region due to a large scale smoothing of the region following deforestation.

Second, the warming in temperature appeared to be related to a change in the surface energy balance whereby a reduced supply of moisture to support evaporation reduced cooling and allowed warmer maximum temperature. The National Research Council (NRC 2005) has recommended the broadening of the climate change issue to include Land use/ Land cover change processes as an important climate force.

Wakeel et al (2005) assessed forest management and land use/cover changes in Kunchgad micro-watershed in Almora district in the central Himalayas. The study is based on interpretation of satellite data and using a geographic information system (GIS). Landsat Thematic Mapper (TM) and Indian Remote Sensing Satellite – LISS-III Standard False Colour Composites at 1:50,000 scales were visually interpreted for mapping land use/cover in 1988 and 1997. During the study period (i.e. 1967–1997) the forest cover was altered drastically with increasing population pressure (both human and animal), agricultural activities and raw material extraction activities. Agricultural expansion at the cost of loss of forest cover was the most prominent change in the forests managed by the people. In Government Reserve Forests, there was no agricultural expansion but changes in tree density and canopy cover were evident.

Pielke et al (2009) investigates the sensitivity of surface temperature trends to land use land cover change over the United States using the observation minus reanalysis approach. Temperature trends results from natural and anthropogenic factors (IPCC 2001). It says temperature is increased with the increase in the greenhouse gases but recent studies and investigation have also shown that climate resulting from land use and land cover change also significantly impacts temperature trends. Land use changes due to agriculture lead to decreased surface temperature or cooling, conversion of agriculture land results into warming. Urbanization and deforestation was also associated with warming.

Mahmood et al (2010) attempts to assess the impacts of land use / land cover change on climate change. Study found that minimum temperature is much more sensitive to land use change than maximum temperature. LULCC can alter the winds near the ground because of changes of the aerodynamic roughness, as well as from the effect of buildings and other obstacles to airflow. The study also focuses on the findings of the National Research Council report (NRC 2005) and it recommended that new climate metrics be developed to address this issue. These are 1) the magnitude of the spatial redistribution of land surface latent and sensible heating. 2) the magnitude of the spatial redistribution of precipitation and moisture convergence. 3) the normalized gradient of regional radiative heating changes.

Srivastav et al (2010) in the report of 'Earth Observation applications in Climate change studies' discussed the topic 'Human dimensions of climate change: A few initiatives'. The report presented certain good examples which were responsible factors or drivers of LULCC and also discussed the impact of LULCC on climate change and further, discussed the implications of these changes on environment.

Punia et al (2010) studied decision tree classification of land cover for Delhi. In this study they explored the potential of multi temporal IRs P6 advanced Wide field sensor (AWiFS) data for mapping of LULC for Delhi. The study presents the result of a decision tree classification of seasonal composite data and identified 13 classes with description of cropping pattern namely, double crops, Kharif, Rabi and Zaid from 56 m spatial resolution AWiFS data. Results indicate that the temporal data set with a good definition of training sites can result in a good overall accuracy (-91.81) as well as individual classification accuracies. In fact AWiFS data can be used to provide timely and detailed LULC maps with limited ancillary data. The AWiFS derived maps could be very useful as input to

Lambin et al (2010) analyses the challenges and opportunities for preserving natural forest ecosystems while enhancing food production in tropical developing countries under conditions of scarcity of unused productive cropland and economic globalization.

Richard Streeter et al (2010) recognizes the flickering between alternate land surface states in advanced threshold change and critical slowing down in advance of both, threshold changes and noncritical transformation.

2.4 Socio- environmental Vulnerability

Limited information is available about the vulnerability of mountain ecosystems to climate change. Intuitively, it seems plausible that these regions where small changes in temperature can turn ice and snow to water, and regions where extreme slopes lead to rapid changes in climatic zones over small distances, will show marked impacts in terms of biodiversity, water availability, agriculture, and hazards that will in turn have an impact on general human wellbeing.

Vulnerability refers to the degree of loss that may occur to elements at risk due to a particular hazard. It is commonly accepted that vulnerability indicates the susceptibility and potential damage of any element at risk having some economic value (Ebert. A, 2006).

Vulnerability can be a broad term, encompassing the effects like 'vulnerability as an internal risk factor' to 'multi-dimensional vulnerability encompassing physical, social, economic and environmental vulnerability.

2.4.1. Types of Vulnerability

(United Nations development Program, 2004) had classified vulnerability into four major categories:

1. Physical vulnerability indicates losses due to the damage of physical infrastructure and buildings and a fixed asset value is required to quantify it (Liu et al., 2002).

2. Environmental Vulnerability includes the loss due to damage of natural resource mainly water, land resource etc.

3. Social vulnerability deals the loss on population and the social structure due to any damaging event.

4. Economic vulnerability is the effect on the economic condition of the affected area and it is assessed on the basis of gross domestic product (GDP), the higher the GDP of an affected area the greater would be the vulnerability.

Social vulnerability can be loosely defined as the predisposition of people, organizations, and societies towards impact from natural and man-made disasters. Social vulnerability assessed using social, economic, educational and financial factors try to create an index that will score the relative level of social vulnerability on a regional level.

International Centre for Integrated Mountain Development (ICIMOD) undertook a series of research activities together with partners in the Eastern Himalayas from 2007 to 2008 to assess the vulnerability of Hindu Kush-Himalayas to climate change (ICIMOD, 2009) the assessment highlighted the vulnerability of the Eastern Himalayan ecosystems to climate change as a result of their ecological fragility and economic marginality.

Ebert et al (2009) dealt with the assessment of social vulnerability (SV). In this article, a new method based on contextual analysis of image and GIS data is presented. An approach based on proxy variables that were derived from high-resolution optical and laser scanning data was applied, in combination with elevation information and existing hazard data. Object-oriented image analysis was applied for the definition and estimation of those variables, focusing on SV indicators with physical characteristics. A reference Social Vulnerability Index (SVI) was created from census data available for the study area on a neighborhood level and tested for parts of Tegucigalpa, Honduras. For the evaluation of the proxy-variables, a stepwise regression model to select the best explanatory variables for changes in the SVI was applied. Eight out of 47 variables explained almost 60% of the variance, whereby the slope position and the proportion of built-up area in a neighborhood were found to be the most valuable proxies. This work shows that contextual segmentation-based analysis of geospatial data can substantially aid in SV assessment and, when combined with field-based information, leads to optimization in terms of assessment frequency and cost.

Ebert Annemarie et al (2010) explores the social and environmental dimensions of land use changes and how they relate to environmental vulnerability such as flood risks. It examines flood risk by considering natural factors and anthropogenic land use change and investigates processes of socio-spatial differentiation, aiming to evaluate their relevance for the attenuation of flood risk and its distribution across various socio-economic status groups.

It also tries to find out the linkage between land use and socio-spatial differentiation processes leading to socio- environmental change and flood risks. The result shows that anthropogenic land use changes increase the exposure of residents to potentially hazardous events and aggravate flood hazards by increasing the surface water runoff after precipitation events.

The review of literature clearly highlights the utility of satellite imageries in Land use and Land cover change which has been used at various spatial and temporal by various researchers. The nature of the mountains fragile and poorly accessible landscapes with sparsely scattered settlements and poor infrastructure means that research and assessment are least just where they are needed most. Nevertheless, remotely sensed data is of great utility in Land use and land cover change due to its repetitive nature, reliability and increasingly finer resolution.

CHAPTER 3

LAND USE AND LAND COVER CHANGE IN BHAGIRATHI BASIN (1979-2010)

3.1 BACKGROUND

Land cover is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater, and it also includes those structures created solely by human activities such as mine exposures and settlement (Lambin et al, 2003; Chrysoulakis et al., 2004; Baulies and Szejwach, 1998). On the other hand, land use is the intended employment of and management strategy placed on the land cover and reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging, and mining among many others (Zubair, 2006; Chrysoulakis et al., 2004). Land use change is defined to be any physical, biological or chemical change attributable to management, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farms dams pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species, and conversion to non-agricultural uses (Quentin et al., 2006).

Land use and Land cover changes may be grouped into two broad categories as conversion and modification. Conversion refers to changes from one cover or use type to another, while modification involves maintenance of the broad cover or use type in the face of changing in its attributes (Baulies and Szejwach, 1998).

Land use and land cover changes result from various natural and human factors within social, economic and political context. Hence, the local human activities expressing the drivers can be determined by measuring the rates and types of changes and analyzing other relevant sources of data like demographic profiles, household characteristics and policies related to land resource administration. LULCC studies have been designed to improve understanding of the human and biophysical forces that shape land use and land cover change. Thus, linking human behavior and social structures to biophysical attributes of the land is a fundamental aspect LULCC research. Land use and land cover plays an important role in global environmental change and sustainability, including response to climate change, effects on ecosystem structure and function, species and genetic diversity, water and energy balance, and agro-ecological potential.The research's which are dealt with Land use change in the mountainous region showing that the main cause of land transformation in that region is the high growth of population and the process of rapid urbanization.(Tiwari 2008).

Changes in the land-use often begin individually as a very small scale measure but over a period of time the cumulative effect become much significant to influence meso and macro level environment. Timely and accurate change detection of earth surface feature provides the foundation for greater understanding of the relationship and interaction between human and natural phenomenon. Land use change detection compares different land use features of different time periods and identifies changes thereof. But human investigations of land use features are limited by time and space. One can see the present land features at certain location but cannot put insight into the past to see what type of land features prevailed in any particular area. Thus land use change study is based on some kind of authentication of land features that exists, and also the assessment in the past at different locations, and quantification on in relative changes. Science has made great stride in sensor techniques. Now a day's satellite imagery provides nearly accurate and synoptic view of a large area. By comparing satellite imageries of different time, one can easily comprehend the land-use changes taking place over a period of observed /static time. The same concept has been applied here by comparing satellite imagery of different years from 1979-2010.

3.2 DATA USED AND METHODOLOGY

Collected maps and images were sorted and classified for the analysis and interpretation. Three pair of, cloud free Landsat images have been used to classify the study area:

Table 3.1 Details of dataset used

WPS:P/R	DATE	DATASET	TYPE	Spatial Resolution (m)
157/39,38	14 Nov,1979	MSS	Geo TIFF	60
146/39,38	12 Nov,1998	TM	Geo TIFF	30
146/39,38	28 Oct,2010	TM	Geo TIFF	30

The satellite data has selected for the October and November months because in summer the soils usually have low moisture, and therefore, show high reflectance; in rainy season the moisture increases temporarily to cause low reflectance by it. Higher moisture of rainy season allows much temporary vegetation growth on land of any area which dies out after the rainy season as the soil slowly loses its moisture. The undue higher vegetation during the rainy season may also give a false impression of the difference between the dense vegetation and sparse vegetation. The surface may show higher presence of water bodies during the rainy season due to rejuvenation of non-perennial streams and accumulations of water in low lying areas. Also due to higher surface manifestation of the water bodies the areas which are usually sandy and barren throughout the year except the rainy season may be misinterpreted. Thus keeping in mind the above complications, in the present study satellite data acquired just before the onset of the winter season has been considered to give true and best possible representation of the prevailing land use of the area. All data were used in this study were projected to the Universal Transverse Mercator (UTM) projection system (zone 44N, World Geodetic System 84).

Arc GIS and Erdas Imagine software were used to device land use/cover classification in a multi-temporal approach. The IDRISI 17.0 Selva version has been used for the analysis of image. Land Change Modeler for ecological sustainability applied to find out the future change of LULCC in the study area. The land-use information for the year 2020 is predicated in Bhagirathi basin.

The training sites developed for this research are based on the reference data and ancillary information collected from various sources. According to the land use classification scheme supervised approach with the maximum likelihood parameter (MLP) system was applied to improve the accuracy of the land use classification for the images for all three dates (1979, 1998 and 2010). Twelve land use land cover classes have been identified in Bhagirathi basin such as fresh snow, dry snow, glacial debris, barren land, dense forest, open forest, scrub land, agricultural land, fallow land, settlements, water bodies and shadow. These are shown in Table 3.2.

Land Change Modeler for ecological sustainability is integrated software developed by IDRISI Selva for analyzing land cover change by which maps were analyzed and found two land cover maps that have identical legends (same code for each class). The change analysis panel provides a rapid quantitative assessment of change by graphing gains and losses by land cover categories. A second option, net change, shows the result of taking the earlier land cover areas, adding the gains and then subtracting the losses. The third option is to examine the contributions to changes experienced by single land cover (IDRISI).

The Change analysis was performed between pairs of images of 1979 and 2010. Accordingly the transitions and exchanges that took place between the various classes during the years were obtained both in map and graphical form. All the units were changed into square kilometers. Cross classification found its most common application in land cover change analysis where a cross tabulation or a cross correlation is done between two qualitative maps of two different dates that targets on the same features (IDRISI). It is used to compare two classified images where the classification assigns the same unique and distinct identifier to each class on both the dates. The aim is to evaluate whether the areas fall into the same class on the two dates or a change to a new class has occurred.

Table.3.2 Land use/ cover classification scheme in the study area.

	LULC CLASSES	DESCRIPTION
1.	Fresh Snow	Fresh (New) snow is a recent snow deposit in which the original form of the ice crystals can be recognized.
2.	Dry Snow	Dry (Old) snow indicates deposited snow whose transformation is so far advanced that the original form of the new snow crystals can no longer be recognized.
3.	Glacial Debris	An accumulation of boulders, stones, or other debris carried and deposited by a glacier.
4.	Barren Land	Those ecosystems in which less than one third of the area has vegetation or other cover. In general, Barren Land has thin soil, sand, or rocks. It includes deserts, dry salt flats, beaches, sand dunes, and exposed rock, strip mines, quaries, and gravel pits.
5.	Dense Forest	All Lands with tree cover (Including mangrove cover) of canopy density of 70% and above.
6.	Open Forest	All lands with tree cover (Including mangrove cover) of canopy density between 10% and 40%.
7.	Scrub Land	Refers to those areas covered with tree, shrub, bushes and some grasses that dominate the foot-slopes and riverine landscapes.
8.	Agricultural Land	Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures.
9.	Fallow land	Fallow land refers to arable land not under rotation that is set aside for a period of time ranging from one to five years before it is cultivated again; or land, usually under permanent crops, meadows or pastures, that is not being used for such purposes for a period of at least one year.
10.	Settlements	A place or area with clustered or scattered buildings and a permanent human population (city, settlement, town, village or hamlet) referenced with geographic coordinates, which is "usually not incorporated and by definition has no legal boundaries."
11.	Water Bodies	The term body of water refers to accumulations of water, such as ponds, puddles or wetlands. Rivers, streams, canals, and other geographical features where water moves from one place to another are also considered bodies of water.
12.	Shadow	Refers to the shadow of the different land use classes.

Source: *Anderson, J.R., Hardy, E.E., Roach, J.T. & Witmer, R.E. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper, No. 964. USGS, Washington, D.C.*

The cross tabulation matrix shows the distribution of image cells between the classes. The categories of date 1 are displayed on the X-axis while in Y-axis displays the same categories of date 2. The cross tabulation shows the frequencies with which classes have remained in same (along with diagonal), or have changed in different classes (off-diagonal frequencies). Cross correlation images show all possible combinations that are used to produce two types of change images. These relative frequencies are known as transition probabilities and are an underlying basis for Markov Chain of future transitions.

3.3 RESULTS AND DISCUSSION

3.3.1 Land Use and Land Cover in Bhagirathi Basin (1979-2010)

As land use is a dynamic concept, its pattern has been changed in the Bhagirathi basin over the assessed period. Twelve land use land cover classes have been identified in study area. These are shown in Table 3.3 with land use classification statistics.

Table 3.3. Land use classification statistics for 1979, 1998 and 2010.

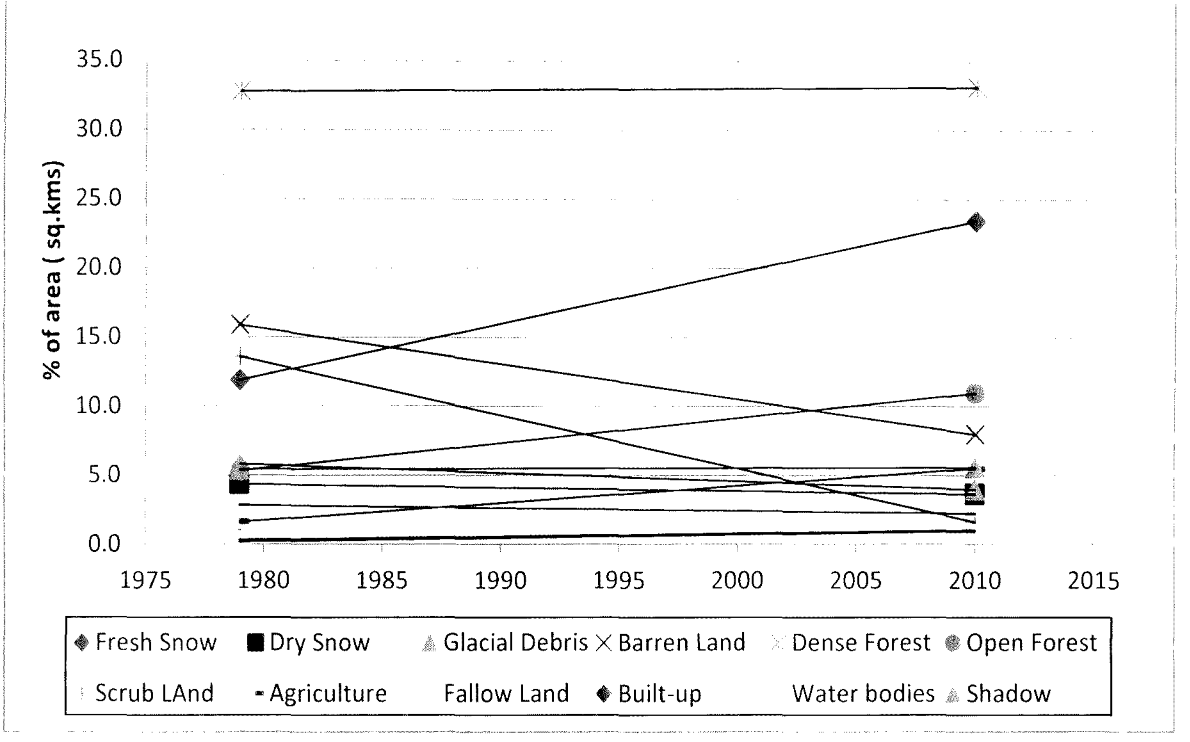
Land use categories	1979 area (sq.kms)	1998 area (sq.kms)	2010 area (sq.kms)
Fresh snow	868.2 (**11.9 %**)	1372.3 (18.9 %)	1706.0 (**23.4%**)
Dry snow	318.9 (4.4 %)	792.4 (10.9 %)	264.0 (3.6 %)
Glacial debris	425.2 (5.8 %)	105.1 (1.4 %)	288.7 (4.0 %)
Barren land	**1160.2 (15.9 %)**	**676.3 (9.3 %)**	**579.2 (8.0 %)**
Dense forest	2395.1 (32.8 %)	1886.3 (25.9 %)	2413.6 (33.2 %)
Open forest	389.3 (5.3 %)	1180.1 (16.2 %)	797.9 (11.0 %)
Scrub land	993.0 (**13.6 %**)	601.4 (8.3 %)	118.6 (**1.6 %**)
Agriculture	**119.0 (1.6 %)**	**173.2 (2.4 %)**	**398.8 (5.5 %)**
Fallow land	207.3 (2.8 %)	132.0 (1.8%)	162.5 (2.2 %)
Built Up	**24.0 (0.3 %)**	**40.1 (0.6 %)**	**75.3 (1.0 %)**
Water bodies	**13.1 (0.2%)**	**11.6 (0.2 %)**	**68.3 (0.9 %)**
Shadow	396.2 (5.4%)	304.4 (4.2 %)	404.8 (5.6%)

Source: *values given in parenthesis are in percentage. Land use Land cover statistics derived from 1979, 1998 and 2010 remote sensing images.*

Land use classification statistics shows the changes that have been occurred in the basin from 1979 to 2010. Data on fresh snow shows expansion in its area. It has been increased by 7 % from 1979 to 1998 and further it has increased by 4 % from 1998 to 2010. Thus fresh snow has increased over the period of time. The second category, Dry snow shows 4.4 percent area to total area of the basin in 1979 and it has increased in 1998 by 10.9 percent area but in 2010 it has decreased by 3.6 percent area which indicates fluctuation in dry snow because of the variation in the seasonal snow cover change. A comparison of the glacial debris extent on the available remote sensing images shows an increase of the relative debris cover over time. Between 1979 -1998 it has started to decreased by 4 % but between 1998-2010, the debris covered area started to increase by 2.5 %. Barren/uncultivated land accounted 15.9 percent area in 1979 which was decreased to 9.3 percent in 1998 and again in 2010 it was decreased to 8 percent. Over this entire category has a declining trend. Dense Forest occupied 32.8 percent of the area in 1979, which is decreased to 25.9 percent in 1998, but it further increased to 33.2 percent in 2010. Thus over the period of 31 years the forest cover has shown mark able change. In the case of Open forests, 5.3 percent area was in 1979 but in 1998 it has increased to 16.2 percent but again in 2010 it was decreased to 11 percent. Scrub land has decreased over the period of 31 years 1979-2010.

After this category, the area occupied by agricultural land, in 1979, 1998 and 2010 the agricultural land occupied 1.6 percent, 2.4 percent and 5.5 percent respectively which showing the expansion in the agricultural land. Under fallow land category 2.8 percent, 1.8 percent and 2.2 percent in year 1979, 1998 and 2010 respectively. Build-up though occupied smaller area but it is important because it usually indicates the use of piece of land that does not go to any other category. Build-up covered only 0.3 percent of the study area in 1979, which is further expanded considerably to occupy 0.6 percent in 1998 and 1.0 percent in 2010. Thus, the area under the Build-up category has consistently grown over the period. The second last important category of land use is water bodies. This category occupied 0.2 percent, 0.2 percent, and 0.9 percent in year 1979, 1998 and 2010 respectively.

Figure 3.1. Land use change trends within 1979-2010

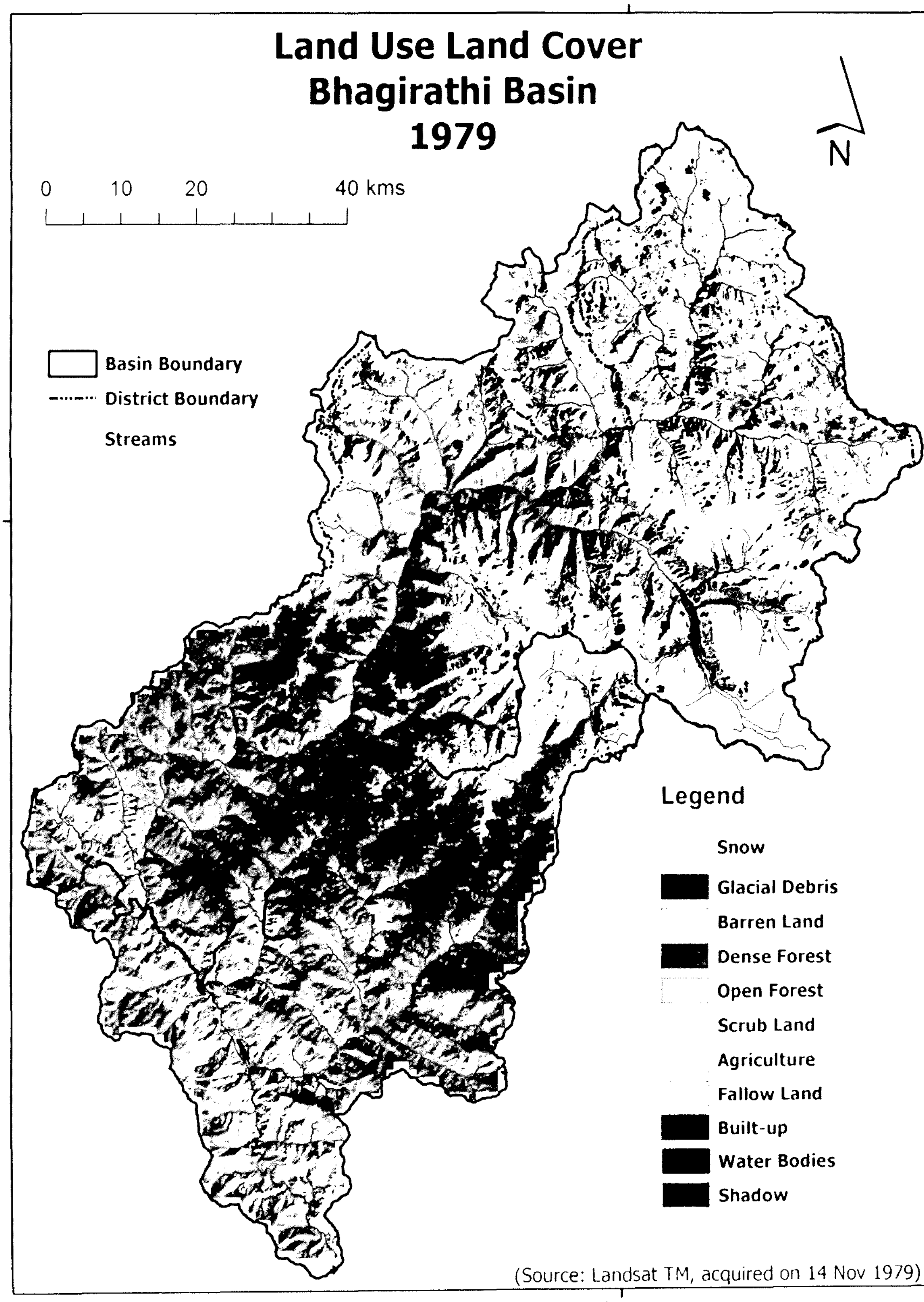


Source: *Table 3.3*

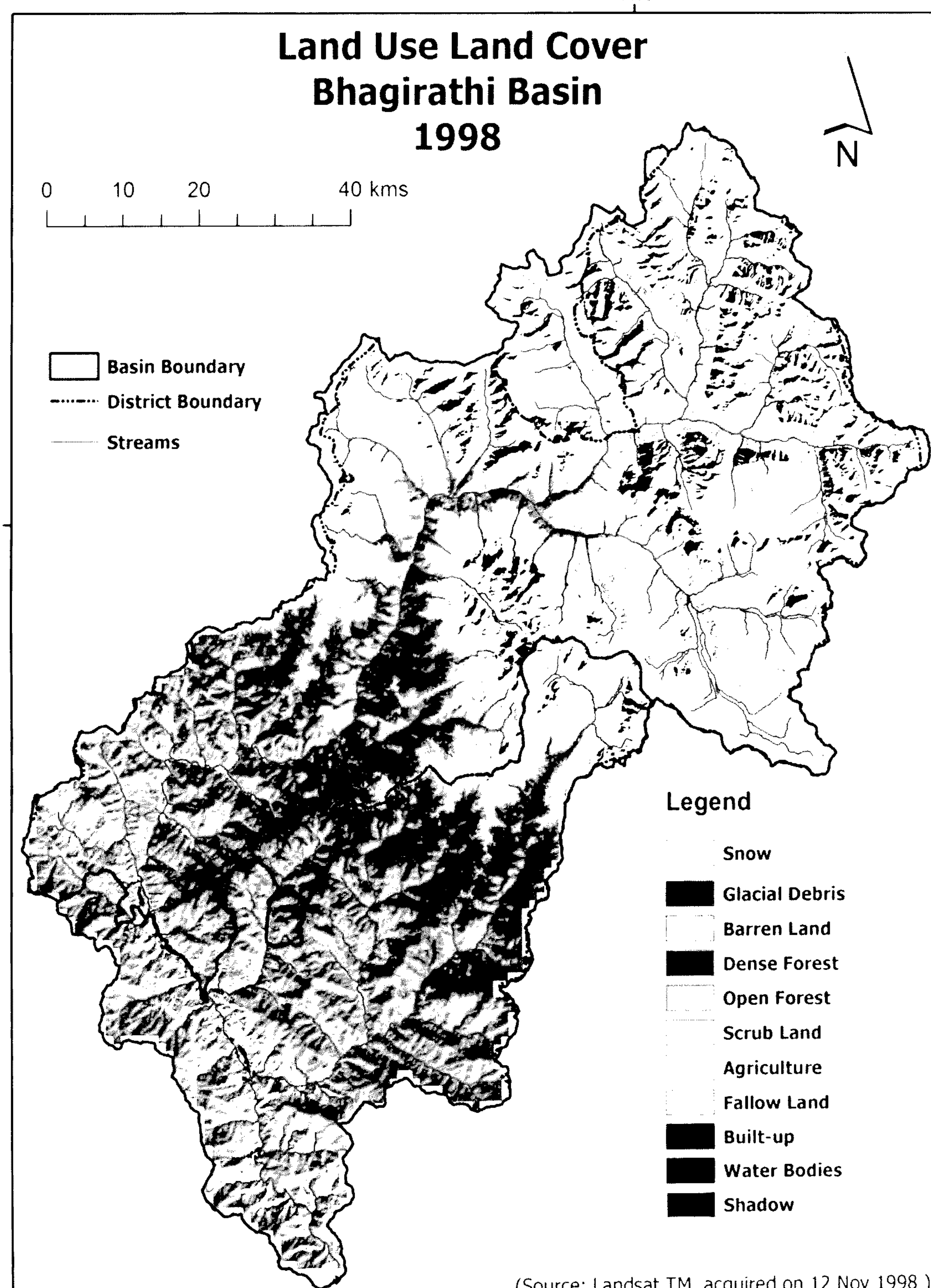
The last important category is shadow which is significant because due to the mountainous region the effect of shadow misinterprets the imagery so to reduce the misinterpretation of the satellite imagery we make it as a separate class.

Deforestation, urban sprawl, agriculture, and other human influences have substantially altered and fragmented our landscape. Such disturbance of the land can change the global atmospheric concentration of carbon dioxide, the principal heat trapping gas, as well as affect local, regional, and global climate by changing the energy balance on Earth's surface. These all types of problems encountered in this region due to the increase in the population growth. The impacts and drivers of land use and land cover change will be discussed in next chapter.

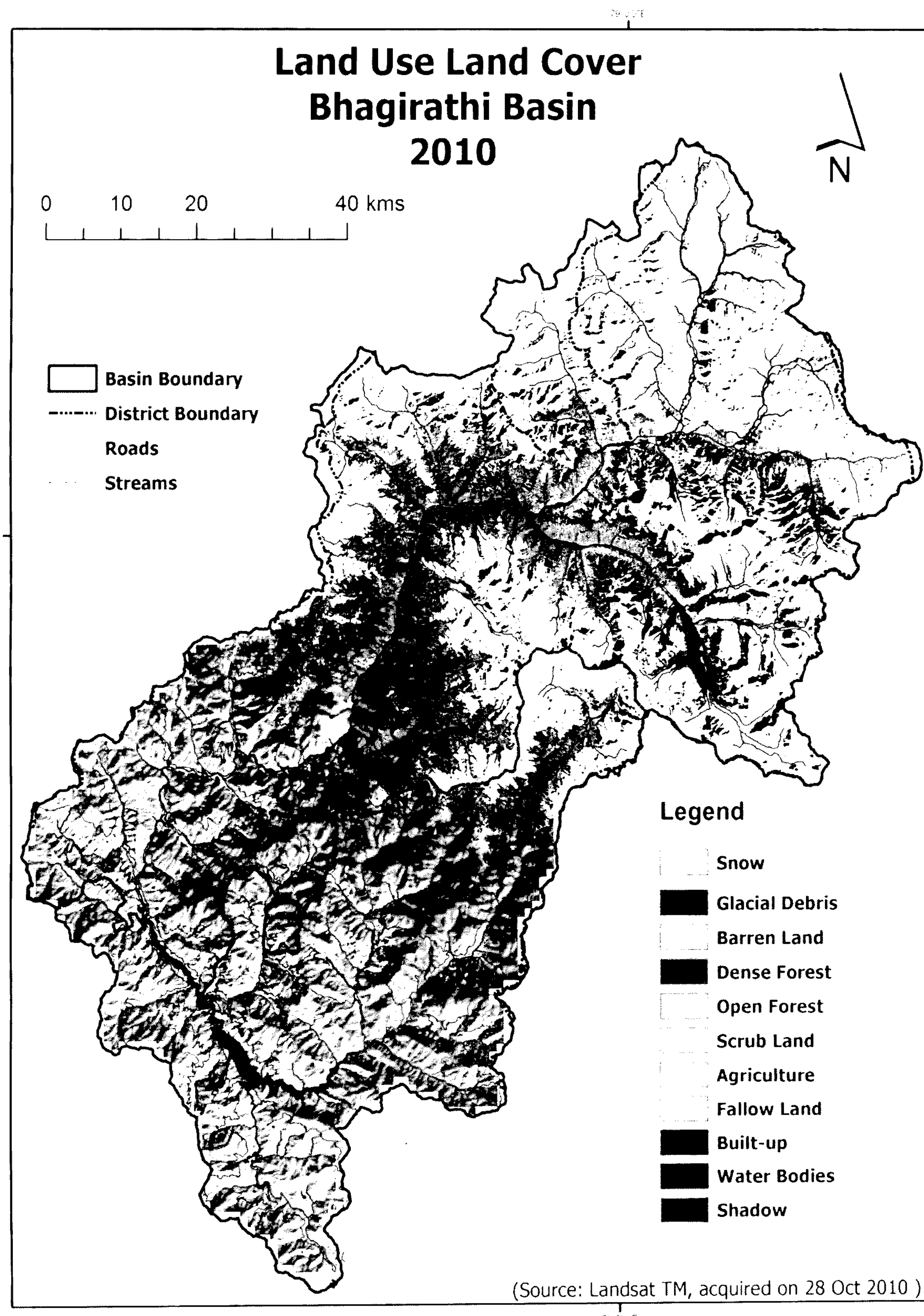
Map 3.1 Land use and Land Cover, Bhagirathi basin (1979)



Map 3.2 Land use and Land Cover, Bhagirathi basin (1998)



Map 3.3 Land use and Land Cover, Bhagirathi basin (2010)

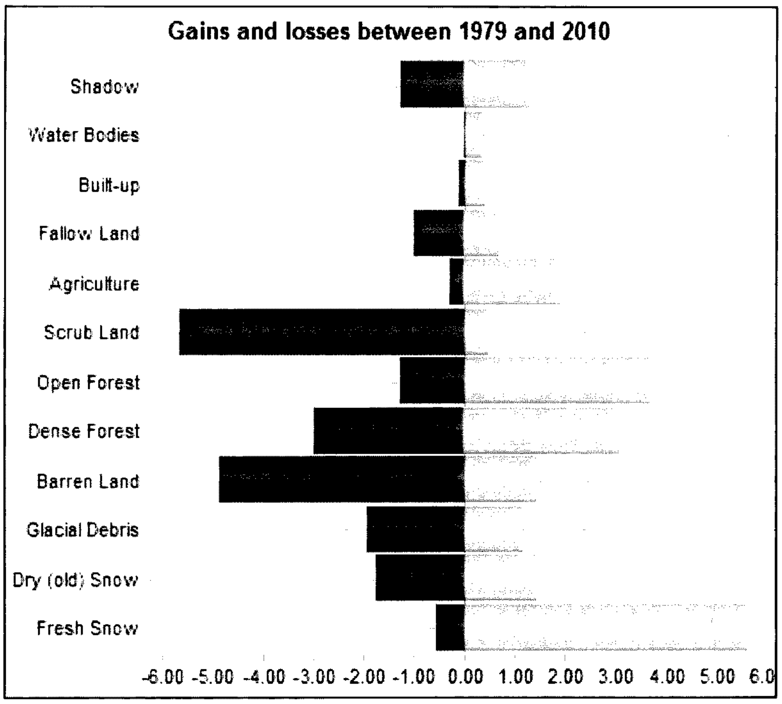


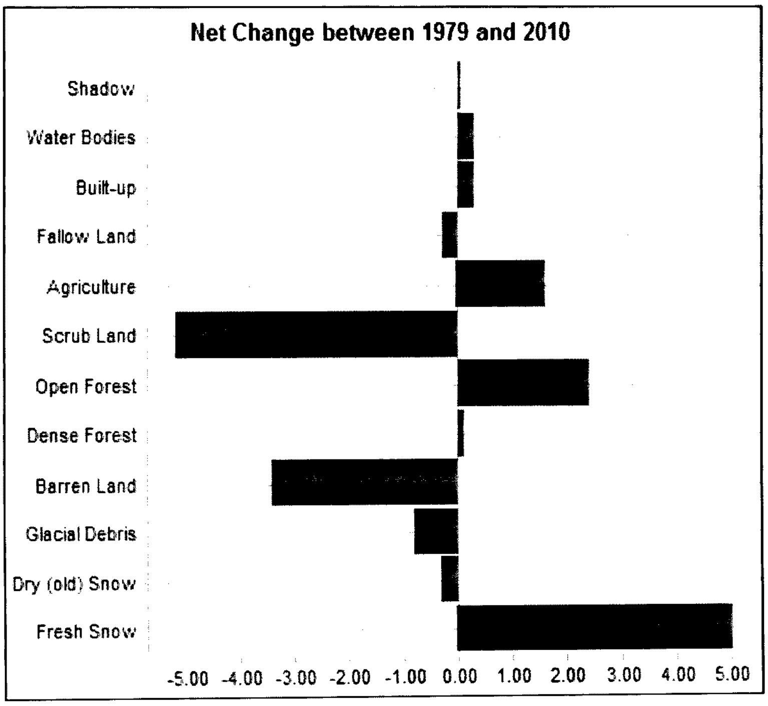
The overall, area under fresh snow, dry snow and glacial debris has expanding; Barren land has decreased. Dense forest has increased with the time; open forest and scrub land has decreased; agriculture and settlements has shown consistent expansion in its area where as water bodies after nearly static shows expansion.

3.3.2 Change Detection Using LCM

Land Change Modeler (LCM) was used to analyze the land use/cover changes between various classes during the period 1979-2010. The basic principle used in the module is to evaluate the trend of the change from one land use category to other, the impact of influencing factors such as roads and different types of visible and invisible infrastructures, and finally predict the land use pattern based on the previous change trend. There are of course several modules already developed such as Markov Chain Analysis, Time Series Analysis, Geomod etc., but LCM is at the moment a widely used ecological modeling tool. The module works on Neural Network and needs to reach accuracy greater than 70%, but accuracy depends much on relative influencing variables. Though research influencing variables were very limited and could not expect much accuracy, the level of accuracy obtained till now was satisfactory. The land use change was assessed through evaluation of gains and losses by classes. Most of the classes have both gains and losses, with exception to water bodies which show gains only.

Figure 3.2 Gains, Losses and Net change between 1979-2010

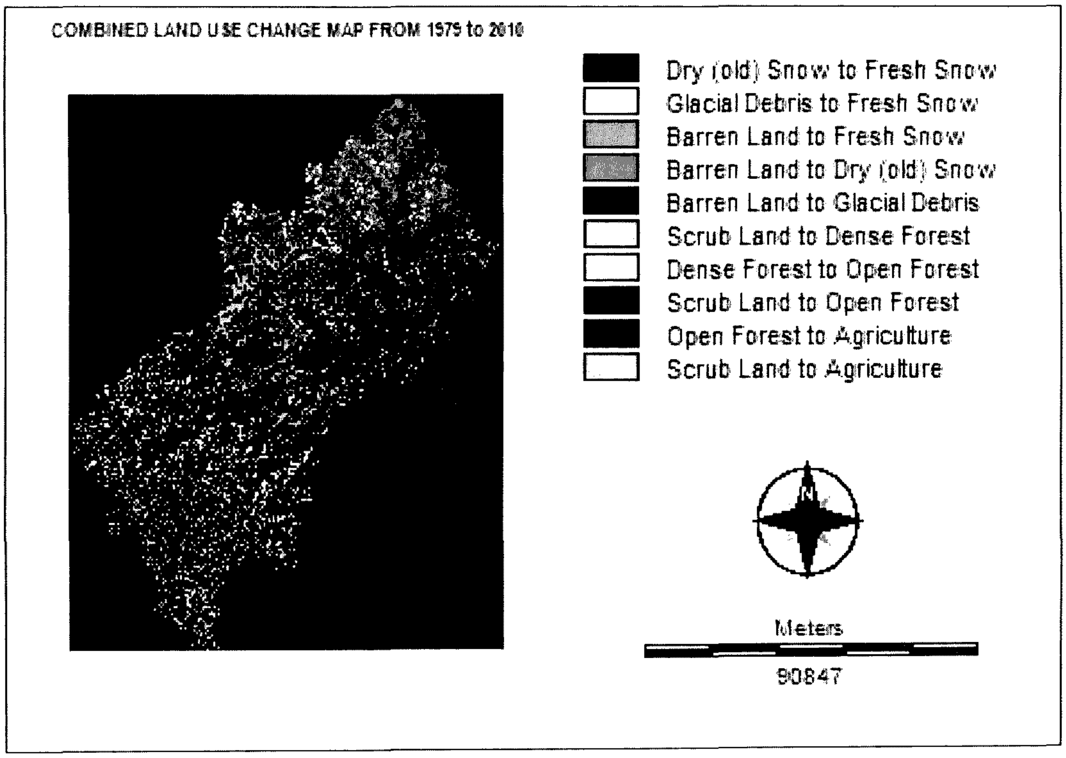
a) 

b) 

Source: *LCM Model*

During the period from 1979-2010 scrub land has been lost 5.65 % and gained 0.49 %, with the net loss of %.16 %. Barren land has been lost 4.87% and gained 1.46% with a net loss of 3.41 %. Fresh snow has been gained 5.60 % and lost 0.56 % with the net gained of 5.04 %. Similarly open forest gained 3.14 % and lost 1.27 % with the net gain of 2.43%. Water bodies gained 0.36 % and lost 0.09 % with the net gain of 0.33 %. But there is interesting result found in the dense forest cover category, we found that there has been loss of 3% and gain of 3.14 % which is more or less same, with the net gain of 0.13 %. Glacial debris, dry snow and fallow land have been lost their area from 1979 to 2010 with the net loss of 0.79%, 0.31% and 0.26% respectively. Conversely, open forest, agriculture and shadow have been gained area from 1979 to 2010, with the net gain of 2.43%, 1.65% and 0.06 % respectively.

Figure 3.3 Combined Land Use Change map From 1979 to 2010



***Source :** LCM Model*

Figure 3.3 shows a pictorial representation of significant changes and summarizes the various land use/ cover classes that have undergone transition from one to another during the period from 1979 to 2010.

Table 3.4 Land conversion from 1979 to 2010

S.no	Land conversion	Area in km^2
1.	Dry (old) Snow to Fresh Snow	209.96
2.	Glacial Debris to Fresh Snow	194.46
3.	Barren Land to Fresh Snow	360.36
4.	Barren Land to Dry Snow	172.74
5.	Barren Land to Glacial Debris	104.33
6.	Scrub Land to Dense Forest	303.48
7.	Dense Forest to Open Forest	299.60
8.	Scrub Land to Open Forest	245.50
9.	Open Forest to Agriculture	103.40
10.	Scrub Land to Agriculture	126.03

Source: *From combined land use change map (1979 to 2010)*

Dry snow, glacial debris and barren land were converted into fresh snow; barren land converted into dry snow and glacial debris; scrub land were converted into dense forest, open forest and agriculture; dense forest were converted into open forest and Open forest converted into agriculture.

For the classes of land use change analyzed above several reasons are responsible. The important one is expansion of fresh snow which depends upon the seasonal precipitation. Scrub land is another important category where losses accounted the highest. This land use class converted into dense forest, open forest and agricultural land.

Table. 3.5 Transition probability Matrix (1979-2010)

area in sq. kms	FS	DS	GD	BL	DF	OF	SL	AL	FL	BU	WB	SH	total
FS	**757.4**	17.0	20.8	2.9	3.5	0.0	0.3	0.0	0.0	0.0	0.0	50.2	852.3
DS	210.0	**18.0**	35.1	6.8	7.1	0.0	0.3	0.0	0.0	0.0	0.1	39.0	316.5
GD	194.5	28.7	**92.6**	63.2	20.4	0.3	1.7	0.0	0.1	0.0	0.6	21.0	423.0
BL	360.4	172.8	104.3	**333.0**	75.2	3.5	34.9	1.5	2.7	0.3	1.1	65.9	1155.8
DF	22.5	0.3	2.5	51.3	**1882.0**	299.8	15.7	32.9	7.8	12.4	18.8	43.9	2389.9
OF	3.0	0.0	0.5	2.7	59.8	**171.8**	11.2	103.5	25.7	6.2	2.8	0.1	387.2
SL	74.5	6.0	16.8	50.9	303.5	245.7	**35.8**	126.1	72.6	32.2	19.3	7.6	991.0
AL	0.1	0.0	0.0	0.6	1.5	28.8	1.8	**67.3**	12.6	3.4	2.6	0.0	118.8
FL	4.4	0.2	1.4	6.7	22.0	41.0	6.3	60.4	**36.9**	16.9	10.6	0.1	207.0
BU	0.0	0.0	0.0	0.5	0.8	5.2	0.2	6.0	3.2	**3.4**	4.7	0.0	24.0
WB	0.1	0.0	0.2	1.5	0.9	1.1	0.1	0.9	0.9	0.3	**6.7**	0.1	13.0
SH	77.4	20.8	14.4	59.0	35.4	0.3	10.2	0.0	0.0	0.0	0.8	**176.5**	394.9
total	1704.4	263.8	288.7	579.1	2412.2	797.5	118.6	398.7	162.5	75.2	68.3	404.5	**7273.5**

Source: *LCM Modeling*

Land transformation in hilly region shows that there is an impact of urbanization or population growth in the area with the time. This table represents the land use transformation from one category to other. Rows represent the 1979 year and column shows the 2010 year. We have seen that built-up area had undergone into water bodies in 2010 that means in the lower basin, with the establishment of Tehri Dam in 2006, most of the villages had submerged into water which showing the remarkable change in the area. Similarly other categories also represents land transformation such as forest area has comes under to agricultural land, agricultural land converted into fallow land, open forest to scrub land etc.

3.3.3 Change Prediction Using LCM

3.3.3.1 CA Markov Modeling

In Markovian processes the future state of a system in time t2 can be modeled based on the immediate preceding state; time t1. A Marcov chain is a random process where the following step depends on the current state. Markov produces a transition matrix, a transition area matrix and a set of conditional probability images by analyzing two qualitative land use images from different dates (t1 & t2).

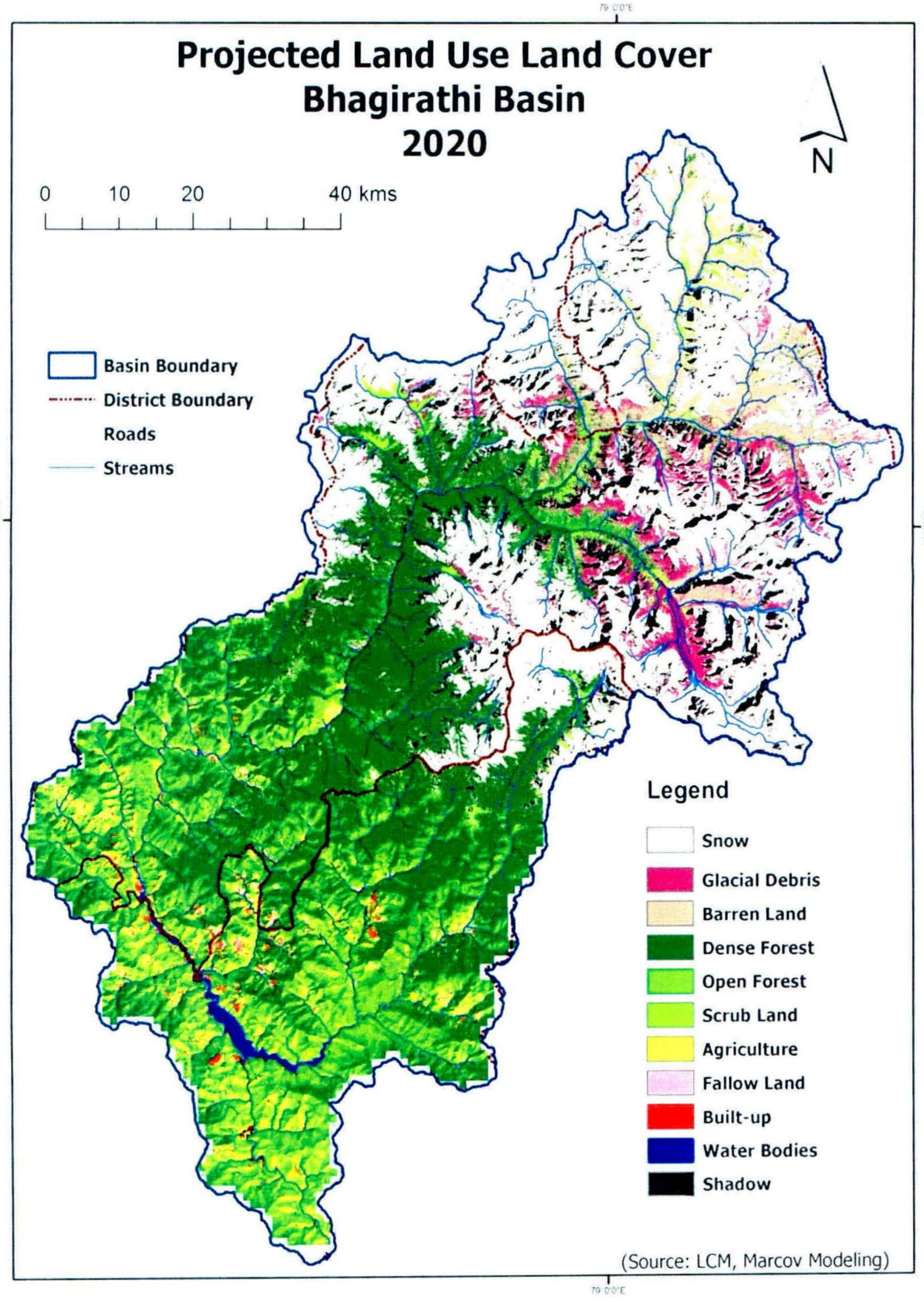
Table. 3.6 LULCC Prediction Statistics of 2020

Classes	2010		Predicted_2020		Change 2010-2020
	area in km²	area in %	area in km²	area in %	in %
Fresh Snow	1705.97	23.44	1681.20	23.11	-0.33
Dry (old) Snow	263.97	3.63	241.38	3.32	-0.31
Glacial Debris	288.69	3.97	334.29	4.60	0.63
Barren Land	579.22	7.96	551.17	7.58	-0.38
Dense Forest	2413.61	33.17	2252.03	30.96	-2.20
Open Forest	797.91	10.96	957.68	13.17	2.20
Scrub Land	118.57	1.63	146.53	2.01	0.39
Agriculture	398.75	5.48	442.09	6.08	0.60
Fallow Land	162.55	2.23	119.13	1.64	-0.60
Built-up	75.25	1.03	75.25	1.03	0.00
Water bodies	68.25	0.94	68.25	0.94	0.00
Shadow	404.77	5.56	404.51	5.56	0.00

Source: *Analysis from the land use map 2010 and predicted 2020; + or - signs indicate direction of change.*

From 2010 to 2020 the predicted land use cover statistics shows interesting results. It is found that there would be increase in the agricultural land in 2020 by net gain of 0.60 % of area in this category. With addition to this glacial debris, open forest and scrub land will also get increase in their area by 0.63%, 2.20 % and 0.39 % respectively. Other land use categories would show decrease in their area in the predicted year of 2020.

Map 3.4 Prediction Land use and Land Cover, Bhagirathi basin (2020)



In table (3.7), the rows represent the older land use/cover classes (2010) and the columns represents the newer land use/ cover categories (2020). Here class 1 to 12 chronologically represents fresh snow, dry snow, glacial debris, barren land, dense forest, open forest, scrub land , agriculture, fallow land, built-up, water bodies and shadow respectively. Marcov analysis was performed for the multi-temporal land cover images of 1979-2010 including predicting year of 2020 as shown in Table3.7.

Table. 3.7 Projected land use/land cover matrix (2010-2020)

area in km^2	1	2	3	4	5	6	7	8	9	10	11	12	total
1	1681.2	23.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1704.4
2	0.0	218.2	45.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	263.8
3	0.0	0.0	288.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	288.7
4	0.0	0.0	0.0	551.2	0.0	0.0	28.0	0.0	0.0	0.0	0.0	0.0	579.1
5	0.0	0.0	0.0	0.0	2252.0	160.2	0.0	0.0	0.0	0.0	0.0	0.0	2412.2
6	0.0	0.0	0.0	0.0	0.0	797.5	0.0	0.0	0.0	0.0	0.0	0.0	797.5
7	0.0	0.0	0.0	0.0	0.0	0.0	118.6	0.0	0.0	0.0	0.0	0.0	118.6
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	398.7	0.0	0.0	0.0	0.0	398.7
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.4	119.1	0.0	0.0	0.0	162.5
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.2	0.0	0.0	75.2
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.3	0.0	68.3
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	404.5	404.5
total	1681.2	241.4	334.3	551.2	2252.0	957.7	146.5	442.1	119.1	75.2	68.3	404.5	7273.5

Source: *LCM Modeling*

The above table represents the projected land use and land cover matrix of 2020. This shows the how much land will tranform in 2020 from one category to another. The projected land use and land cover change analysis gives an idea of probable change in the future. From this matrix one interesting change has been noticed that there might be change in the agricultural land from 398.7 sq.km area to 442.1 sq.km area in 2020 which shows the highest change from all categories. Now a days the change in the agricultural land is the result of increasing population and demand of food. As this region is mountainous area the primary economic activity is agriculture so the increase in the agricultural land would be quite possible.

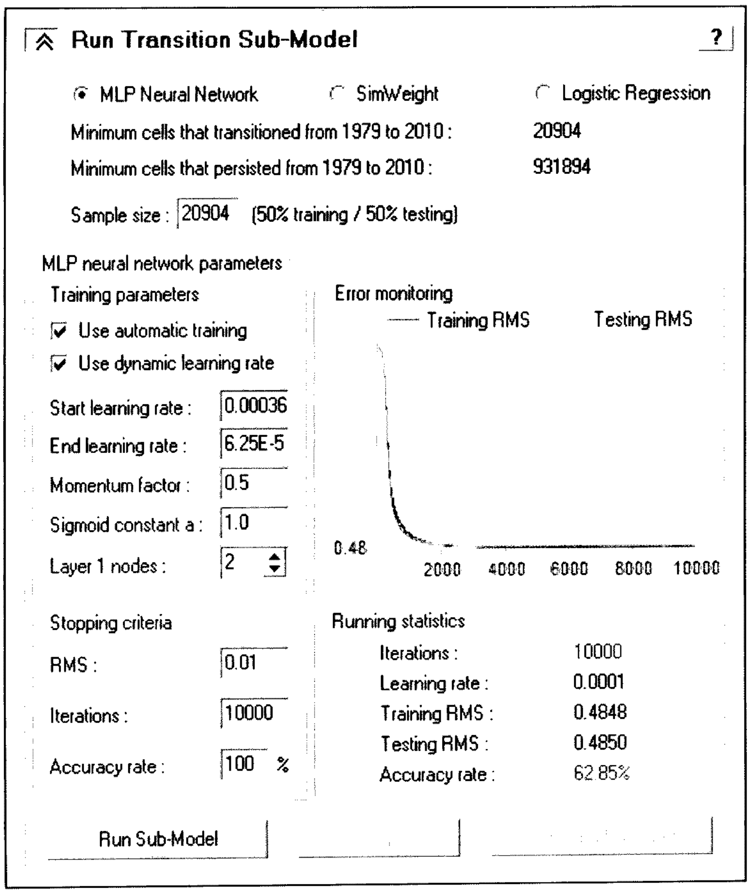
3.3.3.2 Accuracy Assessment

Accuracy assessment should be an important part of any classification without any accuracy assessment we do not know how accurate our classification is. Based on IDRISI LCM modelding accuracy of land use classification has been done. This module is good tool to find out the accuracy of our land change modeling.

There are other methods too which calculate the accuracy of our classified image that based on the user's and producer accuracy but this module gives the better representation of the accuracy of the land use classes because this accuracy derived by the number of explainatory variables such as roads, streams, slope, aspect and constuction.

During LCM modeling these explainatory variables have been used to find out the better results and better classification.

Figure 3.4 Accuracy Assessment



Source: *LCM Modeling*

By using LCM Modeling the accuracy of land use change was done on MLP Neural Network built-in module in the Selva version of IDRISI. Iterations considered were 10000 sufficient for running the data. As shown in fig the accuracy rate is 62.85% which is quite significant. In this module this accuracy is based on the number of drives that basically indicates the change or they represent the cause of change. The drivers and explanatory variables are highly important in the accuracy assessment.

3.4 CONCLUSION

The study has highlighted the significance and applicability of remote sensing and GIS in the form of multi temporal satellite imageries, from the evaluation and monitoring regarding land use land cover changes, it's have an effect on livelihoods, socio-economic condition from the people, ecology and surroundings.

The above analysis of Land use and land cover change in the Bhagirathi basin from 1979 to 2010 shows that the major land transformation has noticed in the Built up area and agricultural land. Because of the urbanization and population growth, area has witnessed the more change in the built-up area which is the result of number of new construction, road construction, dam construction in the region. Over all, we can conclude that the land use and land cover changes in the region reveals that the major change in the region is taken place by the growth of the population and fast urbanization in the area. Due to conversion of agricultural land and forests to urban areas leads to food insecurity in the region. Besides this, it also important to mention that due human interventions in the region land use have changed in very critical conditions like soil degradation, soil erosion and deforestation ,it leads to declines in the productivity of the land. These land use dynamics have not only disrupted the fragile ecological system but have also adversely affected the productivity of rural ecosystem and livelihood securities.

CHAPTER 4

SOCIO-ENVIRONMENTAL VULNERABILITY

4.1 BACKGROUND

Social vulnerability refers to the socioeconomic and demographic factors that affect the resilience of communities. Most of the studies shown that in disaster events the socially vulnerable are more likely to be adversely affected, i.e. they are less likely to recover and more likely to die(Barry E. Flanagan et al,2011). Effectively addressing social vulnerability decreases both human suffering and the economic loss related to providing social services and public assistance after a disaster. This chapter examines the development of social vulnerability index (SVI), from 19 census variables at the village level. These variables include social, economic and infrastructural aspects of the basin. The immediate purpose for developing the social vulnerability model was to make otherwise inaccessible data accessible to disaster management decision makers.

4.1.1 Social vulnerability

As we earlier discussed that the basin level study in mountainous region at different altitude is complex to understand. It has different physical, social, economic aspects at different altitude level. The changes that have occurred in higher altitudes in the basin like variability in snow cover area will impact on lower altitude in terms of change in the river discharge, hydrological cycle, biogeochemical cycle etc. The basin system has linkages from higher altitude to lower altitude and vice versa. Whatever changes occurred in lower altitude will impact to upper altitude such as intensification of agriculture, construction, deforestation etc. leads to the rise in temperature and further it leads to the melting of snow. So this cyclic phenomenon will impact not only on the physical environment it also affect the human environment that lives in the down streams so the vulnerability to these populated region is high in terms of natural disaster.

Mountains play a significant role in impacting on global and regional climates and conditions. By intercepting the global circulation of air, they have a decisive effect on wind, precipitation and temperature patterns. Their climates vary considerably – from year to year, season to season and day to day, at different altitudes and on slopes with different exposures. Traditional land-use systems utilize these small- scale variations, and mountain people have developed sophisticated techniques for farming, livestock breeding, forestry and water use that are adapted to life on steep slopes and harsh, unpredictable conditions. People living in mountains are among the world's poorest and most disadvantaged. Harsh climatic and environmental conditions, remoteness and often difficult access hamper development in mountain regions. They frequently face political, social and economic marginalization and lack access to such basic services such as health and education. Hence, it is important to study the socially vulnerable areas that are more prone to disaster or natural calamity so that by giving attention on it we can reduce the loss and damage accelerated by a catastrophic event (ICIMOD, 2012).

The IPCC Fourth Assessment Report brings about the following key vulnerabilities in mountainous region: Firstly, the Himalayan Eco-system is particularly at risk with the rise in global temperatures. The bio-diversity which resides in the higher altitudes will have lesser and lesser place to occupy and will be at increased risk of extinction; secondly the increase in global temperature will cause increased occurrence of GLOFs (Glacial lake outburst floods) and will affect the size of the glacial lakes. The breakage of such lakes can be extremely devastating to human habitations, among others; thirdly it can be stated that the precipitation will be with increased intensity and become more erratic. This will make the fragile ecosystems susceptible to damage by cloudbursts, increased soil erosion etc. The overall pattern of rainfall is expected to be heavy rainfall followed by long period of droughts. This will reduce the overall availability of water in the hills. Fourthly, the alpine meadows have high soil organic content and are very good at sequestering carbon. They are also extremely rich in biodiversity. The increase in global temperatures threatens the existence of alpine meadows and makes them vulnerable to extinction; fifthly, there will be a gradual shift of plant species towards higher altitudes. This will force local communities to shift to newer agricultural and fodder species. This coupled with the fact that the area lies in a highly sensitive seismic zone, there is bound to be a heavy stress on housing sector; and Lastly ,Increased tourism activities will cause severe stress on the fragile Himalayan eco-systems which are already reeling under the pressure of water-scarcity, excessive constructions, heavy usage of fuel-wood, improper waste management, to name a few.

Some studies examining various aspects Uttarakhand's vulnerability to climate change. These include, for example WWF India's study of the Ganga Basin which examined various factors contributing to exposure, sensitivity, adaptive capacity and vulnerability index. Another study done by Interim report of the Uttarakhand Centre on Climate Change (UCCC), Kumaon University presents a section of evidence of climate change in the state and also includes brief notes on vulnerabilities to various sectors such as water resources and glacier, rivers and lakes, water quality, air and atmosphere, biodiversity, agro-forestry and ecosystem, agriculture , food and livelihood security, human health and environment, disaster and hazard risk, electricity, tourism, and industry and human settlement.

Climate change is recognized as being the biggest threat that the earth and human race face today. Climate change is driven by increase in the average global temperature (global warming) and results in changes in cloud cover and precipitation particularly over land, melting of ice caps and glaciers and reduced snow cover, increase in the frequency of extreme climate events and increase in ocean temperatures and oceanic acidity due to absorption of heat and carbon dioxide from the atmosphere by seawater. It thus encompasses all the environmental changes that are likely to have detrimental effects on nature as also socio - economic aspects of our lives.The impacts of climate change are all the more visible in vulnerable and sensitive regions and Himalaya represents one such region. It forms a formidable physical barrier that has played a major role in stabilizing southwest monsoon over the sub-continent. Precipitation caused by the southwest monsoon is the primary mechanism of fresh water delivery in the sub – continent and is the lifeline of the economy of the region. It thus has a direct bearing upon the ecology and economy of the region. About 10 percent of the world's population depends on mountain resources and a much larger percentage draws on other mountain resources that include water.

Himalaya also acts as a massive fresh water reservoir and a number of perennial rivers and their tributaries have their source in this region. Two of largest river systems of the sub-continent, Ganges and Indus originate in the glaciers of this region and are fed by myriad lakes, glacial melts and streams. These perennial rivers provide water for household, industrial and irrigation purposes and are also the primary source of energy in the region. These bring huge quantities of silt and clay that get deposited in the Indo-Gangetic and Indus plains and thus regularly replenish the soil fertility. It is because of these river systems that these plains are in a position to sustain dense population.

Development priorities of the country/state are often derailed by disasters and therefore it is important to unite various risks reduction strategies with developmental planning. Moreover, based upon their resilience, communities are differently affected by disasters. The most vulnerable sections include poor, women, elderly, children and differentially abled persons. Poverty is often a direct function of the available gainful employment opportunities. Lacking of the gains of development, hill communities in the state face the brunt of forced migration. This results in women taking care of agricultural chores besides routine household chores. Agriculture that is the main economic activity of the region is being adversely affected by changing weather patterns. Bereft of farming hands large tracts of hitherto agriculture lands are being left barren. This is a serious concern as it threatens livelihood, well-being and food security of the masses in the region. It therefore becomes important to quantify this problem in discrete terms and solutions to the problems have then to be devised accordingly.

4.2 DATA USED AND METHODOLOGY

4.2.1 Data used

To examine the social vulnerability, socioeconomic and infrastructural data were taken from Census 1991 and 2001 at village level from Primary Census Abstract of two district of Uttarakhand i.e. Tehri and Uttarkashi. Village and town directory of Uttarkhasi and Tehri were also used.

4.2.2 Methodology

To be able to look at the total picture of Social Vulnerability, Social Vulnerability Index (SoVI) has been used.A set of 19 indicators chosen are selected on the basis of their representativeness of the following :-

1) Social indicators
2) Economic indicators
3) Infrastructure indicators

Table 4.1 Selection of Indicators

COMPONENT	INDICATOR
Social	literacy rate (+) female literacy rate (+) child sex ratio (+)
Economic	T_WPR (+) % of FW to TW (+) % of MAIN W to TW (+) % of MAIN_FW to TW (+) % of NSA to TA (+)
Infrastructure	No. of PS &MS per 500 pop (+) No. of SS,SSH,College &other per 1000 pop (+) No. of Medical(allop,ayur) institution per 1000 pop (+) No. of Dispensery per'000 pop (+) No. of PHSC per 3000 pop (+) No. of PHC per 20000 pop (+) No. of post_tele fac per'000 pop (+) No. of bank fac per'000 pop (+) Drinking water facility (+) Communication facility (+) Power facility (+) (-) Indicates negative indicator (+) Indicates positive indicator

The purpose behind using SoVI is that it summarizes various aspects related to input, process and outcome indicators, so as to be able to identify geographic areas that are prone to natural disaster in terms of overall Social Vulnerability. It helps understand the position of a village vis-à-vis other villages.

After sorting out data the following steps were performed on MS excel and SPSS.

- Based on whether the indicator is positive or negative it is normalized. Upon receiving normalized values, the weights in the computation were determined by using factor loadings and Eigen Values from Principal Component Analysis.
  Then the best and worst values are identified in an indicator, which will depend on the nature of the indicator. In case of a positive indicator, the HIGHEST value will be treated as the BEST value and the LOWEST, will be considered as the WORST value; and vice versa.

  $$NVij = 1 - \left[\frac{\{Best\ Xi - Observed\ Xij\}}{\{Best\ Xi - Worst\ Xi\}}\right] \text{..................................equation 4.1}$$

- Weights are determined after finding eigen values.
- The following formula is used to determine the SoVI by calculating the index as shown below-

  $$I = \frac{\sum_{i=1}^{n} Xi\left(\sum_{j=1}^{n} \cdot \left|Lij\right| . Ej\right)}{\sum_{i=1}^{n}\left(\sum_{j=1}^{n} \cdot \left|Lij\right| . Ej\right)} \text{..equation 4.2}$$

  Where I is the Index, Xi is the ith Indicator; Lij is the factor loading value of the ith variable on the jth factor; Ej is the Eigen value of the jth factor

Based on the SoVI, assign RANK in ascending order. The Highest Index with RANK ONE will be treated as the BEST means low Social vulnerability and the LOWEST

Index, with last rank will be treated as the WORST means high level of social vulnerability among the villages of Bhagirathi Basin, used in computation of SoVI.

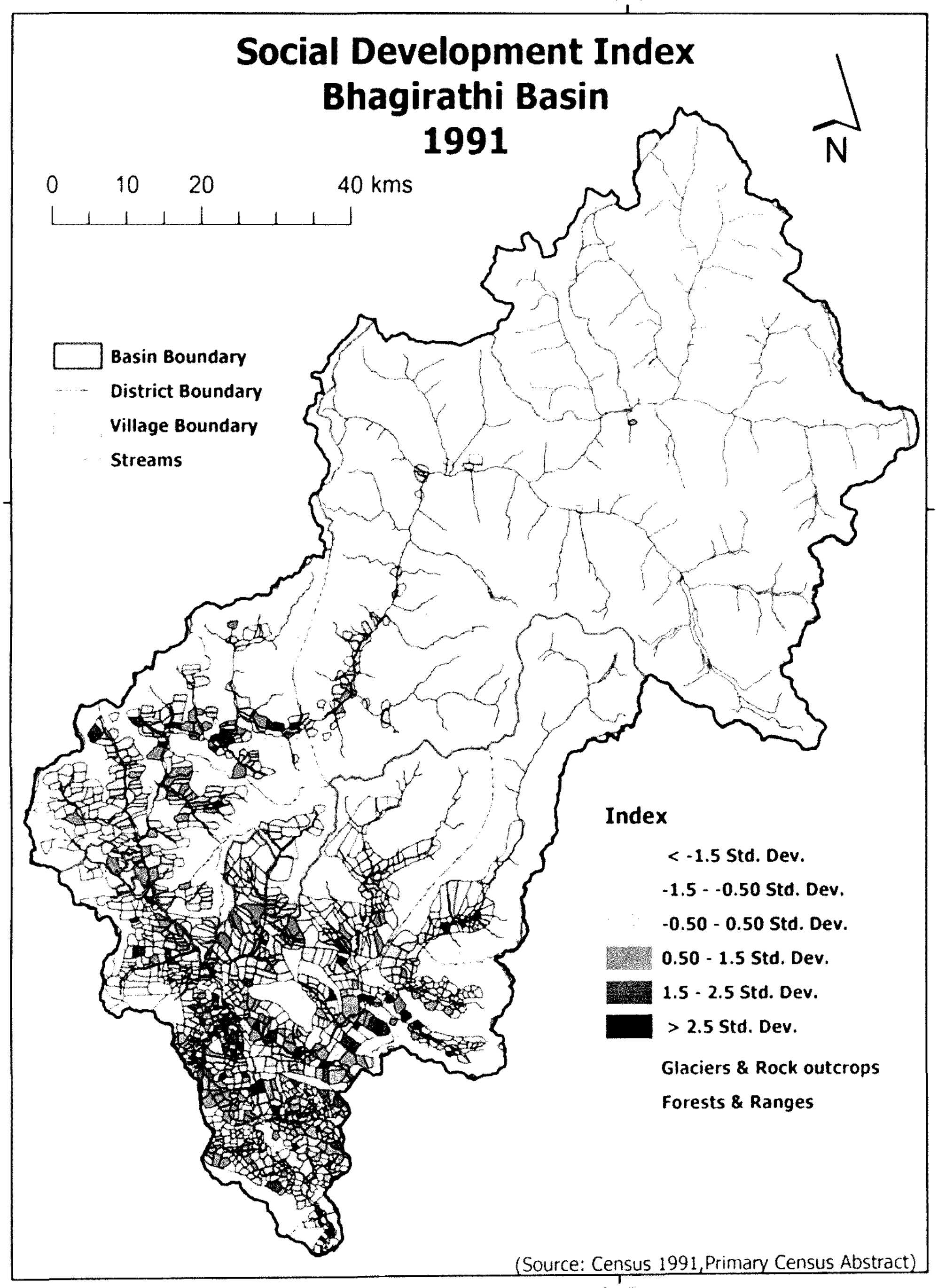
4.3 RESULTS AND DISCUSSION

To know about the socio-environmental vulnerability in the basin, the three basic aspects i.e social, economic and infrastructure have been studied to create the three development indexes. These three pertains the level of development in the study area at village level. Higher the level of development in context to socio-economic and infrastructural aspects shows the less vulnerability. Some studies show these relationships such as socio-economically disadvantaged population are disproportionately affected by disaster. The poor are less likely to have the income or assets needed to prepare for a possible disaster or to recover after a disaster. (Morrow 1999; Cutter et al. 2003). Hence, in this we calculate socio-environmental vulnerability in the Bhagirathi basin. In order to achieve overall vulnerability, firstly social development index, economic development index and Infrastructure development index have been calculated. These are discussed one by one as follows:

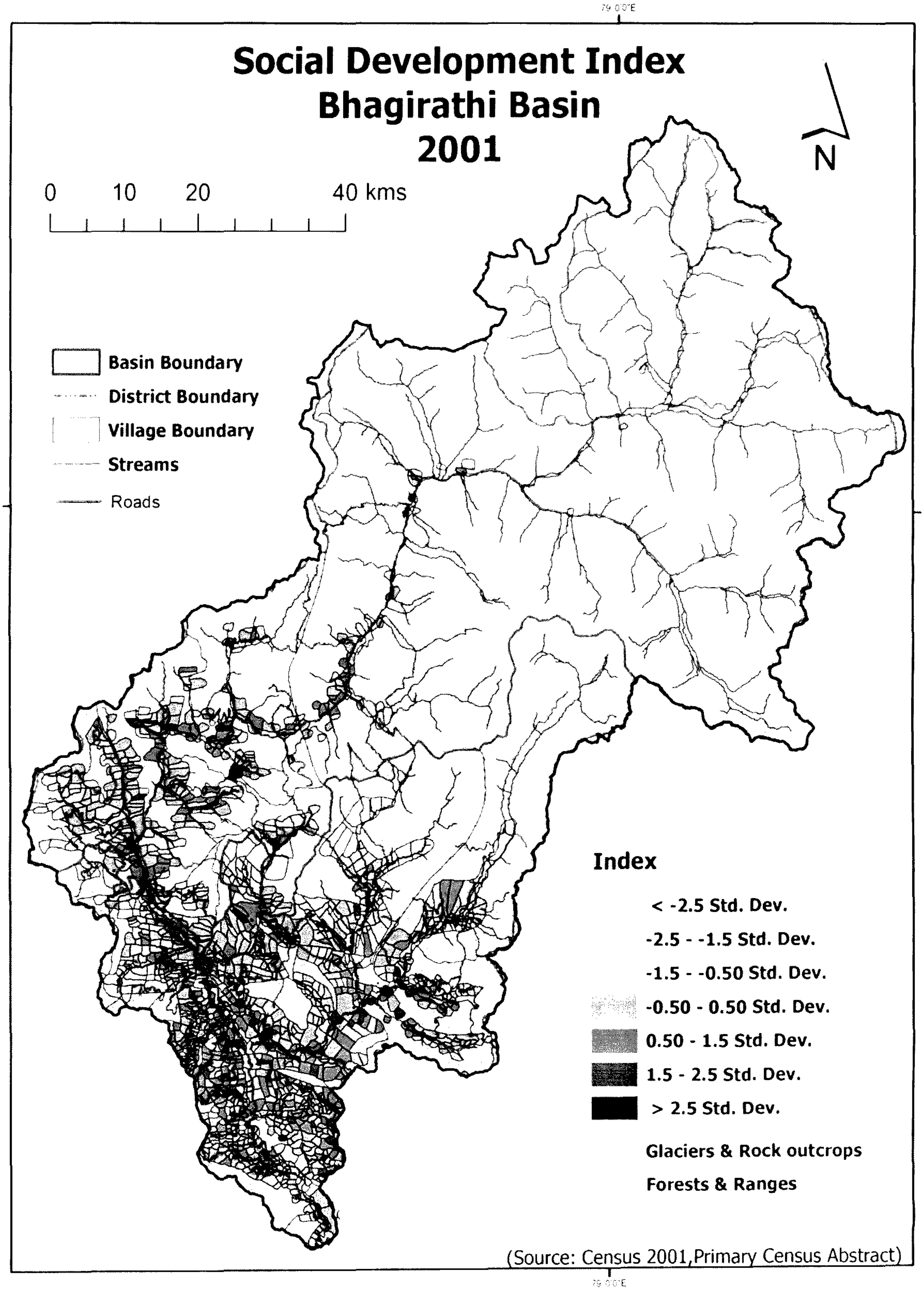
4.3.1 Social Development Index

To analyze Social development index in the catchment literacy rate, female literacy rate and child sex ratio have been undertaken. These variables indicate the societal development for the region but when we relate it with the socio-environmental vulnerability then it becomes more complex. Education is a good indicator for the development in the society. But relationship between education and vulnerability to disaster is not well understood, although education is associated with both income and poverty. People with higher levels of education are likelier to have access to and act upon varied hazard information from preparation to recovery. (Tierney 2006). For people with less education, the practical and bureaucratic hurdles to cope with and recover from disaster prove increasingly difficult to surmount.(Morrow 1999). Child sex ratio actually shows the status of women in the society and if the number of women would be less, less would be the development. Lower child sex ratio refers to lesser women wanted. Some studies shows that more women die in disasters than men (UNDP, IUCN, etc) so they are more vulnerable to natural disaster. Overall the social development index basically depicts the development of the society and this inversely related to the vulnerability.

Map 4.1 Social development Index 1991



Map 4.2 Social Development Index 2001



From the analysis of Census PCA data 1991 and 2001 of study area it has found that the social development in the region has changed with the time. The Social development Index is a relative measure of the overall social vulnerability. To determine the most and least development of the area , the SDI scores were mapped based on standard deviation into six categories ranging from -1.5(least developed) on the upper end to +2.5 (most developed) on the lower end at two time period i.e. 1991 and 2001. In 1991 the SDI ranges from 0 to 0.73 scores. Out of 1357 villages 13 villages were showing high level of social development that is mainly situated at the lower tract in the basin, 159 villages were highly vulnerable because social development was very low. But in 2001 these villages has improved in terms of social development and found that some villages which were situated at the upper basin scored high rank and social development has increased. Out of 1377 villages, five villages have accounted high level of social development whereas 20 villages had low level of social development.

Table 4.2 Social Development Index

Class of SDI	**Number of villages in 1991**	**Number of villages in 2001**
< -2.5 SD (Worst)	-	20
-2.5 to -1.5 or <1.5 SD	51	88
-1.5 to -0.5 SD	419	256
-0.5 to 0.5 SD	480	593
0.5 to 1.5 SD	290	358
1.5 to 2.5 SD	101	56
>2.5 SD (Best)	13	5

Source: *Primary Census Abstract, 1991&2001*

4.3.2 Economic Development Index

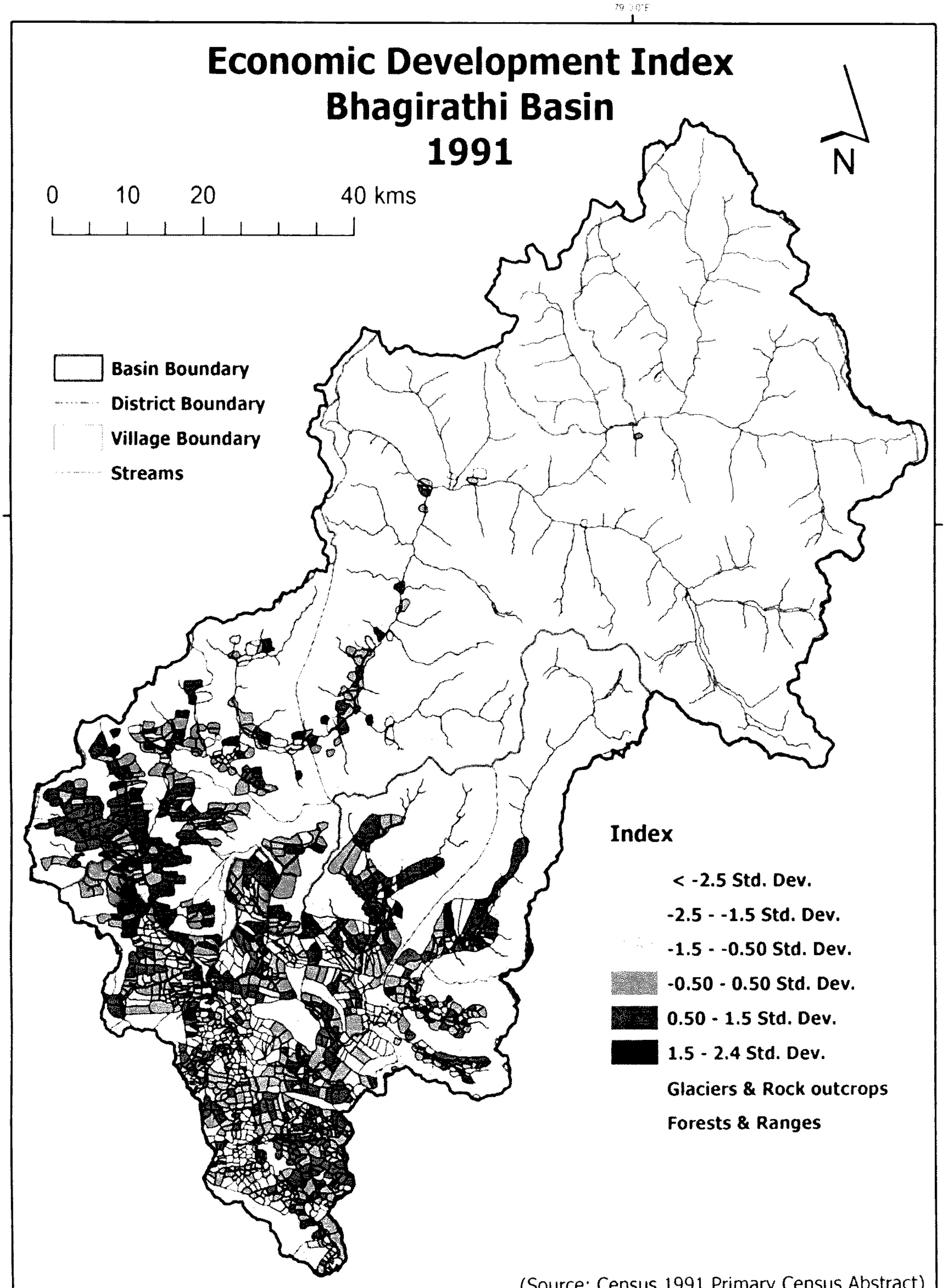
The present section is an attempt for an assessment of the level of economic development and its regional distribution by combining five different variables (discussed in methodology) of economic development. This index has been calculated for two different years 1991 and 2001 to see the changes in terms of level of economic development from earlier year to later. The relative range method has been used for the normalization of these variables then PCA (Principal Component Analysis) has been used to compute the factor loading and weights of these indicators. The score of economic development is marked with notable variations in its distribution among the villages of Baghirathi basin. It may be noted that the highest and lowest scores of economic variables are recorded in the village Makhaliyan chak (0.68), Pajgaon(0.64) and chokhala, Kot Medhe lalasi chak (0.01) in 1991. The general distribution level of economic development as depicted in Fig () shows that the region of very high economic development (more than 1.5 SD from mean) in the lower basin that comes under Tehri region only two villages of Uttarkashi comes in this category namely Kanath (0.57) and Bhatusera (0.53) whereas in 2001 the high economic development (more than 1.5 SD from mean) found in the 18 villages out of 1377 villages. All these villages lie in the lower tract in basin or in Tehri district except one village which is found in uttarkashi district. Very low level of development (less than -2.5 SD from mean) found in only two villages that is Soman (0.002) in uttarkashi and panch Koti (0.113) in Tehri.

Table 4.3 Economic Development Index

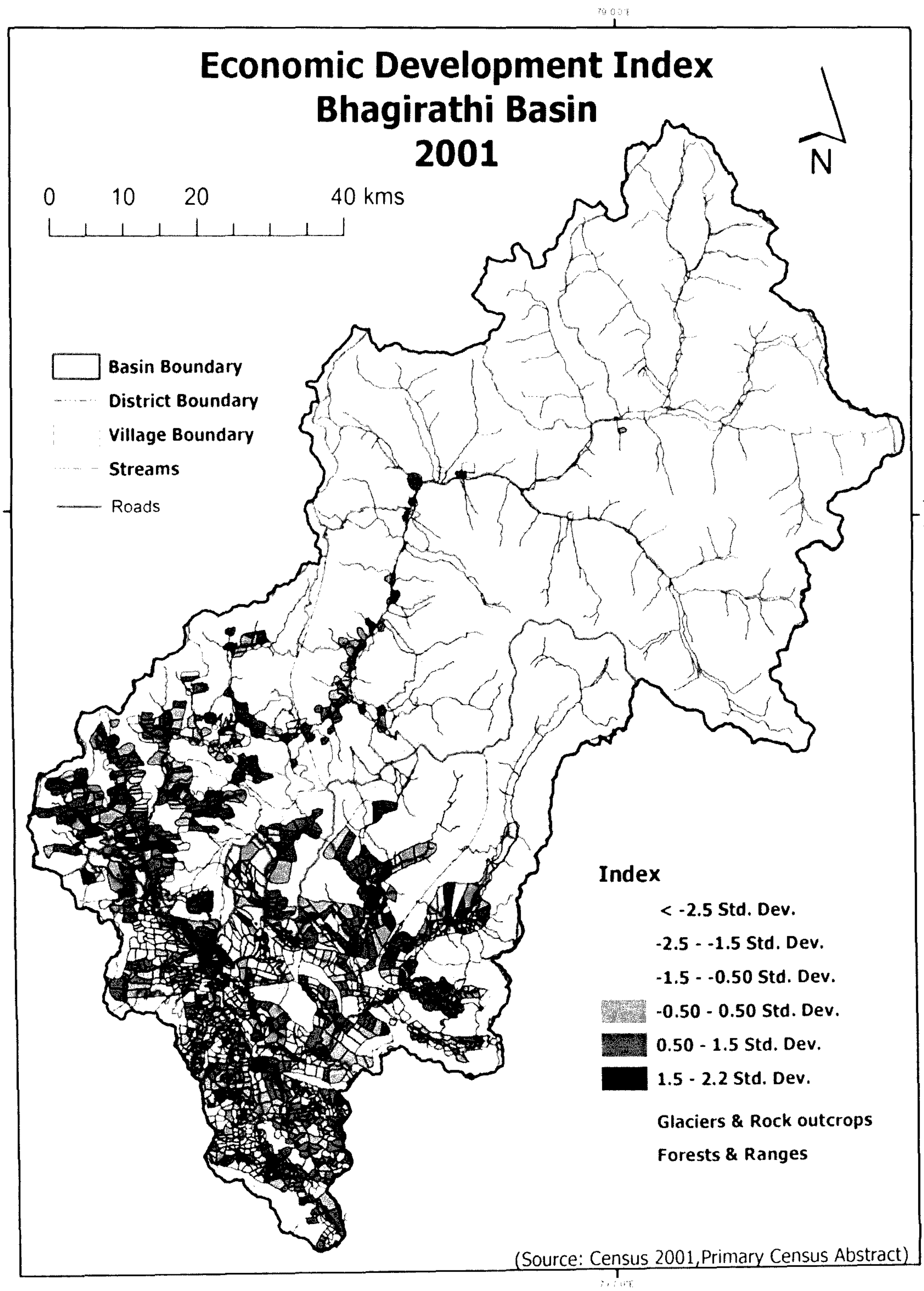
Class of EDI	Number of villages in 1991	Number of villages in 2001
< 2.5 SD (Worst)	26	2
-2.5 to -1.5 SD	144	116
-1.5 to -0.50 SD	141	343
-0.50 to 0.50 SD	530	352
0.50 to 1.5 SD	503	346
1.5 to 2.4 SD (Best)	13	18

Source: *Primary Census Abstract, 1991&2001*

Map 4.3 Economic Development Index 1991



Map 4.4 Economic Development Index 2001



4.3.4 Infrastructure Development Index

Infrastructure plays a very important role for the development of the country. It is of paramount significance during a natural disaster as well. Natural disaster have an intense impact on the quality of life through their destruction of food crops and livestock, shelter and other aspects of the built environment, and forced dislocation of households and communities. Their most devastating impact, however, is their toll on lives and the instant poverty they create. The effect of natural hazards on the loss of human lives is directly related to the poverty levels in given country (ESCAP, 1995). Therefore, to determine social vulnerability in a region, infrastructure development is an important component to understand the relationship between the social vulnerability and natural disaster. As our study area falls under very severe zone of natural disaster so the study of infrastructure in this region is important in relation to vulnerability.

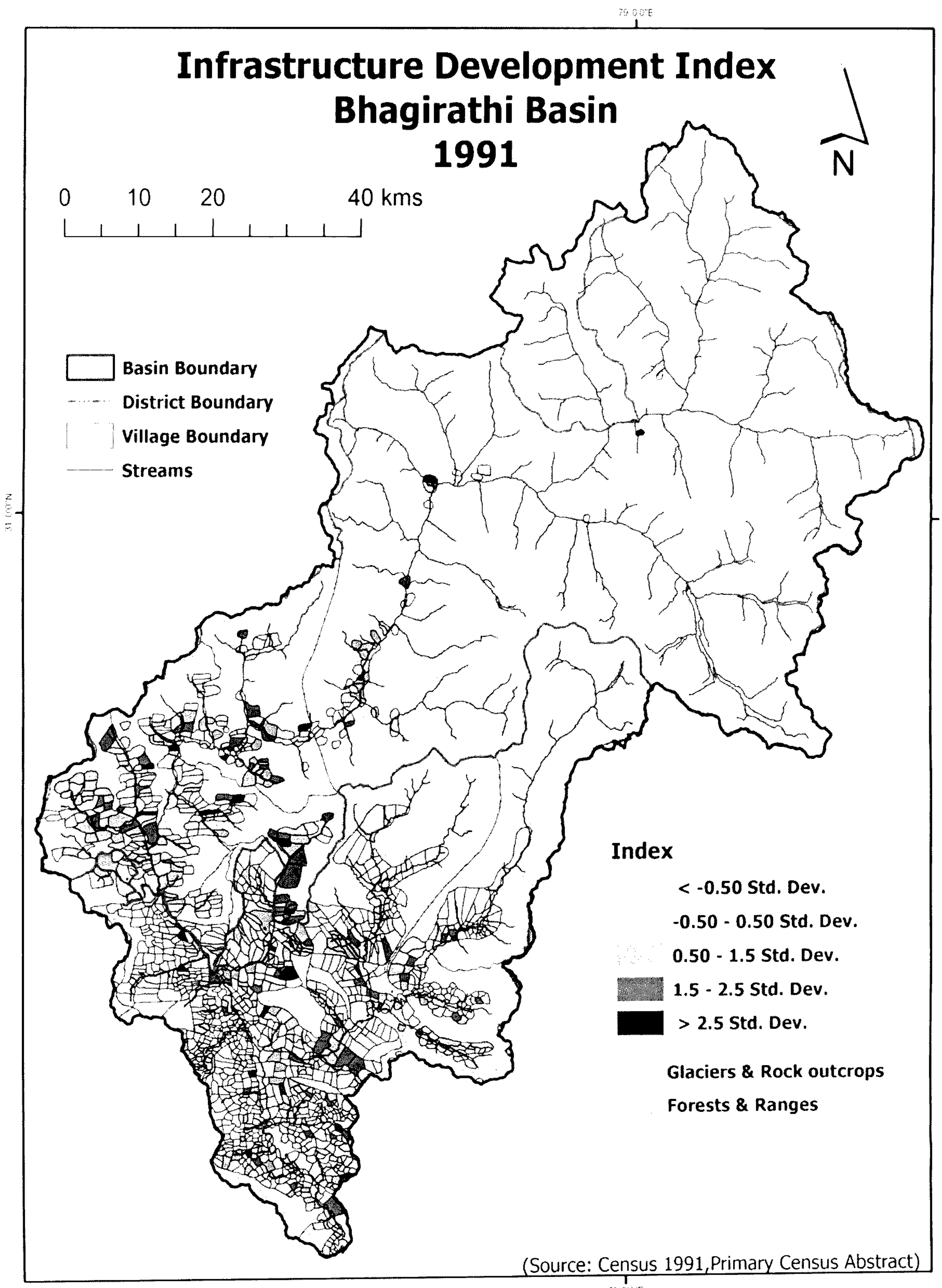
To analyze Infrastructure development index in the Basin ten variables have been taken that includes medical facility, education facility, Drinking water facility, Communication facility and Power facility. The score of index in 1991 and 2001 indicates that infrastructure has been improved in basin with time.

Table 4.4 Infrastructure Development Index

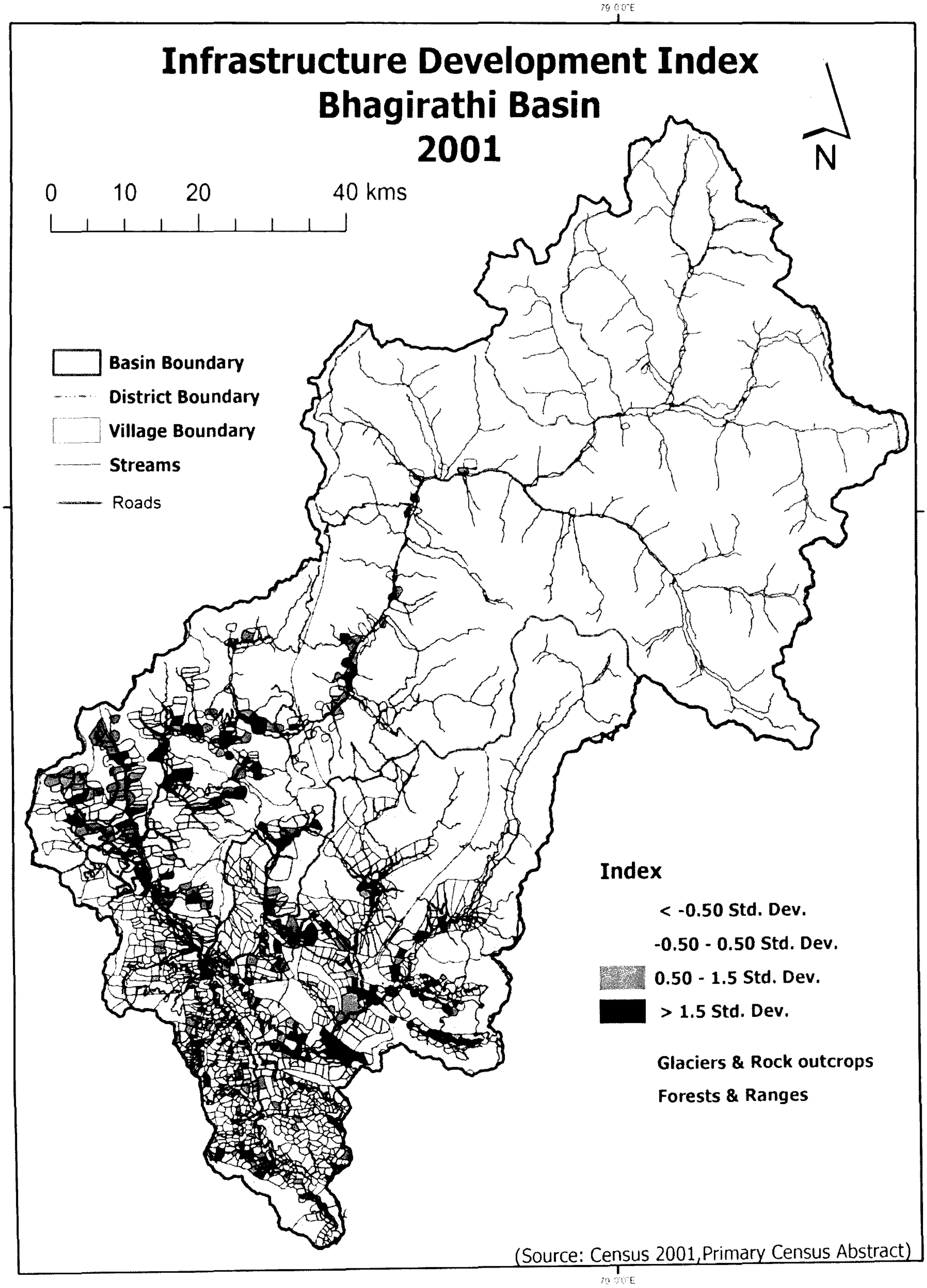
Class of INF_DI	Number of villages in 1991	Number of villages in 2001
<-0.50 SD (Worst)	702	549
-0.50 to 0.50 SD	309	490
0.50 to 1.5 SD	240	184
1.5 to 2.5 SD or >1.5 SD (Best)	83	138
>2.5 SD (Best)	22	-

Source: *Primary Census Abstract, 1991&2001*

Map 4.5 Infrastructure Development Index 1991



Map 4.6 Infrastructure Development Index 2001



From the analysis it has found that in 1991 the score for index ranges from 0 to 0.6 and on the based classifying standard deviation method five classes were found whereas in 2001 only four classes have been classified through standard deviation from mean method because the index value were ranges from 0 to 0.3. In 2001, the general distribution of level of infrastructure development as depicted in Fig () shows that the region of best infrastructure development (more than 2.5 SD from mean) in the Tehri dristict namely Ghanshali (0.37) and Pokhhri (0.31) whereas in 1991 the best infrastructure development found in the Nalang (0.62) which is located near Gangotri town. From the overall picture of basin, we can say that infrastructure is good near the towns and its periphery regions.

4.3.5 Social Vulnerability Index

Social vulnerability reflects the stratified conditions in which people compute for scarce, limited resources to mitigate against, respond to, and recover from disasters. All too often, people lack the means and opportunities to influence their risks significantly. In reality, risk is structured into the social institutions, social processes and policies, and social relationships that are difficult to influence for historically disempowered populations (Boyce 2000).

From the vulnerability paradigm, it is necessary to understand both the physical impact of disasters and social conditions that underlie differential outcomes. The degree to which people receive transportation, shelter, warning, and protective action and are safe from injury, loss of life, or property damage depends on their level of income, quality of housing, type of employment, and on whether or not they are subject to discrimination and prejudice. Thus, the vulnerability paradigm seeks to understand how social, economic, and political relations influence, create, worsen, or can potentially reduce hazards in a given geographic location.

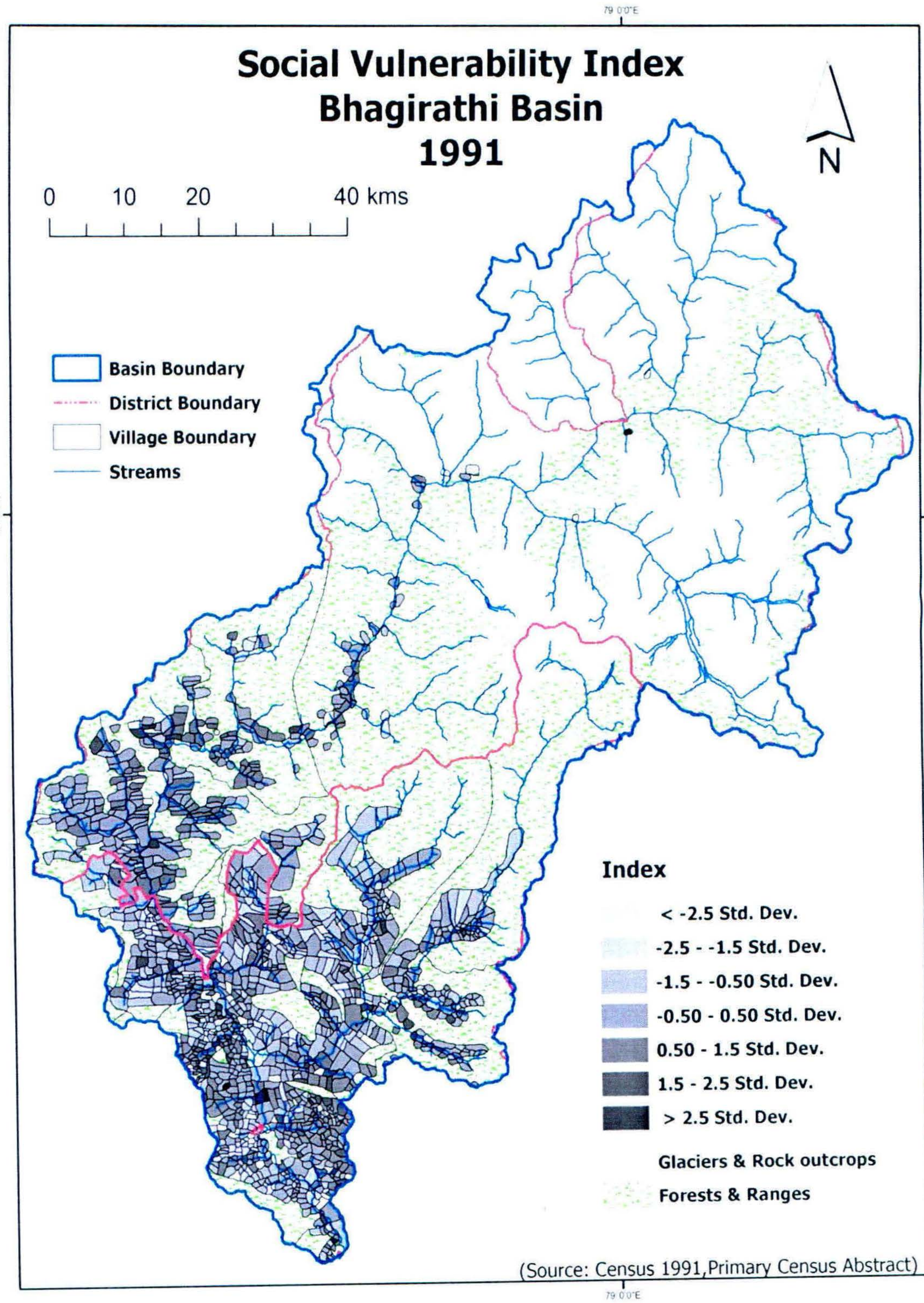
The SoVI composite score was calculated by the overall indexs i.e SDI, EDI and IDI. The scores vary from 0 to 1. Zero depicts the high level of social vulnerability and 1 represents the low level of vulnerability. In 1991 it ranges from 0.09 to 0.6 among the villages of Baghirathi basin whereas in 2001 it varies from 0.004 to 0.89. Nalang and Pipola (0.64) found low level of Social vulnerability in 1991 while Ghansali(0.82), Pokhri(0.76) and Langoor(0.68) in 2001. These villages overall get the highest score so that it depicts that during disaster time these villges would be less affected to a natural disaster so social vulnerability is less. The high level of social vulnerability found in the Mulagaon (0.09) and Barol(0.12) in 1991 but in 2001 Soman(0.0) and Panch Koti (0.01) get lowest score so that it represents high level of social vulnerability.

Table 4.5 Social Vulnerability Index

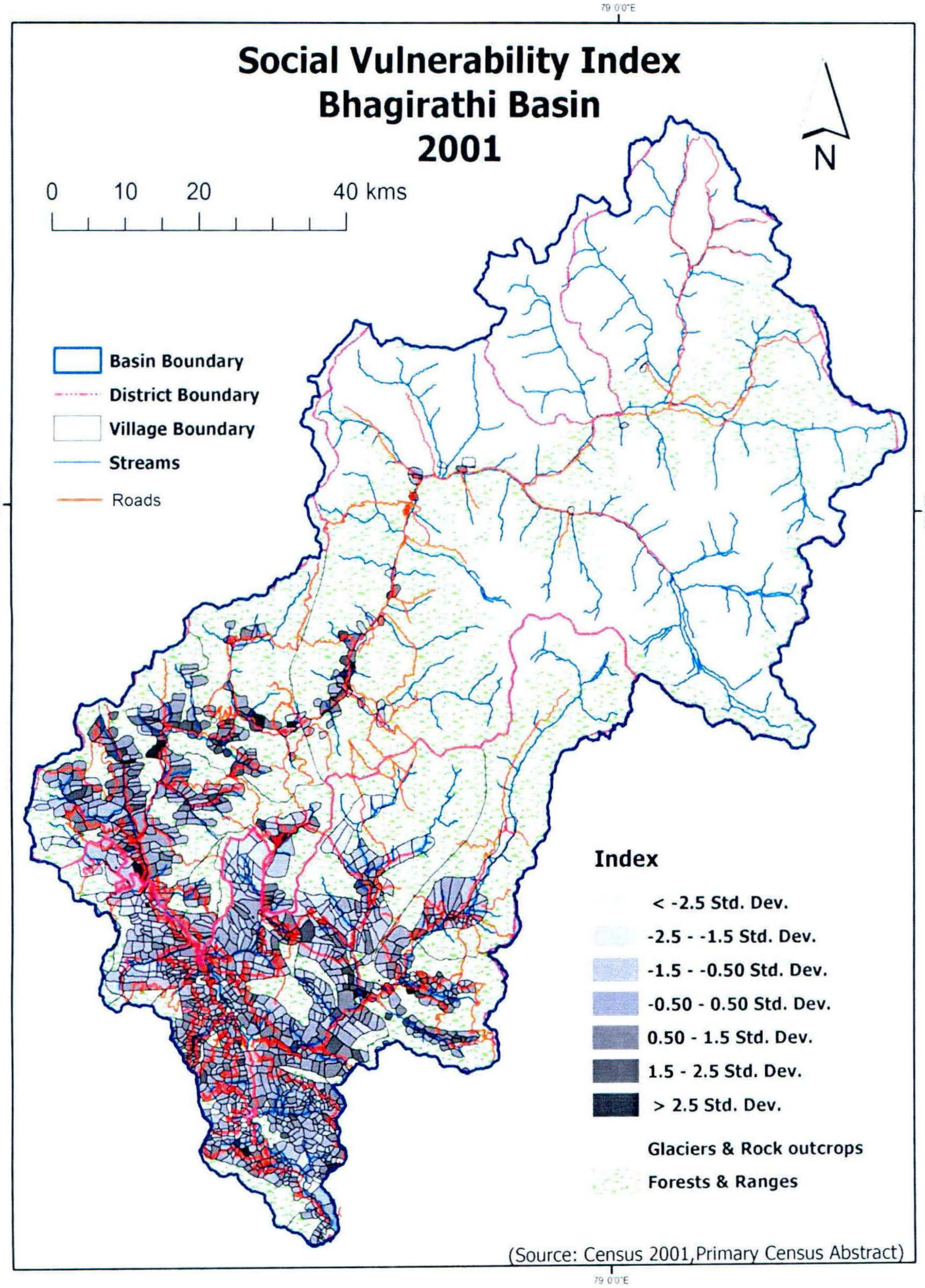
Class of SoVI	Number of villages in 1991	Number of villages in 2001
<-2.5 SD (VV High SoVI)	23	9
-2.5 to -1.5 SD (V High SoVI)	91	78
-1.5 to -0.5 SD (High SoVI)	250	316
-0.5 to 0.5 SD (Moderate SoVI)	574	576
0.5 to 1.5 SD (Low SoVI)	353	299
1.5 to 2.5 SD (V Low SoVI)	60	83
>2.5 SD (VV Low SoVI)	6	16

***Source:** Primary Census Abstract, 1991&2001*

Map 4.7 Social Vulnerability Index 1991



Map 4.8 Social Vulnerability Index 2001



4.4 CONCLUSION

In order to examine the Social Vulnerability Index three aspects have been undertaken that represents the social, economic and infrastructural status of the villages in the basin. Overall good status of the village represents the low level of social vulnerability to a natural disaster. As it is noticed in the basin that most of the social vulnerability found on those areas where the social, economic and infrastructure status was poor such as in the village of Mulagaon (0.09) and Barol(0.12) in 1991 but in 2001 Soman(0.0) and Panch Koti (0.01).

The poor and the minorities were more likely to bear the brunt of disasters than their more privileged neighbors. Socio economic development has a certain relationship with the capability to adapt and mitigate to climatic extreme events such as floods, landslide and earthquakes etc. More socio economically developed region or villages are better equipped to stand any natural calamity and vice-versa. Among all these indices infrastructure index have the potential to rescue a region engulfed into any hazard, hence it is of tremendous significance.

CHAPTER 5

ASSESSMENT OF POSSIBLE DRIVERS OF LAND USE LAND COVER CHANGE AND IMPACTS

5.1 BACKGROUND

Land is the basic natural resource that provides habitat and sustenance for living organisms, and a major source of economic activities (UNEP, 2001).Land transformation is the process where changes in land use/cover are observed at different time periods and it is one of the important fields of human induced environmental transformation. Land is in a continuous state of transformation as a result of various natural and man- made processes.

Mountain ecosystems are commonly regarded as being highly sensitive to global change. Due to the system complexity and multifaceted interacting drivers, however, understanding current responses and predicting future changes in these ecosystems is extremely difficult. The global change refers to changes having both natural and anthropogenic causes and encompass among other factors, climate change, land use cover change, industrialization, urbanization and changes in atmospheric chemistry. Potential effects on mountain ecosystem due to the drivers of climate change and LULCC will impact on whole region. Climate change will have a strong impact on the cryosphere, while impacts on glaciers, permafrost, the altitudinal snow line and cryospheric processes will in turn cause changes in hydrology, vegetation and geomorphology. Permafrost degradation and glacier retreat lead to the destabilization of mountain areas that can result in mass movements such as landslides, rock falls and debris flow. Hydrological processes for example precipitation, evapotranspiration, soil moisture, sediment load, runoff, discharge, and pollution loads of runoff water etc. will not only be affected by climate change, but also by vegetation transformations caused by land use and land cover change (Loffler et al., 2011).

Altitudinal study of mountain region has shown that the drivers for the change in the Land use and land cover will impact on its surroundings. In the upper Bhagirathi basin it has been observed that Gangotri Glacier lost 0.41 ± 0.03 sq. km (~ 0.01 sq. km year-^{1}) area between 1965 and 2006 from its front (Bhambri et al,2012). Singh et al (2012) study also shows that there is an upward shift of vegetation in the alpine zone of the Himalayas. The causative factors which can be cited for the above changes are basically physical drives incorporating elevation, slope, aspect, precipitation, temperature etc.

The several reasons are responsible for the change in the areas they might be bio-physical drives or socio-economic drivers. In the Lower basin the problems concerned with the land use change is deforestation, soil degradation, soil erosion that leads it to declines in the productivity of the land. These land use dynamics in the lower basin have not only disrupted the fragile ecological system but have also adversely affected the productivity of rural ecosystem and livelihood securities because lower basin is more populated than the upper basin. So the direct impact will be on the rural people who are living there.

So, the present chapter is focused on the drivers of land use and land cover change and its impacts to the surroundings. It also examines the altitudinal changes in the Bhagirathi basin owing to the change in the Land use and land cover in the area.

5.2 BASIN LEVEL APPROACH: UPPER BASIN AND LOWER BASIN

In order to study the drivers and impacts of land use and land cover changes in the basin, the study has divided into two broad categories: Upper River Basin and Lower River Basin.

For the Upper Basin, data and methodology as follows:

The present study uses various datasets from remote sensing data to geo-environmental data, all these datasets are immensely helpful to monitoring the glacier and snow cover area fluctuations in the upper Bhagirathi basin. Details of acquired dataset for the present study are summarized in *Table(5.1)*.Important points are kept in mind during the acquisition of datasets. The data source which has been used for the analysis of variability in snow cover area is MODIS for two time periods Ablation and Accumulation.

Table 5.1 Details of Satellite data

SENSOR	ABLATION & ACCUMULATION PERIOD
MODIS Tera	2000 to 2002, 8 day and daily snow over images
MODIS Aqua	2002 to 2012, , 8 day and daily snow over images

There are several methods for mapping snow cover area which have been used by different researchers but mainly there are three methods i.e. Visual interpretation method, Spectral Rationing Method and Classifier method used for the digital mapping of snow cover on the glacier.

Visual interpretation method is a manual delineation to extract the glacier boundary with debris cover from the satellite images. This method is often needed to complement and correct automatic classifications (Kaab,2005). Spectral rationing method is used to enhance the spectral properties of certain objects while reducing the bias in illumination caused by rugged terrain (Holben and Justice, 1981). And Classifier method uses a set of features or parameters to characterize each object, where these features should be relevant to the task at hand. This classification method is of two type i.e. supervisied classifier method and Unsupervisied classifier method.

The present section is aimed to monitor the snow-covered areas in the upper Bhagirathi basin through 8 day composite MODIS snow cover images. The MODIS/Terra Snow cover 8-Day L3 Global 500m Grid (MOD10A2) used for this study contains data fields for maximum snow cover extent over an 8-day repeated period (Hall et al., 2006) and has a resolution of approximately 500m coving the upper Bhagirathi basin completely. A data set of 473 processed MYD10A2 (Aqua) images from 2002 to 2012 have been taken. Then these available images were projected with the WGS 1984 UTM ZONE 44N projection system. The upper basin area was then extracted from the images to assess the snow cover percentage in the study area over a 12 years period. When the percentage of cloud cover exceeded 20 percent on a specific date, the record was eliminated and the average snow cover on this date was estimated by interpolating linearly between the previous and the next available cloud-free images.

For the Lower Basin, data and methodology as follows:

To find the drivers of LULCC in the basin both bio-physical and socio-economic data has been used. SRTM data has been taken to generate the DEM. DEM has been created to know about the slope and aspect of the region with the help of ARC GIS. Sterams also delineated by the help of DEM data. Climatic variables data such as temperature, rainfall have been taken from the IMD for Tehri and Uttarkashi for different years. Bar graphs and trend lines were used to show the variability in the rainfall and temperature. Socio-economic data have been taken from the Census 1991 and 2001for Uttarakand of two districts Tehri and Uttarkashi. The data about roads construction in the basin have been taken from the Pradhan Mantri Gramin Sadak Yojna (PMGSY) web Portal. Different reports used such as State forest report, State development report, report of AHEC-IITR/2011 and a status report on Gangotri glacier.

5.3 RESULTS AND DISCUSSION

5.3.1 Drivers for Land use and land cover change and their impacts

The drivers are responsible for changes in LULC falls essentially in two categories: biophysical drivers and Scio-economic drivers. A biophysical driver includes characteristics and processes of the natural environment such as elevation, slope, soil types, climatic variables etc. A Socio-economic driver includes demographic, social, economic, political and technological factors (Singh et al, 2010). Both plays a very important role in change in land piece and responsible for the environmental implications, such as regional climate change, biodiversity loss, alteration in hydrological processes, changes in biogeochemical cycles, land degradation and its impact on agriculture etc.

A biophysical drivers are static whereas socio-economic are dynamic in nature. The study area found expansion in snow cover area during ablation period with the time at the higher altitudes which indicates that biophysical drivers were more dominate on higher altitude in the basin. During peak ablation period- between 1990 and 1996 the snow spread was between 20-35% of the watershed area while in 1998 the snow spread was almost 47% of the watershed area. The snow spread during peak ablation period after 1999 has again reduced and is a minimum of 14% in 2004. (Tangri, 2003) and further it has increased to 23.4 % in 2010. As slope and soil type are one of the important drivers, it determines the impact of LULCC. A small increases in slope angle above about 30 degrees translated into large increases in landslide erosion as the stress of gravity exceeded the strength of the bedrock. And off course landslides are major phenomena in this region.

Several studies have examined the social and economic factors that drive Land Use and Land Cover change. These includes population growth or decline, as a region's population grows, the new residents need housing, as well as places to work and shop. In a region with declining population, there will be less new construction of homes and businesses. Secondly, economic growth, a booming regional economy will result in construction of new commercial and industrial buildings to house that activity. As the economy grows, the new jobs created will attract workers, leading to population growth, leading to construction of new homes and places to shop. As incomes rise, household may choose to build new larger homes on larger lots, leaving smaller, older houses vacant. Thirdly demographics, the average number of people living in a household has been decreasing over time. Therefore, more housing units are needed to house the same number of people. The number of retired households is increasing, and these households tend to have few members. Meanwhile, the proportion of non-white households is also increasing. These households tend to have more members on average than white households.

Fourthly, agricultural and forest prices, a change in the price of agricultural or forest products can affect landowners' decisions whether to keep the land in those uses. Policies aimed at supporting agricultural prices provide an incentive to keep land in farming. And regional and local planning and policies, regions can influence the rate at which land use and land cover change through a variety of means.

5.3.2 Snow Cover change and drivers in Upper Basin

Although snow only occurs in certain parts of the world, it has far-reaching implications on regional weather patterns. By studying snow, how it forms, where it falls, and how the snowpack changes over time, scientists can help improve storm forecasting and learn more about how snow and weather interact. Scientists also study global snow cover to understand how changes in snow cover affect climatic pattern, glaciers, and water supplies around the world. Snow is an accumulation of packed ice crystals, and the condition of the snowpack determines a variety of qualities, such as color, temperature, and water equivalent. As weather conditions change, the snowpack can change as well, and this affects the characteristics of the snow[21].

Seasonal snow is an important part of Earth's climate system. Snow cover helps regulate the temperature of the Earth's surface, and once that snow melts, the water helps to fill rivers and reservoirs in many regions of the world, especially. In terms of area, snow cover is the largest single component of the cryosphere, covering an average of about 46 million square kilometers (about 17.8 million square miles) of Earth's surface each year. About 98 percent of the Earth's snow cover is located in the Northern Hemisphere. On such a large scale, snow cover helps regulate the exchange of heat between Earth's surface and the atmosphere, or the Earth's energy balance. On a smaller scale, variations in snow cover can affect regional weather patterns. For instance, in Europe and Asia, the cooling associated with a heavy snowpack and moist spring soils can shift the arrival of the summer monsoon season and influence how long it lasts[22].

Snow's albedo, or how much sunlight it reflects back into the atmosphere, is very high, reflecting 80 to 90 percent of the incoming sunlight. Snow's high reflectivity helps Earth's energy balance, because it reflects solar energy back into space, which helps cool the planet. The thermal properties of snow have important consequences for climate, as well.

[21] Nsidc (National Snow and Ice data centre)
[22] Ibid

Snow acts like an insulating blanket. Beneath just 30 centimeters (1 foot) of snow, the soil and the organisms within it are protected from changes in the air temperature above the snow surface. Snow's cold, moist surface influences how much heat and moisture circulate between the ground and the atmosphere. Snow helps insulate the ground below, holding in heat and preventing moisture from evaporating into the atmosphere. Even on top of other frozen material, such as permafrost and river ice or sea ice, snow cover prevents ice from forming as quickly[23].

5.3.2.1 Analysis of snow cover distribution from 2000-2012 in Bhagirathi Upper basin

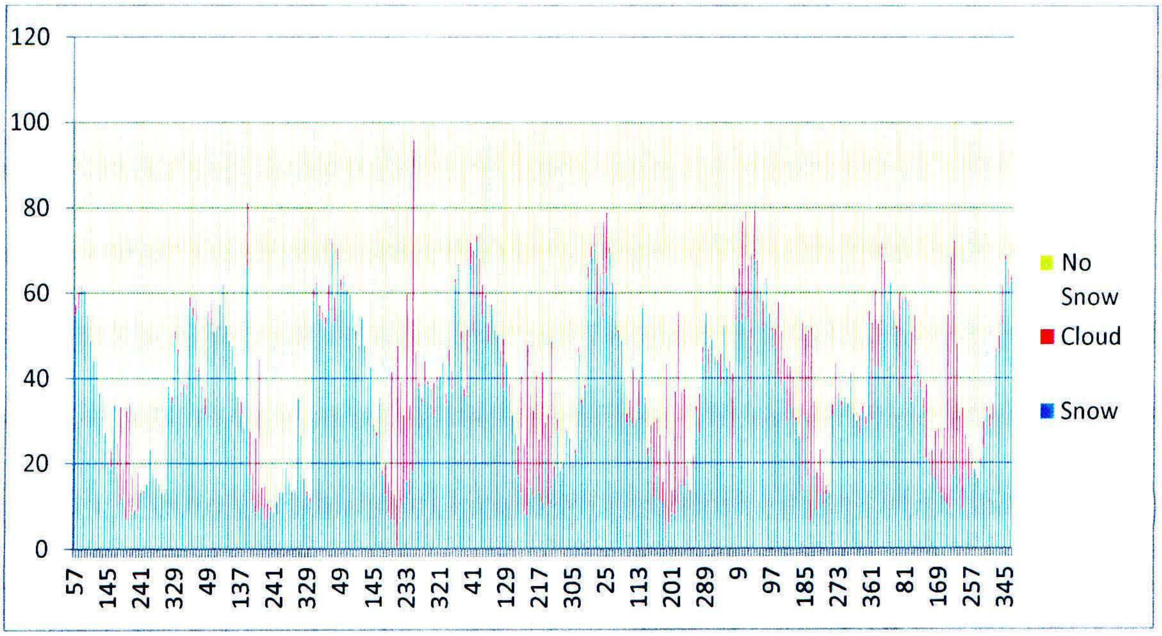
MODIS image analysis for snow cover dynamics over a 12- year period suggest that the snow cover area in the Upper Bhagirathi basin are slightly increased, as shown in Figure 5.1 and 5.2. The increasing trend is not significant but continues to feed the high altitudes, particularly in altitude zone of above 4000, and results in the form of expanding snow cover in the area. This is the area where the mean temperature remains below freezing point throughout the year and the snow cover is expanding as a result of the increasing precipitation trend. Snow cover in the area is at a maximum 70-80 % in the winter seasons (January- February) and at a minimum 10-20% in the summer (June to August). The graph depicts the trend of snow cover change in different seasons during the period of 2000 to 2012 in the Upper Bhagirathi basin. During the period of 2000 to 2001 the snow area extent decimated slightly and then has an increase by 8.2 percent in 2002 which was the highest mean snow cover area in the basin. Whereas, the lowest mean snow cover was in the period of 2000. After 2002 there has been a decrease in the snow cover extent to till 2005. Apparently, it was increase in the period of 2006 by 2.6 percent. Afterwards the mean snow extent decreased marginally (2007-2012). Overall, it is found that there is increment in the snow cover area marginally from 2000 to 2012. Causative factor can be attributed to the peculiar location of the basin which is situated in the zone, surrounded by the area having maximum to minimum rainfall on regional scale. The picture of spatial changes in snow cover area is much clear after season-wise.

---

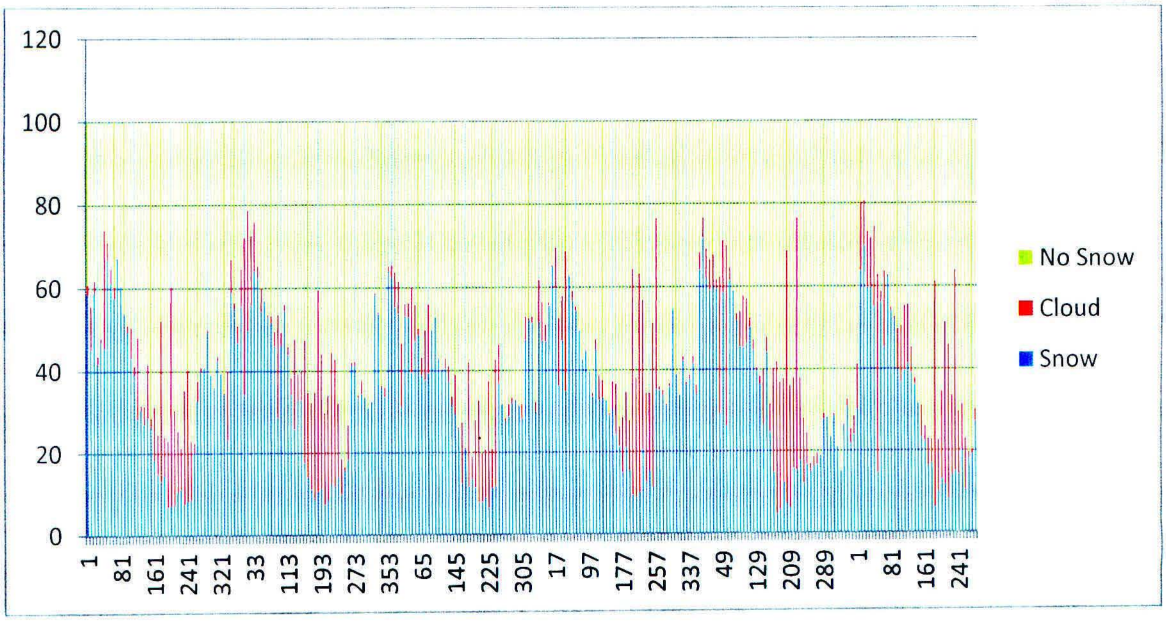
[23] Ibid

Figure. 5.1 a) Snow cover trend from 2000 to 2006 and b) Snow cover trend from 2007 to 2012

a)



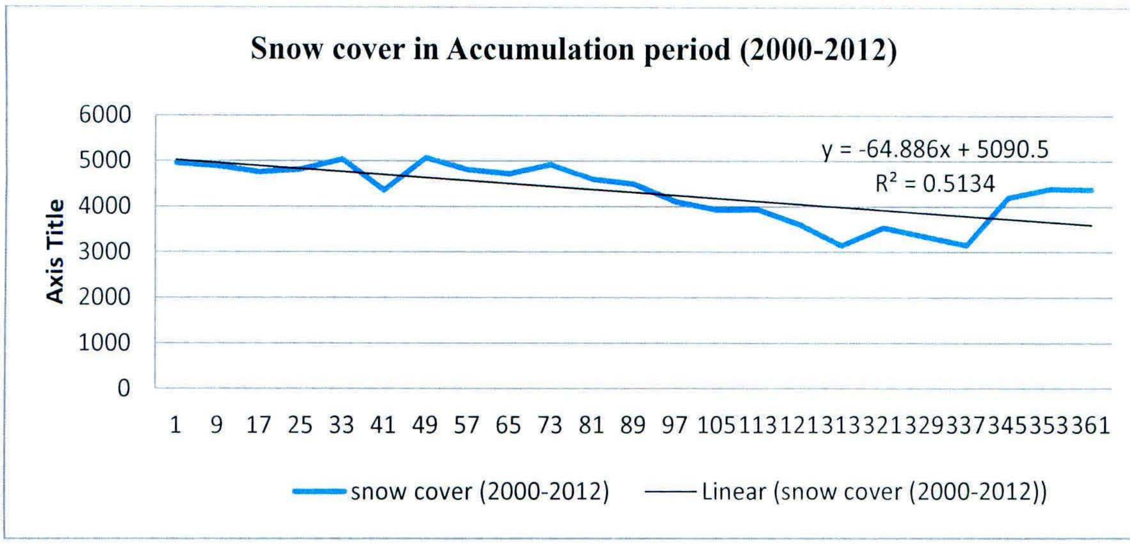
b)



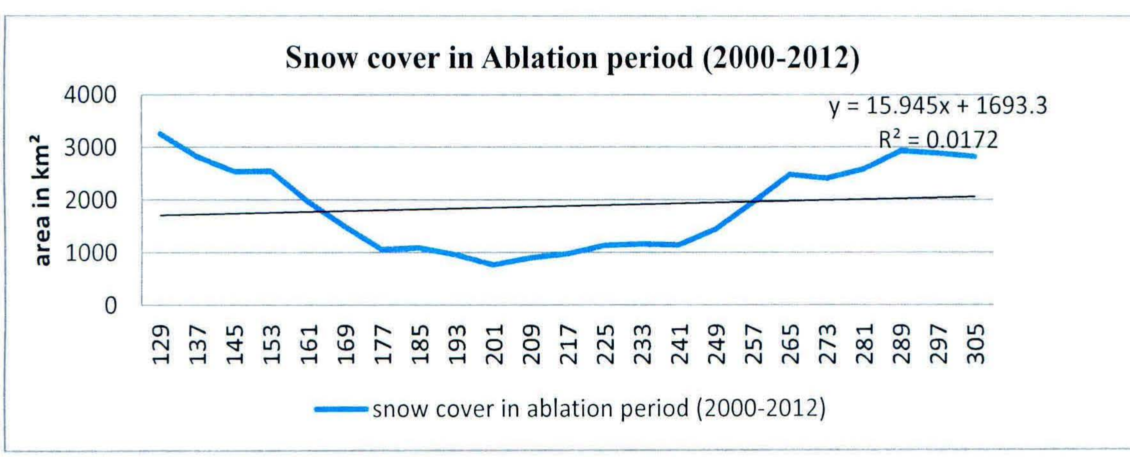
Source: *MODIS Terra and Aqua Satellite Data.*

Figure 5.2 Seasonal Variation in Snow Cover Extent From 2000 to 2012

a) Snow Cover in Accumulation period (2000-2012)



a) Snow Cover in Accumulation period (2000-2012)



Source: *MODIS Satellite Data*

Clearly, there is a significant change within the snow cover during the winter season or from onset of winter time in the basin. During Nov-April month (Accumulation Period) of last twelve years 2000-2012, where significance level designated as r^2 is 0.5134, which describes significant change in snow cover. While examining graphs of snow cover area for last twelve years what we found is that snow accumulation and ablation are continuous process throughout the year. Thawing of large snow area was observed from mid of April to October. During the May to October months (Ablation Period) of last twelve years 2000-2012, the snow ablation is rapid, almost 50 percent of the snow cover melted within this period. The r^2 value for this period is 0.017 which is insignificant. Overall, in the basin it has been observed that the accumulation of snow is more than the ablation.

5.3.3 Land Use Land Cover change in Lower Basin and its drivers

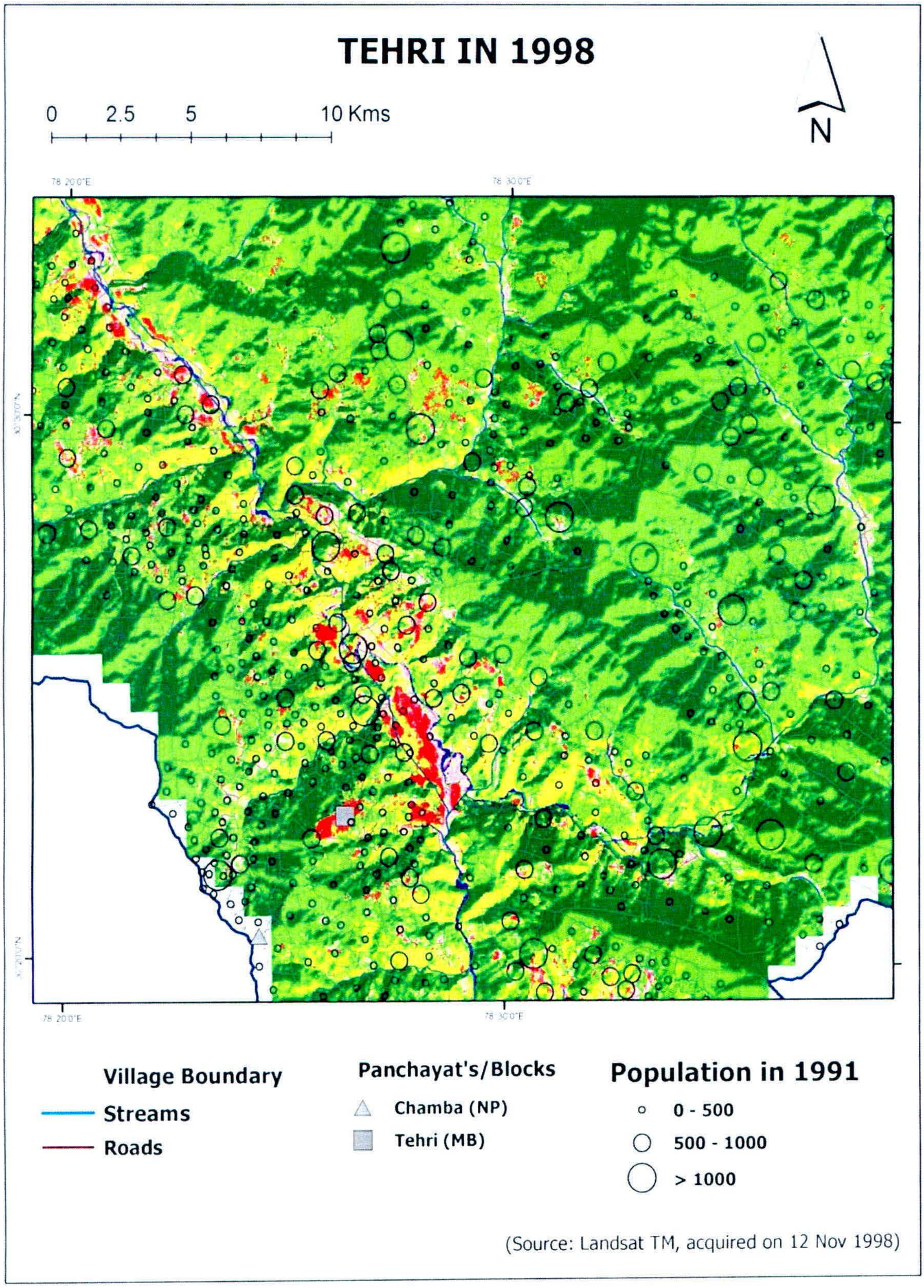
As study shows that LULC drivers in lower basin are dominated by socio economic drivers than physical drivers, the differential characteristics of two broad divisions, which are upper basin and lower basin, is obvious. The LULC socio-economic drivers encompass urban sprawl, road construction, migration, land use policies etc.

5.3.3.1 Built-up growth analysis around towns in the Lower Basin

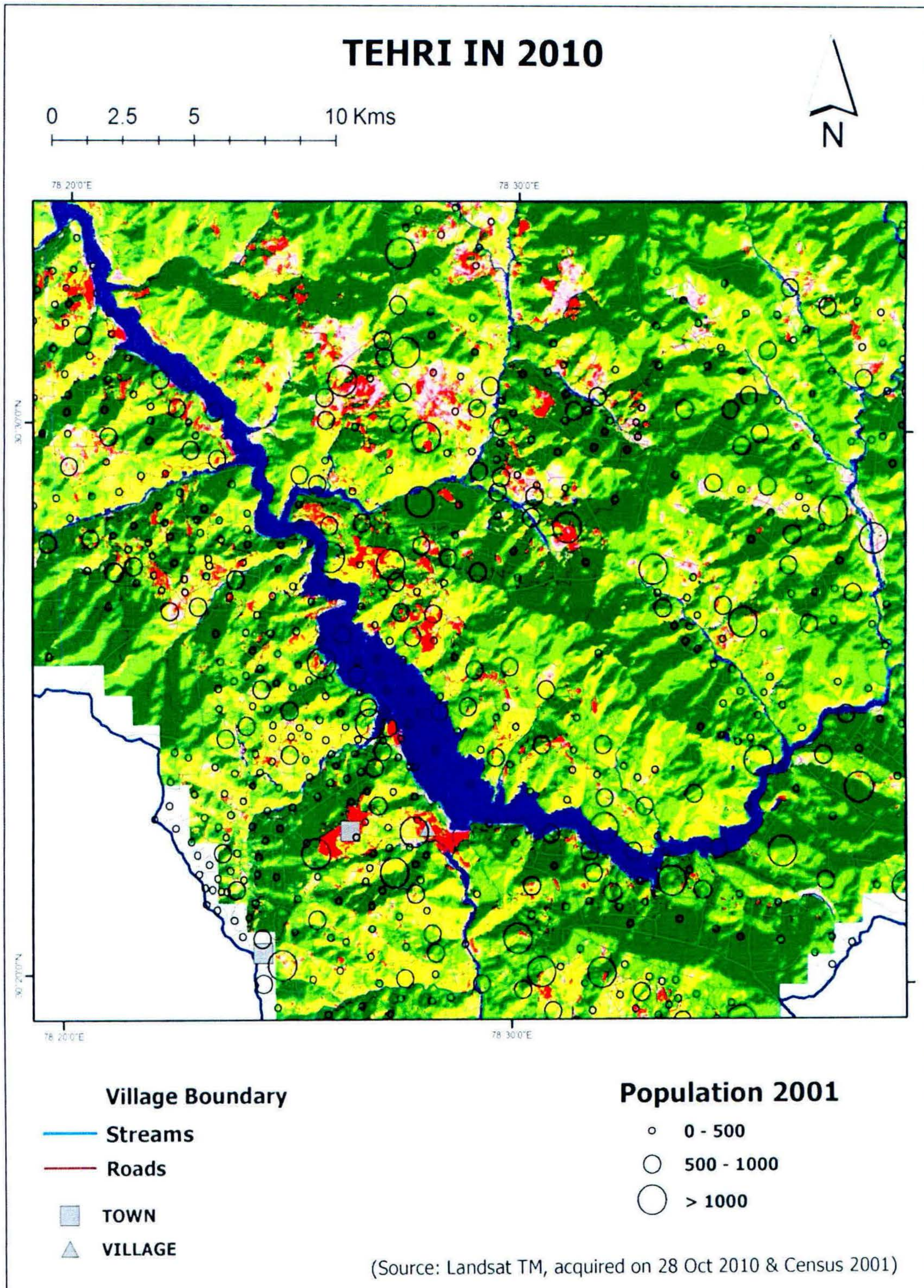
Urbanization is an index of transformation from traditional rural economies to modern industrial one. It is a long term process. Urbanization and Land change are two global processes with far reaching consequences. (Seto, et al., 2012). Urbanization may be a driver for land change or with the increase in population and land demand. In the case of Bhagirathi basin, urbanization plays a very important role in land use and land cover change. As we discussed earlier that from 1979 to 2010 the built-up area is rapidly increasing day by day which showing the change in land cover. The major changes found in the towns and its peripheral areas. This causes the pressure on land. Although urbanization is an indicator of the development but it leads to the several environmental problems such as deforestation, soil erosion, water pollution etc. As this region is a hilly terrain which is very sensitive zone, man-induced changes have larger implication on the land. Increasing population linked with accelerated urbanization has detrimental impact on land resources which are constrained by the carrying capacity of the land. Vulnerability of the region exacerbates as anthropogenic interventions increase changing the natural land cover pattern.

5.3.3.2 Town in Bhagirathi Basin : Tehri and Uttarkashi

Map 5.1 Land use and Land cover pattern in Tehri (1998)



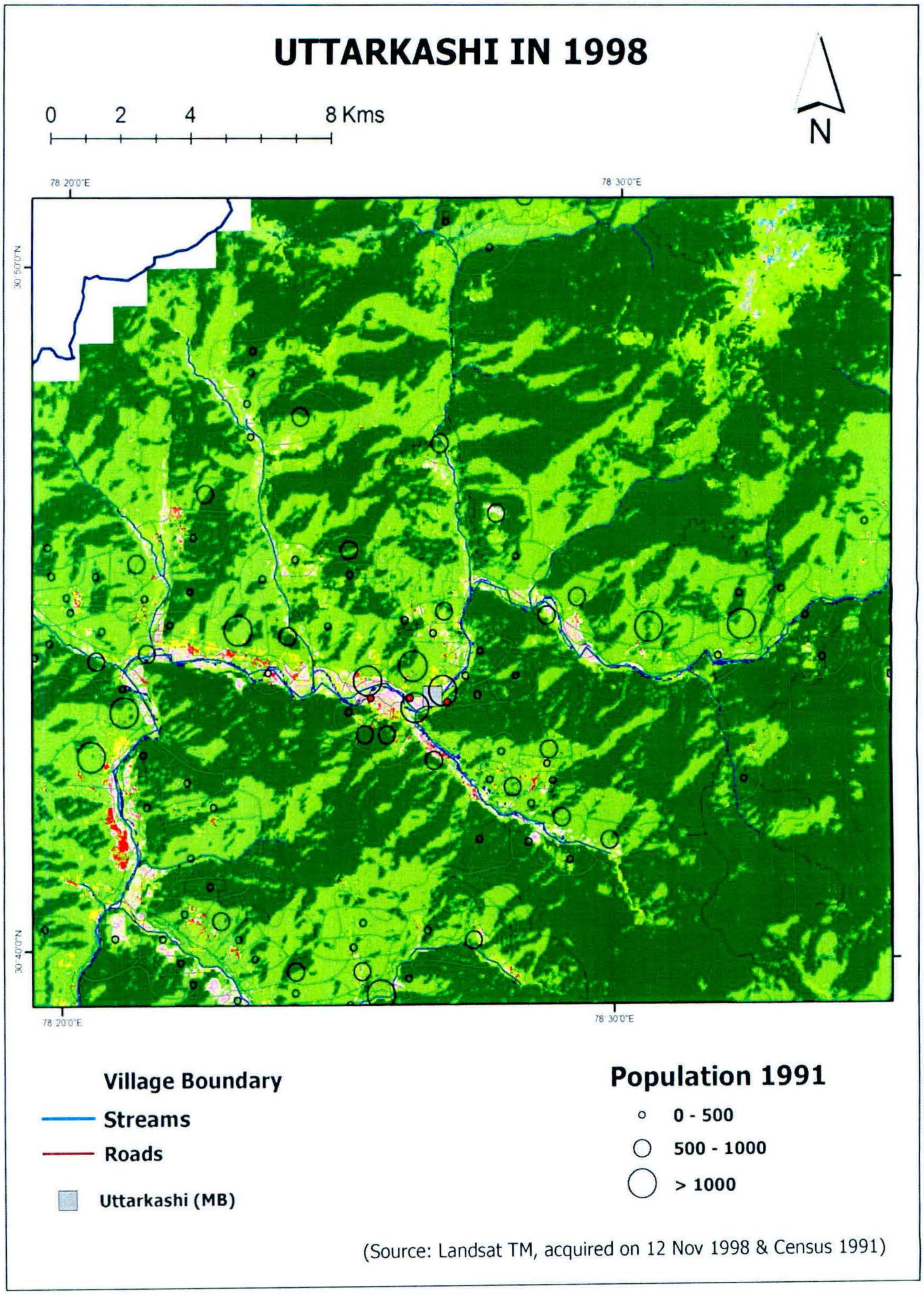
Map 5.2 Land use and Land cover pattern in Tehri (2010)



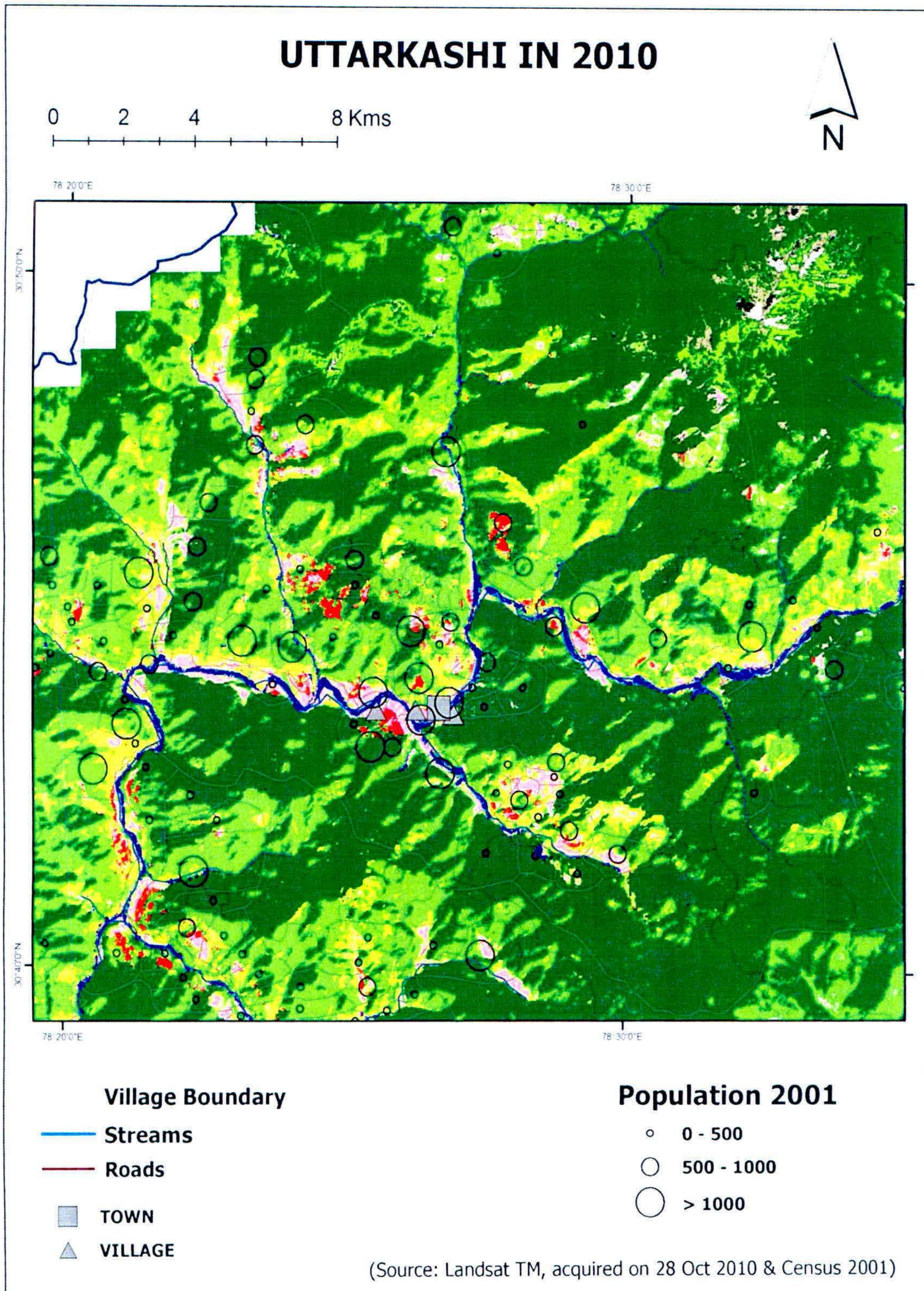
Tehri area has witnessed maximum change in the last decade of the twentieth century. With the commissioning of the Tehri Hydropower project in year 2006, the formation of reservoir on Bhagirathi River was started which has become a large lake with an area of 42 sq. km. by year 2010. Tehri project is a multipurpose project that has been constructed near the old Tehri town. It uses water of Bhagirathi and Bhilangana rivers for irrigation and hydropower generation. In addition, the reservoir space is also used to moderate floods in downstream areas. Besides providing much needed power to the Northern Grid, the command area is availing irrigation benefits from the project and drinking water is being supplied to Delhi. The reservoir of the project also helps in moderating floods in the downstream areas only marginal change has been observed in the New Tehri town in terms of enhancement in the built-up area. Density of vegetation has appeared to be slightly decreased in southern Tehri.

From 1979 to 2010, appreciable changes have been observed in Uttarkashi town, with considerable increase in settlements along the Uttarkashi- Chinyalisaur road and Uttakashi- Gangotri road. Density of built-up area has also increased. The Maneri-Bhali Phase-II project has been completed and there is a remarkable increase in settlements and other activities in that area. There has been a reduction in agricultural areas, while a marginal decrease in vegetated area has also been observed.

Map 5.3 Land use and Land cover pattern in Uttarkashi (1998)

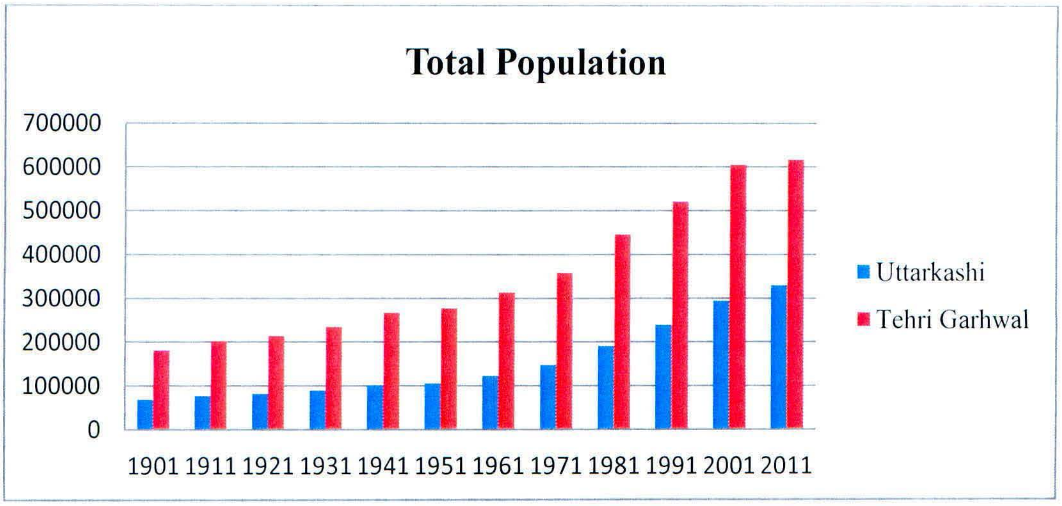


Map 5.4 Land use and Land cover pattern in Uttarkashi (2010)



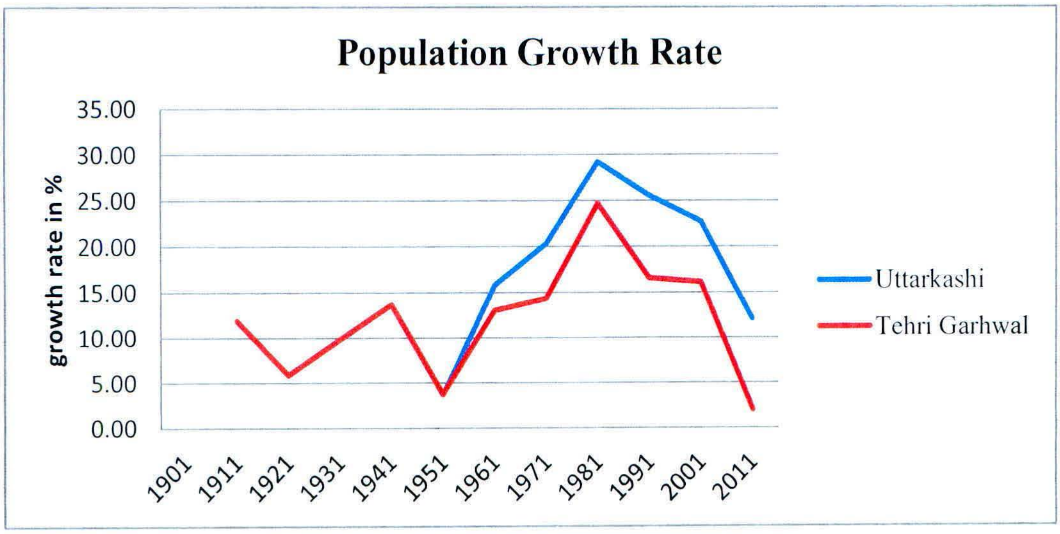
Demographically, the region is highly interesting having variety of trends and patterns. Population density in upper region i.e Uttarkhasi is 41persons per sq.km and in Tehri i.e. in lower region is 169 persons per sq.km in 2011 that showing the concentration of population is more naturally towards the south which is more favorable from the point of view of relief, climate and other resultant and related aspects.

Figure 5.3 Total Population in Tehri and Uttarkashi (1901-2011)



Source: Census of India

Figure 5.4 Population Growth Rate in Tehri and Uttarkashi (1901 to 2011)



Population growth in the region, as is evident from the Fig (5.4), has showing that form 1901 to 1951 both districts had similar population growth rate but aftermath Uttarkashi has shown a more population growth than the Tehri. During 1971 -1981, the growth is the highest in both districts (24 percent). From 2001 to 2011 the growth has declined in Tehri (1.95 percent) whereas it was higher in Uttarkashi (12.07 percent) but it is also declined vis-a-vis earlier year.

5.3.3.3 Road development as driver of land use change in the basin

Roads are called as arteries of a nation since they play a significant role in balancing surface-deficient interface of any production factor and output itself. Road network works as catalyst factor for development of a region. Along the lines of the roads population settlement tends to develop because of the accessibility factor. Roads facilitate inflow of the labor and they actually provide a platform for immigration resulting into population of particular region, hence, having impact on the land resources especially when hilly region is concerned.

Road construction in mountainous areas can result in deterioration of livelihoods of the rural people living in an agricultural subsistence economy. Use of land to provide the road formation width, the construction of side drains, retaining walls and breast walls, the degradation of cultivated land due to side casting and the effects of spoil spillage on downside land areas are all factors directly affecting the livelihoods of the people.

In the period from 2001 to 2012 in Tehri Garhwal district there has been increase of 387 kms. new road network, whereas in the same reference period increase in the Uttrakashi district is 164 kms (PMGSY). Montane nature of the northern Uttrakashi provides formidable obstacle to the development of the road network in the region compared to southern Uttrakashi where comparatively less undulating relief is conducive for the growth of same. In the Tehri Garhwal district only the north eastern area is devoid partially of road network, which can be attributed to the highly undulating terrain. Rest parts of Tehri Garhwal are connected with well integrated road network, which provides the region much needed employment opportunities through tourism etc.

Table 5.2 Road Development in Uttarkashi, Since 2000

Name of Block	Road Name	Total Length in kilometer	Completion year
Bhatwari	MDR,Kishanpur road & Gangotri-Nald- Motor road Gangotri Uttaron motor road	20.13	2010 2012
Chinyalisaur	Khalsi Motor road Barethi motor road	22.34	2011 2012
Dunda	Gangotri to Baun motor road Dhauntri-Srigaon road Risikesh-Gangotri road to Baun, Newgaon-Huldiyana Motor Road	58.57	2008 2009 2012 2012
Nangaon	Naugaon Paunti Rajgarthin to Paunti Motor road Nanai Motor road Hanuman Chatti Kharsali M/R	62.51	2010 2012 2012
Total Length of Roads in Uttarkashi		**163.5 Kilometers**	

Source: PMGSY (Pradhan Mantri Gramin Sadak Yojna)

Table 5.3 Road Development in Tehri, Since 2000

Name of Block	Road Name	Total Length in Kilometer	Completion year
Devprayag	Paurikhal-Toli (Chapoli)MotorRoad,Gaumukh - Simlashu (Dobe) Motor Road Hindolakhal - Unana Motor Road, Saurpani - Chamarada Devi Motor Road Stage-II Mulyaguan - Palethi Motor Road	9.08 13.87 7.78 **30.73**	2010 2011 2012
Narendranagar	Gular-Nai - Mindath Motor Road,Nai Silkan - Mathiyali Km 0-19.32 Motor Road Nai Silkhani - Mathiyali Motor Road-Stage II,Gular - Nai Mindath Motor Road Stage-II Gular-Nai - Mindath Motor Road,Nai Silkan - Mathiyali Km 19.32 - 30.58 Motor Road	55.04 37.47 36.28 **128.79**	2010 2011 2012

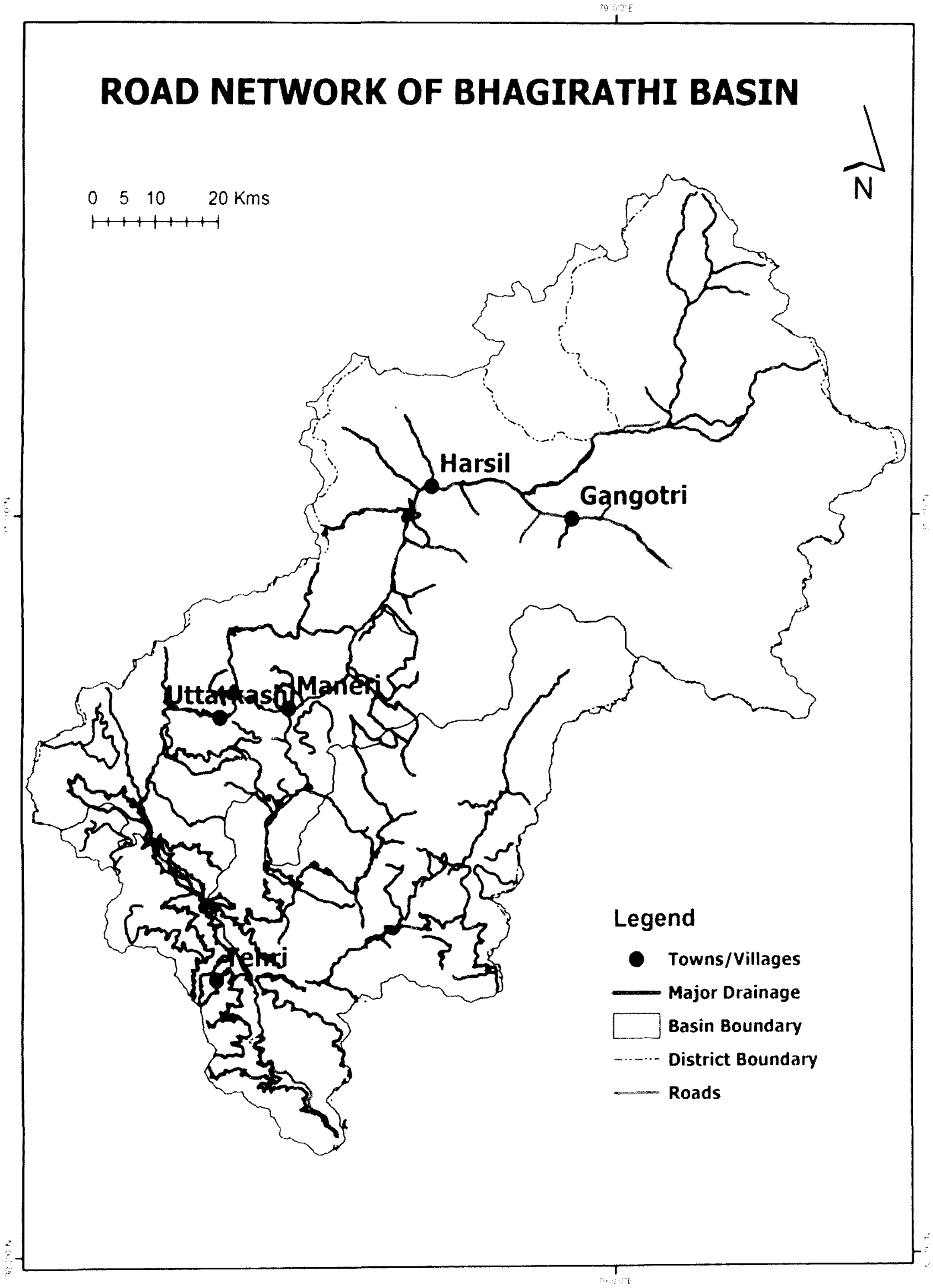
Pratapnagar	Jonkani Bhelunta Motor Road Lambgaon Kandiyal Gaon M/R Sirkholi to Bharpur Motor Road Gairiraj (Gari Rajputo Ki) - Kordi Motor Road Sirkholi - Godari-Kyari Motor Road Lambgaon - Kandyal Goan Motor Road-Stage II Chamba Dharasu Motor Road - Kyulagi Motor Road	6.23 8.03 6.61 3.65 11 4.73 5.75 **40.25**	2012
Chamba	Nakot to Chamni, Nagni Jardhar Gaon Road Kuriyal Gaon Chamba Marora to Banali Motor Road, Chopriyal Sour M/R, New Tehri - Budogi Motor Road Stage-II New Tehri - Budogi Motor Road	24 26.85 4.03 **54.88**	2004 2011 2009
Bhailgana	Syalkund-Mangra - Koti Motor Road Mulgarh - Tharti Motor Road, Vinakkhal - Bheti Motor Road Pilkhee (Gaujiyana) - Vanchuree Moolgarh - Tharti Motor Road-Stage II Vinay khal - Bheti Motor Road-Stage II Sarkanda - Gauna Motor Road Staage-II Syalkund Mongro Koti - May Mangro Motor Road Stag-II	4.03 11.55 49.28 **64.86**	2007 2010 2012
Kirti Nagar	Bicchu Link Rd - Bicchu Motor Road,Kilkileshwar - Naithana Motor Road Khola - Dharpanyakoti Motor Road,Nainisain - Pathwara Motor Road, Khatwar Bend - Ringoli Malli Motor Road	3.5 36.52 **40.02**	2010 2012

Jakhnidhar	Pratap nagar-Tehri Road (Km-22) - Nelda Motor Road,Madan Negi - Khola Motor Road Sain Mandar Road, Jaknidhar Nawakot Motor Road Tipri to Chah Gadoliya Doong (Sainmandhar M/R Km 11 - Doong Khabogi Motor Road Madan Negi - Khola Motor Road Pratapnagar km 27 - Nelda Motor Road Stage-II Madan Negi - Khola Motor Road Stage-II Pratapnagar-Tehri Road (Km-20) - Kaflog Motor Road	10 50.49 5 **65.79**	2010 2012 2013
Total length of roads in Tehri		**425.32 Kms**	

Source: Source: PMGSY (Pradhan Mantri Gramin Sadak Yojna)

But besides having positive externalities, road development phenomenon also have some embedded negative externalities as far as hilly terrain like Garhwal Himalayas are concerned. Road construction basically facilitates in the accessibility of the areas which were not accessible earlier thus, making the land resources more available for purpose of residential, tourism, industrial and commercial uses etc. These roads are always susceptible to the landslides and other natural hazards. Construction of roads aligning with rivers and their flood plain wreaks havoc during natural calamities like floods, since settlement encircling the roads is inflicted. Road exposes the region to outside world, which may not be sensitive to the tender nature of the region where these road lies.

Map 5.5 Road Network in Bhagirathi Basin.



Source: *Google Earth Images and PMGSY*

5.3.3.4 Migration as driver and impact of land use change

Migration seems to be a significant demographic accelerator in the rural population of the Garhwal Himalayas. Every aspects of the population have trace of it. The phenomenon of the migration is associated with the centrifugal and centripetal forces of the region itself and outside of the region.

According to the table given, in the both districts in and out migration has increased from the decade of 1971 to 2001. However both the districts shows different trajectory of migration pattern. In Uttarkashi , historically in migration has been on the cards owing to colonization and repatriation in economically prospective area of Dun, Tarai and Bhabar, partition during 1950s, besides natural growth. In the reference period, construction activities of dam projects has resulted into increased in migration in the region, besides pilgrimage.

Table 5.4 Migration in Uttarkashi and Tehri

Year	Utarkhashi (migration from on district to other in Uttrakhand itself)		Tehri Garhwal(migration from on district to other in Urttrakhand itself)	
	In migration	Out-migration	In migration	Out-migration
1971	12900	4200	11700	28300
2001	19931	9626	22755	71142

Source: *Census of India, 1971 and 2001*

In the district of Tehri Garhwal, increased out migration more than in migration steals the limelight. Dislocation and relocation due to Tehri dam project, paucity of resources, lack of local employment opportunities, are the main factors which can be attributed to the magnificent out migration. Out migration in the region has resulted into higher sex ratio since out migration is age and sex selective (young age group and male population). Overall Sex ratio in 1981 was 1088 and in 1971 in age group of 20-24 was 2390, which is outstandingly high. Sex ratio in 2001 was 1049 which still a high number considering the national average. So age and sex selective migration has have a paramount impact on the demographic composition of the migration fields. Out migration from interior parts of the region has given birth to what is known as "money order economy".

Increased migration have potential to put burden on the land resources, which can ultimately lead to increase in construction activities in river flood areas, putting agricultural and open forest land into residential use, imbalancing ecosystem of the region.

5.3.3.5 Impact of Land use change on Agriculture

Agriculture has been one of the greatest forces of land transformation in the montane region. Much of this agriculture land has been created at the expense of natural forests, grasslands and wetlands. Mountains are under pressure from subsistence farming activity. Tendency of shifting from subsistence forming to commercial and cash cropping system has been observed with implication on the overall Land Use and Land Cover of the study region. Cultivation of barley and ragi in the region has paved the way to cultivation of rice and wheat which demands for more nutrients and agricultural inputs putting pressure on constraint land fertility. Cultivation of cash generating crops including fruits and off season vegetables are also a classic example of shifting pattern of agriculture in the region.

5.3.3.6 Land use policies as driver of land use change

Land use policies can be counted among the potential agent of land use change in the concerned region. A Land use policy decides the nature of present and future land use pattern for a better environmental system to live. These policies have tremendous impact on the present pattern of land use thus deciding future of overall region.

Table 5.5 Typical Land-related Policies, Rationale and Impacts in the montane region:

Policies/Laws	Rationale	Impacts
Country-wide Land Survey (19th century)	Fix territorial identities, Demarcate boundaries, Improve revenues Plan road, rail and communication systems.	Political and economic management improved . Infrastructural development took place Boundary disputes reduced.
Land laws and land settlements (19th an early 20th century)	Provide some kind of tenurial security to landholders. Facilitate imposition and recovery of government taxation.	Tenure systems continued to be hierarchical and multiple with actual tillers often becoming tenants at will; intermediaries continued to exploit the tillers.
Forest Act 1878	Improve management of forests, Delineate forest lands Conservation.	Forest settlements initiated, User claims accommodated to some extent , Unmeasured lands remained unregulated and were often overdrawn to almost exhaustion.
Policy enunciated in 1893 (in Uttar Pradesh hills) declaring unmeasured lands as 'district protected forests' and Forest Policy 1895	Prevent over-use of unmeasured land Regulate access.	Resentment against authorities Efforts were made to increase the area of reserved forests, Commercial use of forests became a policy priority affecting resource access of people, People burned forests.
Policy accepting recommendations of Kumaon Grievance Committee (1921) in the Uttar Pradesh hills	Contain disaffection and Dissatisfaction, Address needs of local communities for forest resources to which they had historically had access.	Level of people's dissatisfaction came down but shift towards industrial and commercial afforestation and use of contractor system created problems , Forest degradation continued.
Land reform legislation enacted soon after Independence	Secure land tenures and eliminate intermediaries, Empower tillers to have greater control over their lives and resources.	Positively helped small landholders, Land productivity improved gradually for long-term investment now became possible, Fragmentation of land continued and created problems of land management.
Land ceiling legislation	Reduce social disparities , Distribute surplus land amongst the landless or small landholders.	Small landholders and many landless persons benefitted. However, many people

		managed to retain large holdings under false names and groupings.
National Forest Policies (1952 and 1988) and recommendations of National Agricultural Commission 1976	Emphasis increase in supply of fuel wood and grazing needs and mobilize people for tree growing (1952 policy), Shift emphasis to production forestry (NAC 1976), Stress protection and environmental functions of forest and designate community needs for fuel/fodder as first priority (1988 policy).	Changing policies created problems in management and quality of forests , Plantation programmes became industry-oriented rather than people-oriented or environment-friendly.
Forest Conservation Act 1980	Prevent loss of forest land to non-forest uses	Diversion of forest lands to non-forest uses came down sharply, Many development projects for which forest land was the only available land were delayed Obtaining clearances from central government took too long resulting in public protests; so much so, that, in 1988,Trees movement was launched in the Uttar Pradesh hills.
In 1981, orders issued banning green felling of trees above 1,000 m in the Uttar Pradesh hills	Response to the intensity of protests especially by the Chipko movement	Helped in improving the green cover at higher altitudes but scientific silviculture also stopped, which might affect long-term health of high hill Forests.
Joint Forest Management Policy 1990	Emphasis community participation in forest management, Extend principle of participation to government forests with provision for benefit-sharing by communities.	The joint forest management initiative has started giving results but institution-building remains a problem.
Biodiversity, wildlife laws and policies (setting up of biospheres, parks and sanctuaries)	Provide a long-term scientific Measures, Provide aesthetic, environmental and economic benefits, Maintain ecological balance.	People's access drastically reduced, For affected communities, it amounted to a challenge to their survival Friction between park/sanctuary/reserve managements and affected communities has developed.

Source: ICIMOD,2000, Land policies, Land Degradation in the Hindu Kush-Himalayas, India Study Report.

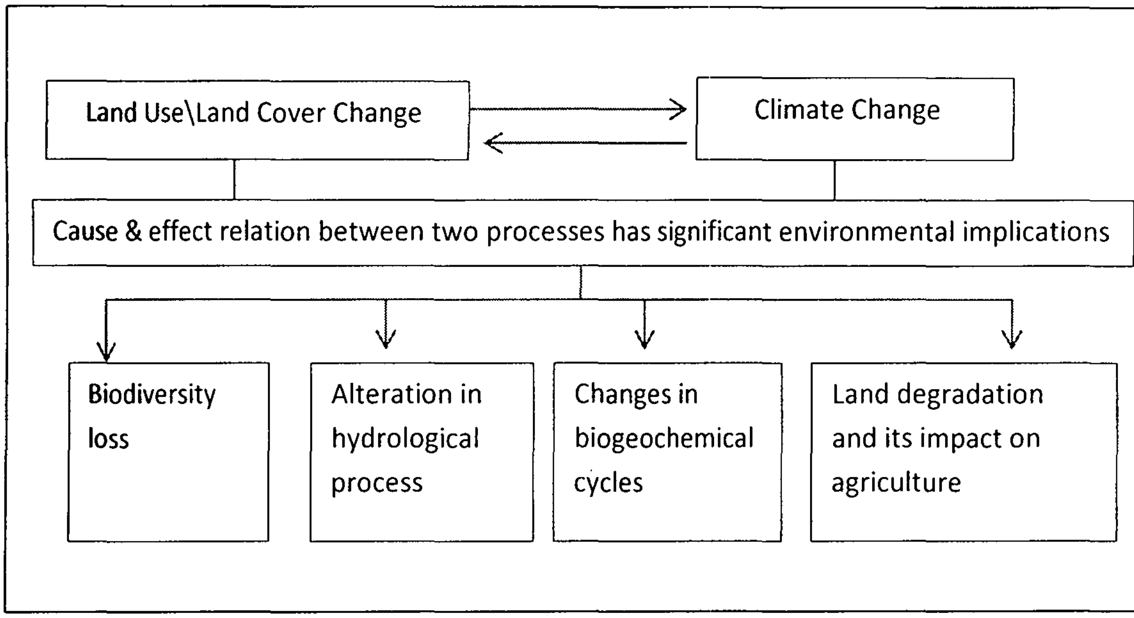
One of the biggest change in the land use and land cover scenario in the study region is Chipko movement ogf 1970's which had triggered a response from the government to formulate the policies to prevent illegal and indiscriminate lumbering and falling of trees in the garhwal region. Forest act of 1982 has provide a legal framework for conservation and protection of pristine forests and protected areas. Establishment of Van Panchayat's in the region has been a conducive factor in afforestation and reforestation in the region, ultimately affecting the land use and the land cover scenario.Establishment of soil conservation department has paved the way to legal sanction for soil conservation including measures of preventing soil erosion, gully erosion, splash erosion ans sheet erosion through fluvial processes and degradation of land on the barren tracts through wind erosion.

5.3.4 Impact of Land Use and Land Cover Change on Climate Change

LULC change is central to climate change as both the process are linked with each other in a complex way at multiple, spatial and temporal scales. The changes in LULC alter the energy fluxes thereby affecting the climate, while climatic variability and change in turn affect the LULC patterns through the feedback mechanism.

Climate is influenced by precipitation, sunshine, wind velocities, temperature and humidity. Changes in the climate system occur slowly and are responsible for the biodiversity on the planet. However, the last 200 years have witnessed an unnatural acceleration in this phenomenon such that the flora and fauna have not been able to adapt to. Human activities are largely responsible for this and human induced climate change has been widely recognized as one of the major problems threatening the planet today.

Figure 5.5 Flow chart: Cause and effect relation between two processes LULCC and Climate Change



Source: *Singh et al.(2010).*

5.3.4.1 Likely impacts of Land use and Land cover change:

Land surface changes can affect precipitation and temperatures. Vegetation patterns and soil composition can influence cloud formation and precipitation through their impact on evaporation and convection (the rise of air)(de Sherbinin 2002). The effect of land cover on climate depends on the type of land cover that is present in a specific region. For example, barren lands tend to heat more rapidly and can transmit this heat to the lower atmosphere.

Land surface changes can affect temperatures not only in forests or agricultural land but also in urban areas. For example, average temperatures in downtown areas of a city can increase due to the high density of construction materials such as pavements and roofs. Higher temperatures in urban areas compared to lower temperatures in surrounding rural areas, has been called by scientists the urban heat island effect.

Air Quality: The pattern of land use in a region can affect its air quality. If residential areas are located far from shopping and work centers, automobile use and emissions will be higher. If forests or other natural areas that purify air are developed, local air quality can worsen. Changes in vegetative cover can also lead to local changes in climate.

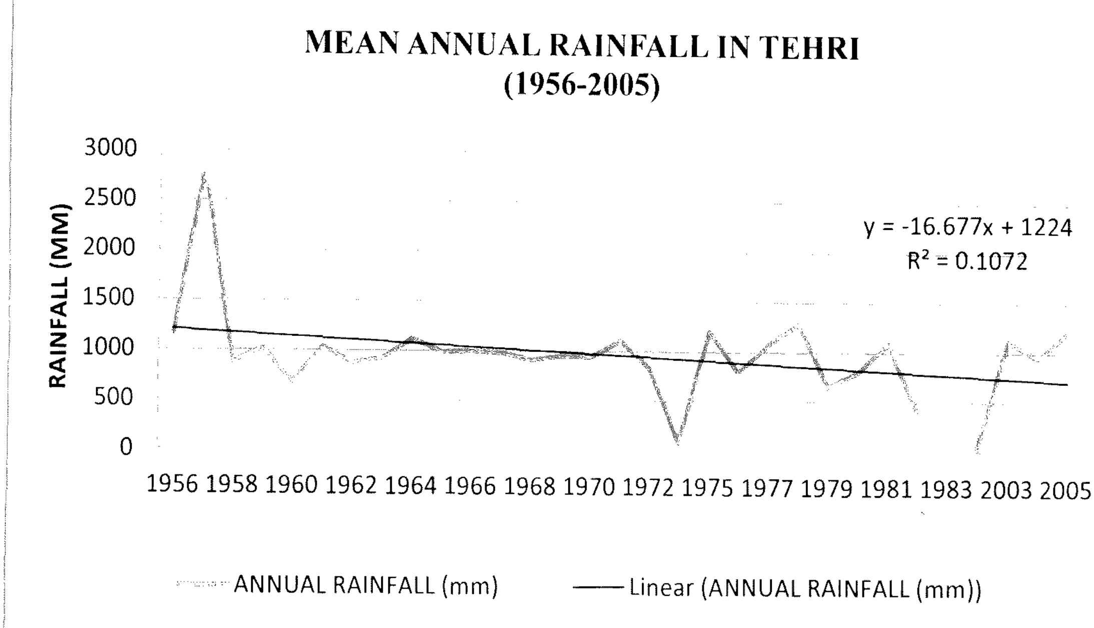
Carbon Cycles: More-natural landscapes can capture and store carbon in the soil, decreasing the amount of carbon dioxide in the atmosphere. If vegetation is cut and/or the soil is disturbed, stored soil carbon can be released back into the atmosphere.

5.3.4.2 Observed impacts of Land use and land cover change on regional climate change

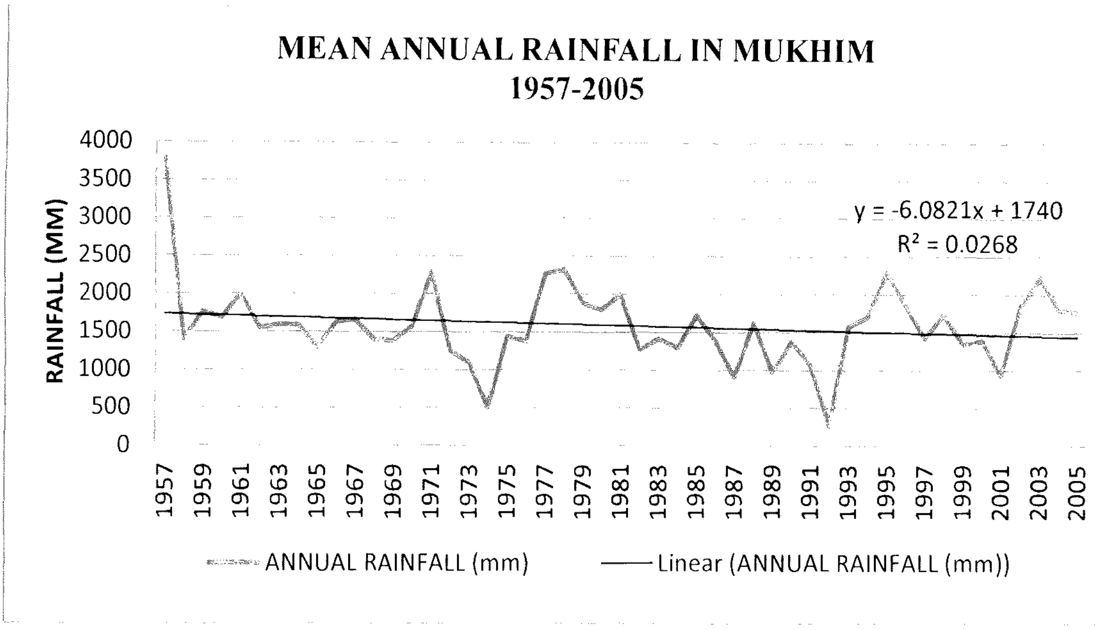
As the study area lies in a relatively isolated location there is not much data which could be used to gauge the impact of land use cover change. This problem severely restricts the study of impacts and is a major handicap in terms of assessment of observed impacts. Nevertheless, data on rainfall pertaining to the period of study only for 1957 to 2005 at Mukhim and Tehri station and for temperature trend analysis available only for 2009 to 2010 at Uttarkashi. There is also annual maximum and minimum temperature data available for the year 1979 to 2004 at tehri station which is not sufficient to measure the impact analysis but we can assess the trend of temperature in the study area.

The Bhagirathi river basin experiences strong climatic seasonal variations, which is also reflected monthly variation in stream flows. The maximum rainfall and rate of snow melt are at maximum during june to September. The annual rainfall trend from 1957 to 2005 at tehri and Mukhim is showing decrease in the rainfall trend in lower basin.

Figure 5.6 Mean Annual Rainfall in Tehri and Mukhim



a) Mean Annual Rainfall in Tehri (1956-2005)

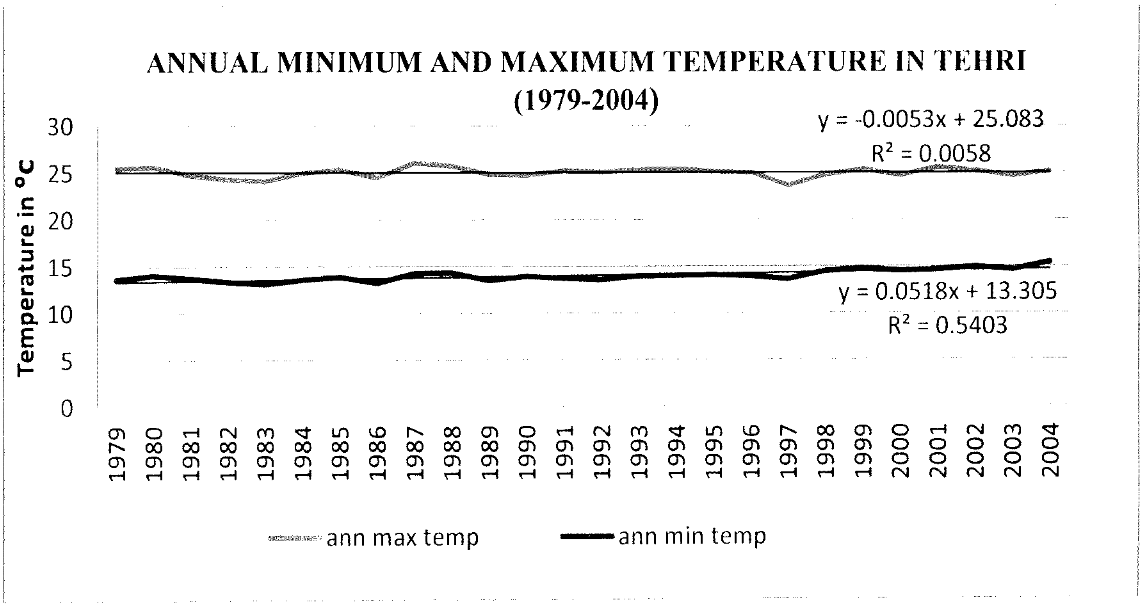


b) Mean Annual Rainfall in Mukhim (1957-2005) ***Source:*** *IMD*

Recent investigations have shown that climate forcing from land use and land cover change also significantly impacts temperature trends. The LULC change can significantly influence climatological variables such as maximum, minimum and diurnal temperature range(Gallo et al., 1996; Hale et al.,2006, 2008). The impact of LULC change on climate, it has been reported that land use changes due to agriculture lead to decreased in surface temperature (Mahmood, 2006; Roy, 2007) and minimum temperature is more sensitive than maximum temperature to change in climate forcing and land use change (Mahmood., et al., 2010).

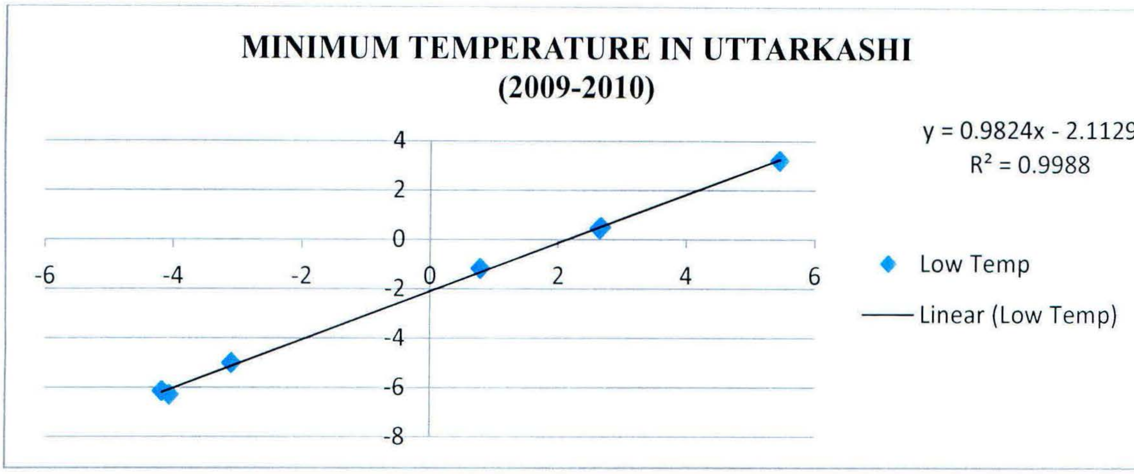
The present study area is more sensitive to change in climatic variables. In the analysis done on the temperature trend in Bhagirathi basin shows that there is an impact of land use land cover change on the maximum and minimum surface temperature. In Tehri the trend analysis from 1979 to 2004 shown that there is a slightly declining trend at minimum temperature whose r^2 value is 0.5 which is quite significant. At Uttarkashi the trend analysis for 2009 to 2010 only for winter season shown that minimum temperature is more likely sensitive than maximum temperature to change in climatic forcing. The r^2 value here found 0.9 which is highly significant. The change in land use lead to the change in the surface minimum and maximum temperature.

Figure 5.7 Annual minimum and maximum temperature in Tehri (1979-2004)



Source: *Indian Meteorological Department*

Figure 5.8 Minimum Temperature in Uttarkashi (2009-2010)



Source: *IMD*

Overall, in relation to land and use and land cover change in the Bhagirathi river basin, it is experienced that there have been increase in the forest cover area from 1979-2012 and also from literatures it is found that there has been upward shift of alpine tree line in the Bhagirathi basin (Singh et al., 2012). It indicates that LULC and climatic variables are responsible for this change due to cooling effect. The seasonal variability in snow cover area in the Bhagirathi basin demonstrate that due to the change in the pattern of ablation and accumulation, the equilibrium line migrate from year to year. The accumulation is more than ablation in our study region which shows the significance of the cooling effect. The cooling effect of the temperature and rainfall leads to the increase in the glaciers and snow cover area and decrease in the barren land and in our study same results have found. Even agriculture has also increased within this period which means conversion to agriculture land shows cooling effect.

5.3.4.2.1 Extreme rainfall event in Uttrakhand (Flood occurred on 16-17th , June 2013)

One of the impacts of land use land cover changes on climate change includes triggering of natural disaster which inflicts irreversible damage to ecology of the region, besides property and loss of life simultaneously. A wide range of slope failure, river erosion, wind erosion, avalanches , landslides and flash floods related problems which have been accentuated by the anthropogenic activities are designated is natural hazards. The recent flood leading to natural hazard is classic example. On morning of June, 17, 2013 an artificial lake above Kedarnath gave way due to a cloud burst and flood water and five to ten feet of debris fell on the temple town, Gaurikund, Rambara. Pilgrims living in some 60 Dharmshalas in Kedarnath were also affected.

In climate literature, rainfall more than 150 mm in a day is termed a very heavy rain event. Dehradun on 17th June, 2013 morning registered a record rainfall of 340mm. This amount of rain in June is seen almost after five decades. A cloudburst reported on 17th June, 2013 in the Kedarnath region in Uttarakhand state and subsequent increased river discharge in river Alaknanda and tributaries has led to catastrophic flood in the region. Heavy rainfall has wreaked havoc on the region with the fragile nature on the Himalayan range and poor soil stableness in its sharp slopes. Flooding in the hills has caused unprecedented destruction in Uttarakhand. The tragedy has hit during the peak of the Char Dham Yatra season. Over a million come for this pilgrimage stretching over six month ending in September. Till June, 21 there were 31 completely destroyed buildings with one partially destroyed. Total being approx. 70,000 people were stranded, out of which 9831 stranded in Uttrakashi[24].

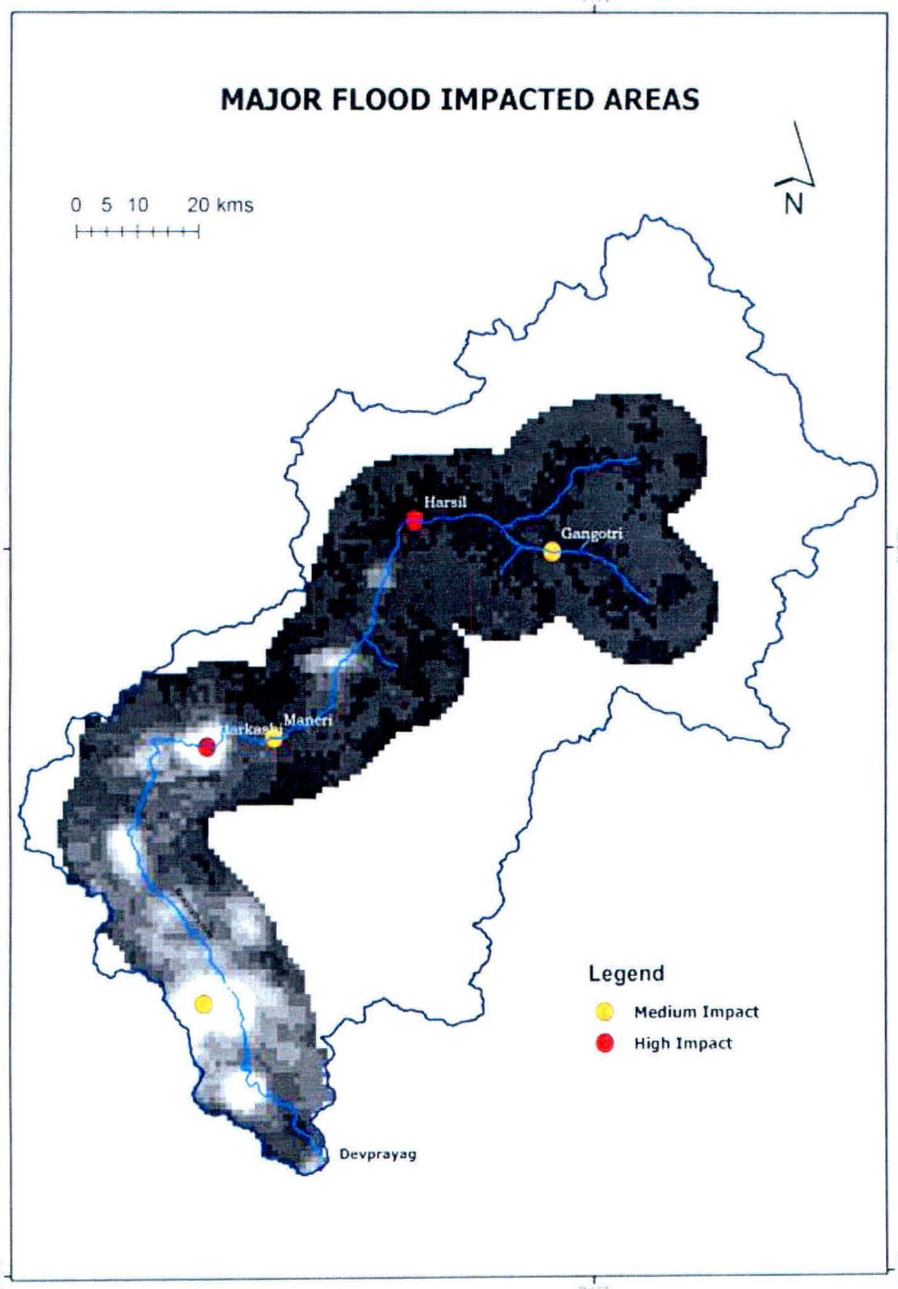
5.3.4.2.1.1 Affected areas in Bhagirathi Basin and impacts

In Bhagirathi basin most of the damage and loss happened in Uttarkashi and Harsil. They are the high impact areas. Around 2,397 houses and 194 bridges were damaged in the floods. The Gangotri Highway in the Uttarkashi district is reported to be blocked at eight

[24] Chandramohan,C.K,.(21 june, 2103),When death gushed in., *The Hindu*. pp 13.

points. Government of Uttarakhand said that the state suffered a loss of Rs.700-800 crore in the floods[25].

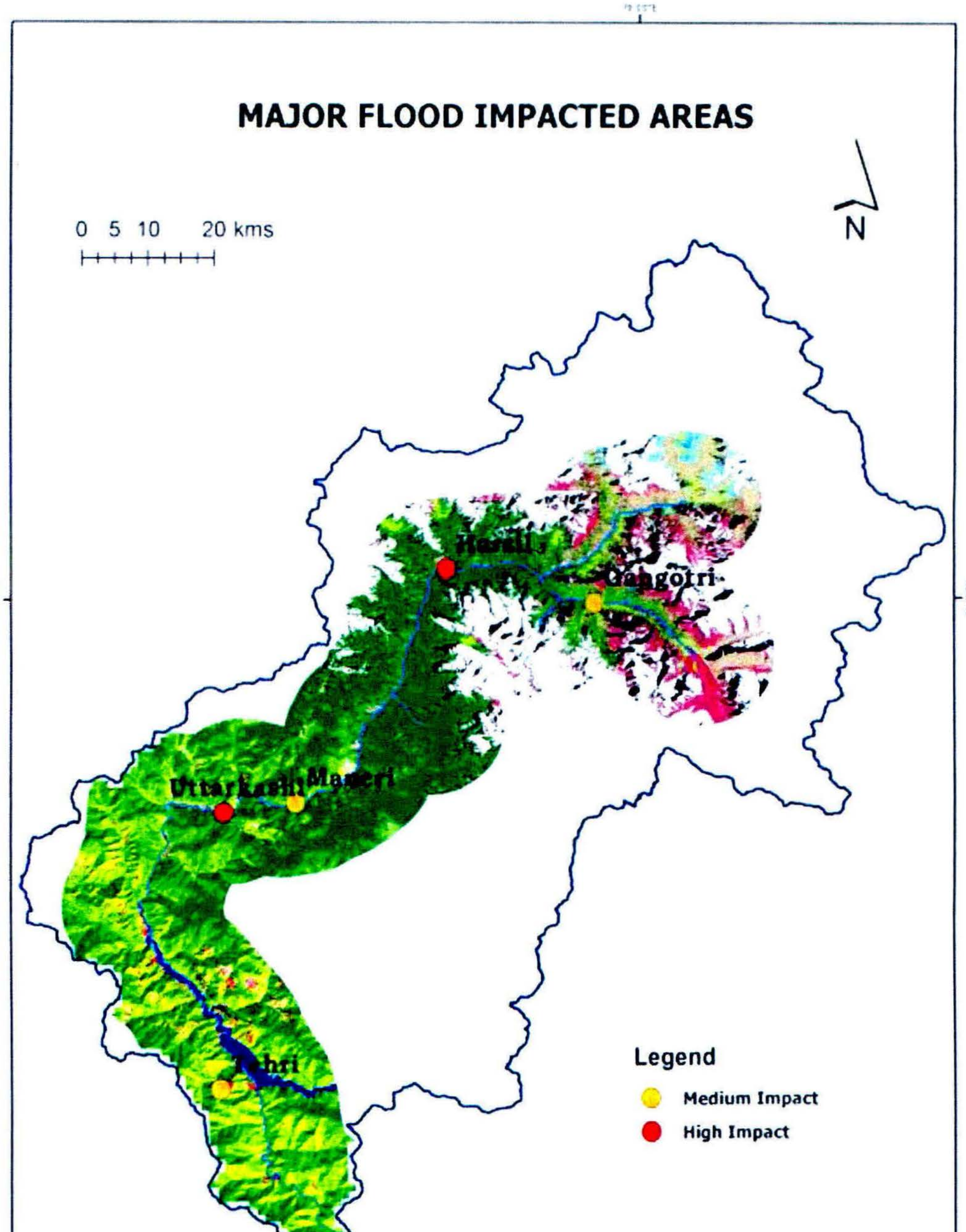
Map 5.6 Major Flood Impacted Areas in Bhagirathi Basin



*(**Source:** OLS DMSP, NASA)*

Map 5.7 Major Flood Impacted Areas along the River bed

[25] Mapinnews (July 2, 2013), Flood effected areas in uttarakhand.



Source: *2013, Uttarakhand Flooding , Published by Google Crisis Response*

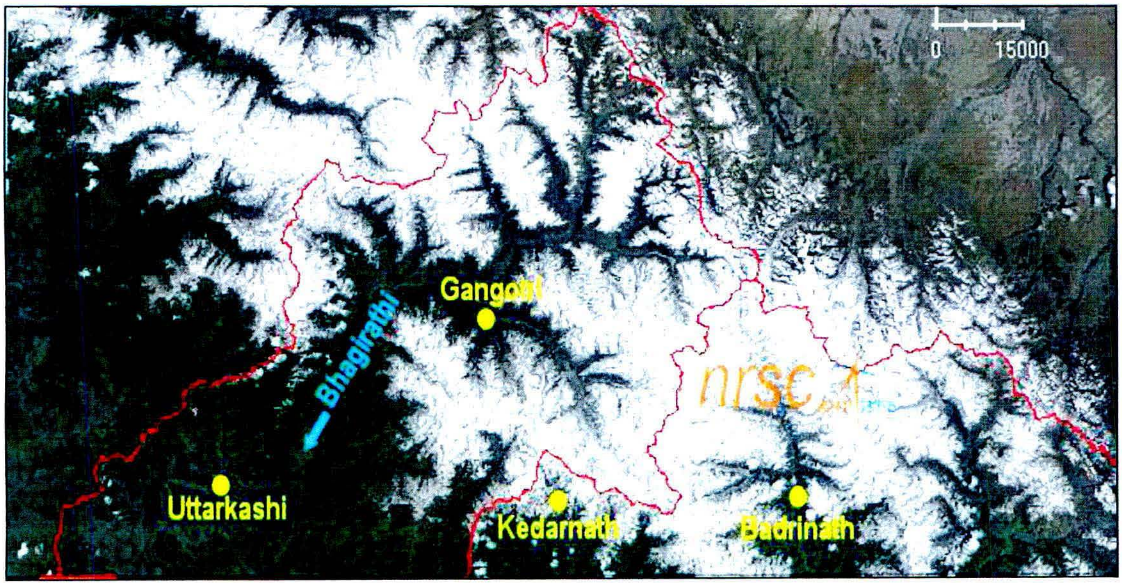
http://google.org/crisismap/2013-uttrakhand-floods?gl=in

5.3.4.2.1.2 Impacts

The satellite image from Resourcesat-2/AWiFS on 28th May/1st June, 2013 shows less snow cover (seen in white color along the mountain ridges) in the Himalayan river basins. The satellite image from Resourcesat-2/AWiFS on 28th May, 2013 shows melting snow cover in Bhagirathi and Alaknanda river basins[26].

The satellite image from Resourcesat-2/AWiFS on 21st June, 2013 shows increase in snow cover in Bhagirathi & Alaknanda River. The satellite image from Resourcesat-2/AWiFS on 20th/21st June, 2013 shows increase in snow cover (seen in white colour along the mountain ridges) in Sutlej, Bhagirathi, Alaknanda and Yamuna river basins. During the same period, the snow cover has reduced in Chenab and Beas basins, indicating normal snowmelt occurrence expected during June[27].

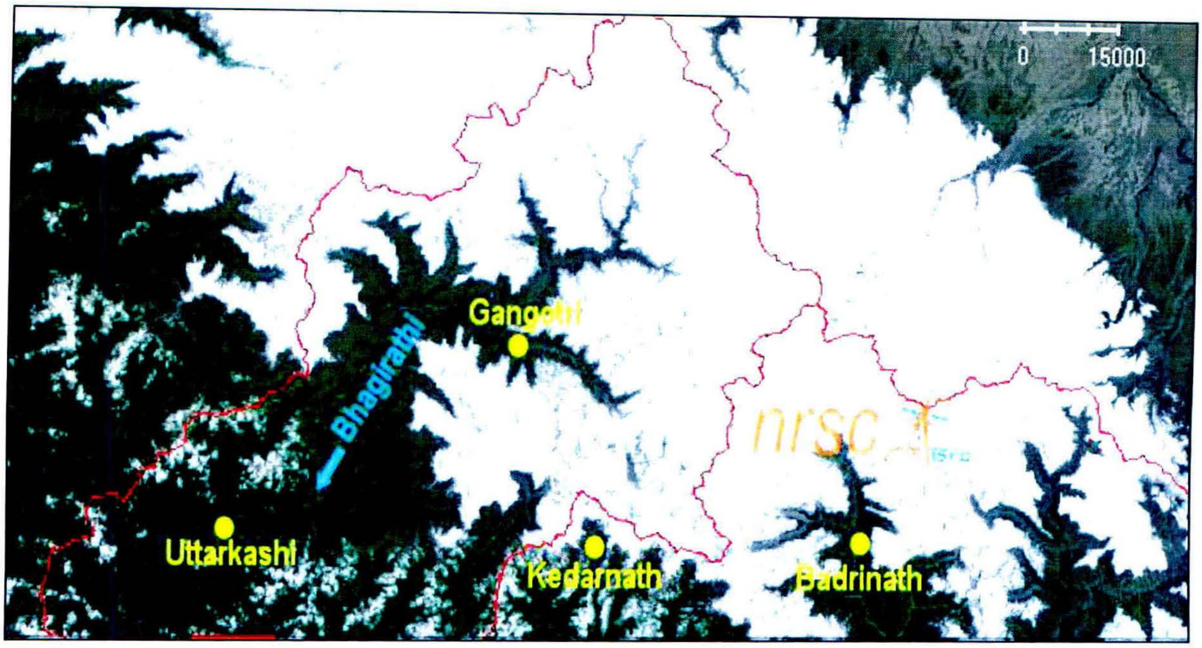
Map 5.8 The satellite image from Resourcesat-2/AWiFS on 28th May, 2013 shows melting snow cover in Bhagirathi and Alaknanda river basins.



Source: *NRSC, Hyderabad*

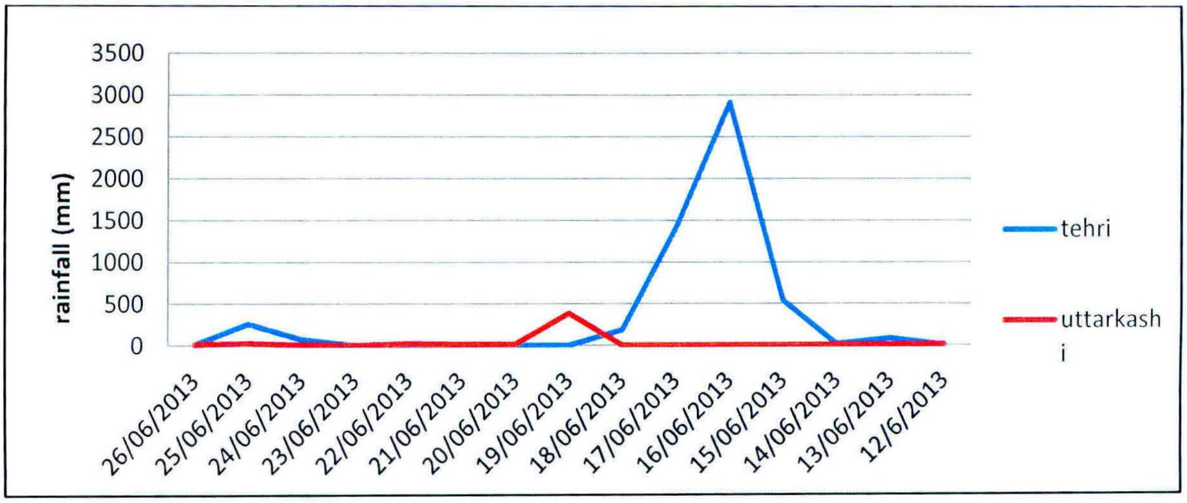
[26] NRSC
[27] Ibid.

Map 5.9 The satellite image from Resourcesat-2/AWiFS on 21st June, 2013 shows increase in snow cover in Bhagirathi & Alaknanda river basin.



Source: *NRSC, Hyderabad*

Figure 5.9 Rainfall at Tehri and Uttarkashi from 12 June, 2013 to 26, June, 2013



Source: *AWS data, Indian Meteorological Department*

From the above figure it is clear that water level in Bhagirathi River has constantly on the rise. It has been noticed that villages of Tiloth and Joshiyara in Uttarkashi and some villages in Tehri facing the danger of being inundated.

5.3.4.2.1.3 Possible Causative factors for such an extreme rainfall event

There is little doubt that the present Himalayan disaster has been triggered by natural events, but the catastrophe is man-made. Environmentalists describe the death and damage as a man-made disaster while geologists say the extent of destruction could have been far lesser if stricter regulations had been put in place and the authorities equipped to deal with the situation. Here it would be appropriate to discuss anthropogenic drivers of this tragedy.

First and foremost, there is ample scientific evidence that the Himalayan watersheds have witnessed unprecedented deforestation over a long period. Deforestation as a commercial activity began during the British Raj and has continued unabated after independence. While official estimates say forest cover has increased in the Himalaya, a number of credible independent studies have found significant discrepancies in this claim. The fact is that forests have been diverted for a host of land use activities such as agriculture, human settlements and urbanization. Massive infrastructure development such as hydropower construction and road building has taken place. Scientific studies indicate that at the current rates of deforestation, the total forest cover in the Indian Himalaya will be reduced from 84.9 per cent (of the value in 1970) in 2000 to no more than 52.8 per cent in 2100[28].

Vegetative cover slows the speed of falling rain and prevents soil erosion and gully formation — the precursors to landslides and floods. Dense vegetation, by evapotranspiration, also stops nearly 30-40 per cent of rainwater from falling to the ground, thereby significantly reducing run-off. Besides holding the soil together, forests and soil soak water from the rain, release it slowly and prevent water flowing as run-off. So, deforestation brings about slope destabilization, landslides and floods. Given that the

---

[28] Pandit, M. K.,(21 june,2013), Nature avenges its exploitation, *The Hindu*, pp 11.

Himalayan range is geologically young and still rising, it makes the area vulnerable to erosion and instability.

Secondly, there is mounting evidence that global warming is fast catching up with the Himalaya. In a recent study, we reported that Himalayan ecosystems have experienced faster rates of warming in the last 100 years and more than the European Alps or other mountain ranges of the world. In such a scenario, we expect faster melting of glaciers causing higher water discharges in the Himalayan Rivers[29].

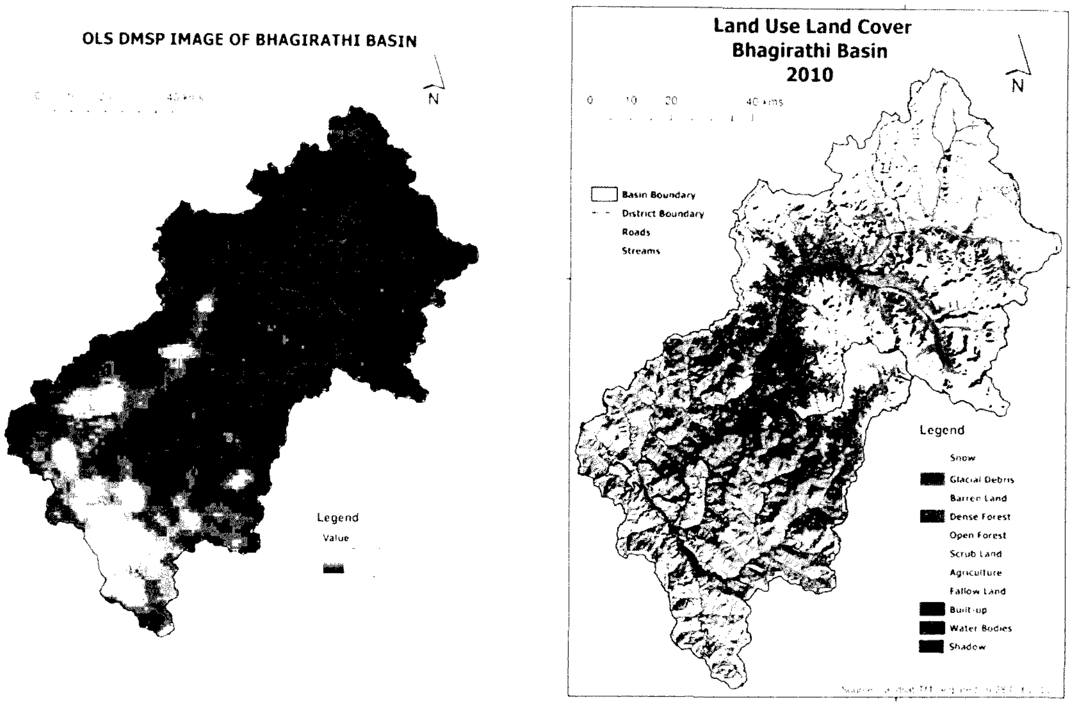
Thirdly, expanding human settlements and urbanization which, besides bringing about land use changes offer themselves as easy targets to the fury of natural forces. While it is important to appreciate the aspirations of the local people and their economic activities, there cannot be a lack of enforcement of land use control laws on the part of local governments and officials. Huge building construction, cheap hotels and individual dwellings at Uttarkashi, on the banks of the Assi and Bhagirathi rivers have been allowed. There is little buffer between the river and the human settlements.

OLS DMSP[30] night time image of Bhagirathi basin and Land use and Land cover image depicts that how built-up area has been increased along the river. Most of the built up and road construction and Dam construction activities were around the river. OLS DMSP carries very sensitive light sensors that can detect light emission from the earth surface at night. We can see from the image that light emission from the Bhagirathi basin was found most in the lower part or along the river side. So it represents the built-up area that has been constructed along the river side.

[29] ibid

[30] The US Air force (USAF) Defence Meteorological Satellite Program (DMSP) operates a series of satellite which carry very sensitive light sensors known as the Operational Line scan System (OLS) that can detect light emission from the earth surface at night. It has a ground swath of about 3000km and has two broad spectral bands, one covering the near infrared region (0.5 -0.9μm) and other is in the thermal infrared region around 10μm.

Map 5.10 Comparison of LULC and OLS DMSP Map of Bhagirathi basin



Source: *OLS DMSP and Landsat TM*

Fourthly, large-scale dam building in recent years has caused massive land use changes with ensuing problems in the Himalayan watersheds. Hydropower and allied construction activities are potential sources of slope weakening and destabilization. Massive intervention in the Himalayan ecosystems through manipulation of rivers and their hydrology, is linked to what we are witnessing today. Most downstream damage in otherwise flood-free areas is caused by dams and barrages, which release large volumes of water to safeguard engineering structures. Dam operators often release more water during rains than the carrying capacity of downstream areas, causing floods.

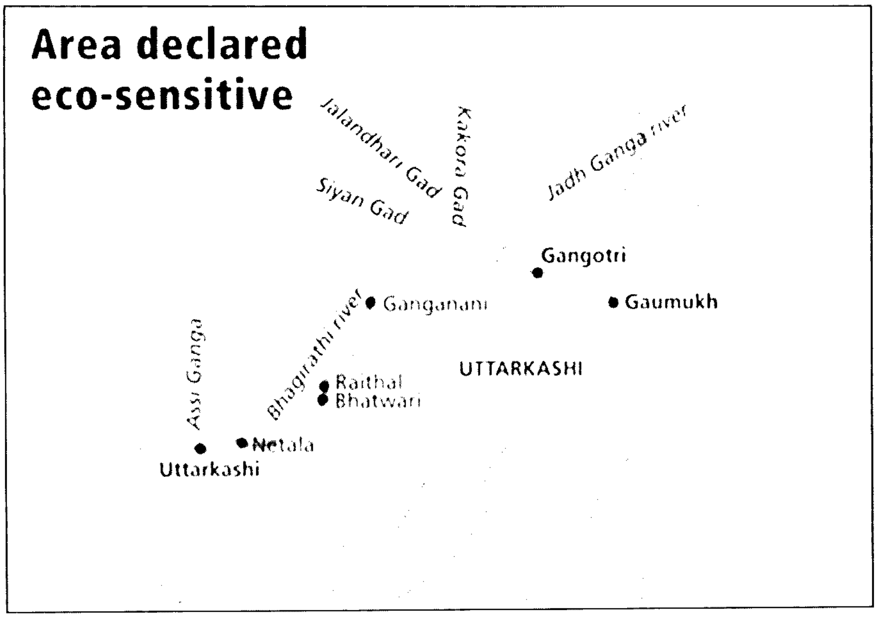
Fifthly, neo-religious movements, linked to changing socio-political developments in India, are responsible for significant human movement into the Himalaya beyond the region's carrying capacity, whether it is Amarnath in Jammu & Kashmir, Kedarnath, Badrinath, Gangotri and Hemkund in Uttarakhand. The heavy pilgrim population has also resulted in the mushrooming of shanty towns, cheap accommodation and numerous ramshackle buildings along river banks.

Sixthly, lack of coordination between different state and national level agencies has aggravated the situation. Despite IMD warning of heavy rainfall state agencies and administration had cold response on warning. Authorities should have been prepared to deal with the threat, or they would have stopped more people from going to these places. There seems to be no accountability and no coordination,

5.3.4.2.1.4 Cope up strategies and measures

December 18, 2012 notification of the Ministry of Environment and Forests, which declares the entire watershed around the 135-km stretch between Gaumukh and Uttarakashi, along the Bhagirathi River, as an eco-sensitive zone under the Environment Protection Act, 1986, has been a contentious issue. This, in practice, bans all construction activity in the area. The State government has been opposing it stoutly, arguing that such an order will adversely affect development and the economic progress of the region.

Map 5.11 Eco-sensitive Zone in Bhagirathi Basin



Source: *Basu,S.(Jul 31,2013),Insensitive to sensitive zone, Down to Earth*

The notification, if implemented, would result in the closure of hydropower projects of 1,743-MW capacity along the Bhagirathi and a ban on mining and construction, especially of hotels and resorts, and land use conversion. Power projects and mining and construction activities are the main causes of preventable environmental degradation. The approach to declare region an eco-sensitive zone is devoid of developmental aspiration of people of the region. A balanced approach needs to be adopted.

There needs to be an integrated policy on the Himalayan environment and development. Governments must impose penalties on building structures within 200 meters of river banks. Hydropower policy must consider building fewer dams and prioritize those that have the least environmental and social costs. Independent and serious monitoring of the catchment area treatment plans proposed by Forest Departments with funds from hydropower companies needs to be carried out and reported to the Green Tribunal. Himalayan State governments need to consider imposing high environmental tax on visitors, particularly during summer and monsoon months. Heavily sizing down pilgrim numbers in fragile areas must begin. All vulnerable buildings need to be either secured or relocated away from rivers.

Development fundamentalism, combined with religious tourism, is eroding ecological heritage. In the aftermath of these disasters, if lessons are indeed learnt, all ongoing development projects must be reviewed, and their carrying-capacity and cumulative impact on the Himalayan ecosystem should be assessed and the ecological integrity of the Himalayan watershed made non-negotiable.

CHAPTER 6

SUMMARY AND CONCLUSION

The study examines the assessment of land use and land cover dynamics in the Bhagirathi basin with an analysis of the Socio-economic vulnerability profiling.Land use and land cover changes have interlinkages and interdependencies on the other elements of physical arena such as geomorphology, climate etc. as well as social arena such as dam construction, road development etc. these interlinkages transmits the whole chain of changes from one realm to another realm in the study area itself. Most importantly, Human activity in the form of population density and land use is direct driver of environmental change in mountains. Creation of infrastucture speacially roads, is crucial step in triggering land use intensification.

The result of LULC analysis in the reference period depict that major changes includes increase in built-up area beside the increment ion agriculture land in lower basin region. In upper basin region snow cover area has shown positive growth. Area under Dense forest cover has increased marginally, whereas area under open forest cover has decline over all. There has been a remarkable increase in area of water bodies showing fivefold increment which can be attributed to Tehri Dam Project and area surrounded by it. According to LCM Modeling, Land use change projection in 2020 highest growth would be seen in agriculture land.

Vulnerability is the degree to which a system is susceptible to, or unable to deal with, adverse effects of climate change. Social vulnerability can be designated as the socioeconomic and demographic factors that affect the resilience of communities regarding any hazard mainly human induced one. Effectively and efficiently attending social vulnerability decimate both suffering inflicted on humans and the economic loss related to providing social services and public assistance after a disaster has occured.Under the Socio-economic vulnerability impacts study emphasizes basically on preparation of Socio- economic vulnerability index which is constituted of social development index, economic development index and infrastructure development index. PCA prepared SoVI illustrates that high value of the index has been found where the infrastructural amenities are not up to the mark and vice a versa. The index indicates that the study region is one of the vulnerability hotspot in the entire Himalayan system. Highest vulnerability has been computed in remote areas, areas near forested region, areas lacking accessibility.

A driver of LULC change includes physical driver encompassing soil, slope, climatic variables, elevation etc. and socio-economic drivers incorporating demographic, economic, political and technological factors. In upper basin region physical drivers are more dominant and active where as in lower basin region socio-economic drivers share pre-eminence. The study of variability of Snow cover assessment in the upper basin region has two time period of peak ablation and peak accumulation which shows that after 2000 there has been a decline in ablation depicting enhancement of snow cover area, which signify that there is an increment in snow cover extent. This increment can be attributed to increased precipitation in the upper basin.Though significant decimation in snow cover extent in winter season has been validated.

In the lower basin drivers for land use and land cover change are quite different from those of upper basin region. Urban sprawl in Uattrakashi and Tehri Garhwal region has played a significant role in putting pressure on land resources through diversion of agriculture and forested land towards residential and industrial use. Population growth has also been a factor which has accelerated the change in land use pattern for its survival in the resources deficit region like Himalayas. Higher population densities lead to a higher presurre on land resources and land carring capacity and intensified the land use and therefore the human signature will be higher. The growth of cities eg. Uttarkashi, Tehri, Gangotri etc in the mountain world places further stress on mountain ecology. Road construction in the hilly area has destabilized the region through interference in the steep slopes and has change the land use pattern through accessibility facilitated by road development phenomenon. Human accelerates slope failures through road building activities, specially when roads are situated in mid slopes location instead of along ridge tops. One of the most dramatic effects of human activity on landscape processes is the construction of large dams in mountain area eg. Tehri Dam. Natural peak flow are reduced and distributed over time and the discharge of streams in adjacent watersheds is altered through water diversions. There are likely to be massive changes in sediment transport of major rivers pre and post dam construction.In the tourism industry extensive infrastructure and many technological measures like grooming of ski slopes or artifical snow making are required which have strong negative impact on natural system, beside extra burden on land resources due to temporary immigration of tourists. Migration, especially immigration in the Uttarkashi region has exacerbated the problem of pressure on land resources. Agriculture has been a potent driver of land use change in the study region. From subsistence farming to commercial farming in the mountaain region depicts a sharp paradiagm shift in land use changes. Agricultural land has been drived by clearing forests, natural grasslands, natural wetlands which have a important role to play in the ecological sysytem of the study region. Land use policies have determining impact on the present and future LULC in the Bhagirathi basin.

Linkages between climate, land use and land cover and landforms are complex one. Climate driven landscapes changes sare likely to be accelerative. Magnitude, mode and time frames of morphological adjustments to the climate change are likely to very significantly between different morphological elements of landscape. As far as the Himalayan mountain system is concerned, there is a temporal lag between climate changes and morphological adjustments that is responsiveness to the climatic changes.

Land use Land cover change can enhance a cooling or warming effect case by case as case may be. For example, As in the land conversion to agriculture will have a cooling effect on climate, whereas land conversion to built-up area and barren land will culminate into warming effect on climate of the region. Air quality, carban cycle etc are other affected arena of LULC change and climate change interface. The linkages between the Land Use Land Cover change and its effects on the climate of a particular region is hard to identify and establish.

Recent extreme rainfall event in Uttarakhand has time and again emphasized on the fragility and vulnerability aspects of Himalayan regions. Though Kedarnath region bears most of the brunt of the catastrophic flood , study area is also not unaffected. Being a man induced calamity deforestation, change in the agricultral practices inclusing shifting to the commercila farming, global warming, settlement development in the river flood plain zone and steep slopes multitude of dam projects pilgrimage associated with tourism and lack of coordination between state and national level agencies are the main triggering factors. An integrated policy based on the sui generis development model of the study region according to its typical nature and needs would be most appropriate encompassing regional aspiration of people for development with sustainable development.

BIBLIOGRAPHY

Ahmad,S., Hasnain,S.I and Selvan, M.T (2004).Morphometric characteristics of Glaciers in the Indian Himalayas,*Asian Journal of water, Environment and pollution*, 1(1&2),109-118.

Amin. A, and Fazal. S.(2012).Land Transformation Analysis Using Remote Sensing and GIS Techniques (A Case Study), *Journal of Geographic Information System*, 4, 229-236.

Anderson, J.R, Hardy, E.E ,Roach, J.T. and Witmer,R E.(2007).A Land Use and Land Cover Classification System for Use with Remote Sensor Data, A Revision of The land Use Classification system as Presented in U.S.Geo-logical Survey Circular 671, United States Government Printing Office, Washington, 1977United Nations,World Urbanization Prospectus: The 2007 Revision, United Nations, New York.

Anonymous (2011) Climate Variability and Change in the Himalayas: Community perceptions and responses, International Centre for Integrated Mountain Development, Kathmandu, Nepal

Anonymous (2011), Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins, Alternate Hydro Energy Centre (AHEC), Indian Institute of Technology Roorkee

Aoki, T., Hori, M., Motoyoshi, H., Tanikawa, T., Hachikubo, A., Sugiura, K.,Takahashi, F. (2007).ADEOS-II/GLI Snow/ice products —Part II:Validation results using GLI and MODIS data. *Remote Sensing of Environment,* 111(2-3), 274–290. doi:10.1016/j.rse.2007.02.035

Arora, M.K., and S. Mathur, 2001. Multi-source classification usingartificial neural network in rugged terrain, *GeoCarto International*, 16(3):37–44.

Barry, R.G , Crane, R.K., Weaver, R. L. and Anderson, M. A.(1984).Sea Ice and Snow – cover data availability, needs and problems.*Annals ofGlaciology,* 5.

Baulies, X., and Szejwach, G., (1998). LUCC data requirements workshop survey of needs, gaps and priorities on data for land-use/land-cover change research organized by IGBP/IHDP-LUCC AND IGBP-DIS, Barcelona, Spain, 11-14 November 1997 LUCC report series no. 3.

Bolch,T. ,Kulkarni, A. ,Kääb,A. Huggel,C. Paul, F. ,Cogley,G.,Frey,H., Kargel,J.S , Fujita, K., Scheel,M ., Stoffel,M. ,Bajracharya,S. (2012).The state and fate of Himalayan Glaciers. *Science*, 336 (310-314).

Bhambri, R., Bolch,T and Chaujar, R. K. (2012). Frontal recession of Gangotri Glacier, Garhwal Himalayas, from 1965 to 2006, measured through high resolution remote sensing data. *Current Science*, 102 (3) feb.

Bhambri, R., Bolch, T.&Chaujar, R. K. (2011).Mapping ofdebris covered glaciers in the GarhwalHimalayas using ASTER DEMs and thermal data. *International Journal of RemoteSensing*, 1–25.

Bayer , L.B ,Vanden Hurk , B. J. J. M , J. Strengers , and J. G. van Minnen . (2012). Regional feedbacks under changing climate and land-use conditions,Earth System Dynamics Discussions (ESDD),3,201–234

Bhambri, R.,Tobias, Kumar, R. and Chandra,S.(2011). Glacier changes in the Garhwal Himalayas, India, from 1968 to 2006 based on remote sensing. *Journal of Glaciology*, 5(203).

Bhambri, R and Bolch, T (2009). Glacier mapping: a review with special reference to the Indian Himalayas. *Progress in Physical Geography* ,33(5) ,672–704.

Bindschadler,R.(1998).Monitoring ice sheet behaviour from space. *Reviews ofGeophysics*,36 (1) .79–104.

Christopher, G., Fletcher, Hongxu, Z., Paul, J. Kushner and Fernandez ,R. (2012).Using models and Satellites observations to evaluate the strength of snow albedo feedback, *Journal of Geophysical Research*,117

Chrysoulakis, N., Kamarianakis, Y., Farsari, Y., Diamandakis, M. and P.Prastacos, (2004).Combining Satellite and Socioeconomic data for Land Use Models estimation. In Goossens, R.(Editor), Proc.Of 3rdWorkshop of EARSeL Special Interest Group on Remote Sensing for Developing Coutries. 1-15.

Covault, J.A., Craddock. W.H., Romans, B.W., Fildani, A. and Gosai, M.(2013).Spatial and Temporal in Landscape Evolution: Historic and Longer-Term Sediment Flux through Global Catchments.*The Journal Of Geology*, 121(1), 35-56.

Cusker, B.M .(2004). Land Use and Cover Change as an Indicator of Transformation on Recently Redistributed Farms in Limpopo Province, South Africa. *Human Ecology*, 32 (1), 49-75

Charney,J. Stone, PH. (1975). Drought in the Sahara: a bio geophysical feedback mechanism. *Science* ,187,434–35

Cutter, S.L.; B.J. Boruff; W.L. Shirley. (2003). Social Vulnerability to Environmental Hazards. *Social Science Quarterly* 84(2) ,242–261

Dozier ,Jeff and Marks , D.(1987).Snow Mapping and classification from Landsat Thematic Mapper data. *Annals of Glaciology*,9.

Dozier, Jeff, Green, O.R. , Nolin, A. W. and Painter ,Thomas ,H. (2007). *Interpretation of snow properties from Image spectrometry*. University of California.

Dozier Jeff and Painter. Thomas, H. (2004). Multispectral and Hyperspectral Remote Sensing of Alpine Snow Properties, *Remote Sensing of Alpine Snow*.

D.K.Hall &Martinec, J. (1985).*Remote Sensing of Ice and Snow*. Chapman Hall, New York, U.S.A.

Dyurgerov, M.B.and Meier, M.F., (1997) Mass balance of mountain and subpolar glaciers: a new global assessment for 1961–1990. *Arctic and Alpine Research*,29(4),379–391

Eric F. Lambin,(May - Jul., 1999),Monitoring Forest Degradation in Tropical Regions by Remote Sensing: Some Methodological Issues, Global Ecology and Biogeography, 8, (3/4), *Tropical Open Woodlands Special Issue* 191-198.

Essery, R. (1997). Seasonal Snow cover and climate change in the HadleyCentre GCM. *Annals of Glaciology*,25.

Ebert, Annemarie., Kerle, Norman. and Stein, Alfred.(2009). Urban social vulnerability assessment with physical proxies and spatial metrics derived from air- and spaceborne imagery and GIS data, *Natural Hazards* . 48,275–294.

Ebert, A.,Welz,J., Heinrichs, D.,Krellenberg, K. and Hansjurgens, Bernd. (2010). Socio-Environmental Change and Flood risks: The case of Santiago De Chile. *Erdkunde*.164(4) , 303-313.

Fall ,S., Pielke ,S., Niyogi, D., Gluhovsky, A., Kalnay ,E and Gilbert, R.(2009) .Impacts of land use land cover on temperature trends over the continental United States:assessment using the North American Regional Reanalysis.*International Journal Of climatology*.

Flanagan, Barry E.; Gregory, Edward W.; Hallisey, Elaine J.;Heitgerd, Janet L.; and Lewis,Brian (2011) "A Social Vulnerability Index for Disaster Management,"*Journal of Homeland Security and Emergency Management:* Vol. 8: Iss. 1, Article 3.DOI: 10.2202/1547-7355.1792

For SVI Uttarakhand State Action Plan for Climate Change. Supported by UNDP,Government of India. Revised Version June (2012)

Facing the Facts: Ganga Basin's Vulnerability to Climate Change, WWF-India, 2011Interim Report, Uttarakhand Centre on Climate Change (UCCC), Kumaon University, March 2011

FAO/UNEP. 1997. Negotiating a Sustainable Future for Land. Structural and Institutional Guidelines for Land Resources Management in the 21st Century. FAO/UNEP, Rome

Gloersen, P. and Salomonson , V.V.(1975), Satellites-New Global observing techniques for snow and Ice, *Journal of Glaciology*, 15(73).

Hoinkes, H.(1967).Glaciology in the international hydrological decade. *IAHS Commission on Snow and Ice: Reports and Discussions* ,79 ,7–16

Inman, Mason . (2010).Settling the science on Himalayan glaciers, *Nature reportsclimate change* . 4.

ICIMOD .(2010).Climate Change Impact and Vulnerability in the Eastern Himalayas – *Synthesis Report*. MacAurthur Foundation.

Jacqueline Geoghegan, Lowell Pritchard, Jr.,Yelena Ogneva-Himmelberger, Rinku Roy Chowdhury, Steven Sanderson, and B.L. Turner II (1998), "Socializing the Pixel" and" Pixelizing the Social" in Land-Use and Land-Cover Change, *People and Pixels Linking Remote Sensing and Social Science,* National Academy Press, Washington, D.C.

Joshi, Manoj. Et al. (2011) .Projections of when temperature change will exceed 2 °C above pre-industrial levels. *Nature Climate change*,1.November.

Kalnay, E. and Cai, M. (2003). Impact of urbanization and land-use change on climate. *Nature*, 423, 528-531.

Lambin, E.F., Turner II, B.L., Geist, H., Agbola, S., Angelsen, A., Bruce, J.W., Coomes, O., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skaines, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T., Vogel, C., Xu, J., (2001). Our emerging understanding of the causes of land-use and -cover change.*Global Environ. Change* 11, 261–269.

Lambin, E.F., Geist H.J., and lepers, E., 2003. Dynamics of land-use and land-cover change in tropical regions, *Annual review of environmental resources*, 28:205–41.

Lambin, E.F., 2005. Conditions for sustainability of human–environment systems: Information, motivation, and capacity, *Global Environmental Change* 15 (2005) 177–180, Elsevier.

Lambin, E.F. and Strahler, A.H., 1994. Change-vector analysis in multispectral space: A tool to detect and categorize land-cover change processes using high temporal-resolution satellite data. *Remote Sens. Environ.*,48, 231-244.

Lambin, E. F., and Meyfroidt, P.(2010). Land Use transitions: Socio-ecological feedback versus socio-economic change. *Land Use Policy* (27) , 108-118.

LiJensNieke, Yukinori Nakajima, Fumihiro Takahashi, (2007), ‘ ADEOS-II/GLI snow/ice products — Part II: Validation results using GLI and MODIS data, *Remote Sensing of Environment.*111, 274 – 290

Loffler, J., Anschlag, K. Baker, Barry.,Finch, O. D.,Diekkruger, B.,Wundram, Schroder, B., Pape, R. and Lundberg, Anders. (2011).Mountain Ecosystems Respose to Global Change.*Erdkunde,* 65 (2) , 189-213.

Lundberg, A. (2011). Climate and Land-Use Changes as driving forces in low land seminatural vegetation dynamics.*Erdkunde,*65(4), 335-353.

Lyapustin, Alexei., Aoki, Teruo. Et al. (2009).Retrieval of snow grain size over Greenland from MODIS, *Remote Sensing of Environment*, 113,1976– 1987

Mahmood R, PielkeSr, Kenneth G, Niyogi D, Bonan G, Lawrence P , Richard Mc N, Clive M, Andress E, Samuel G, Budong Q, Andrew Carleton, Adriana Beltran, Thomas , C . (2010). Impacts of land use/ Land cover change on climate and future research priorities.*American Meteorological Society*, January.91, 37–46

Martinec, J.,A. Rango and R. Roberts.(1998). Snowmelt Runoff Model (SRM) User's Manual. Dept. Geog., Univ. berne, Geographicaberensia.

Maikhuri,R.K, Rao.K.S. and Semwal. R.L,(2001).Changing scenario of Himalayanagroecosystems: loss of agrobiodiversity, an indicator of environmental change in Central Himalaya, India, *The Environmentalist*, 21, 23–39

Mahajan.S and Panwar. P,(2005). Land Use Changes in AshwaniKhand Watershed using GIS techniques, *Journal of the Indian Society of Remote Sensing* , 33(2).

Meyer, W.B. and Turner II, B.L. (1996). Land-use/land-cover change: challenges for geographers. *Global Change and Environmental Issues: Research and pedagogy.* 39(3), 237-240.

Mishra, Tapas. (2012). Carbon emissions and sustainability, *Nature Climate change* ,2

Montpetit, B., Royer, A. , Langlois, A. , Cliché, P., Roy, A., Champollion,N., Picard G, Domine, F. and Obbard, R. (2012).Instruments and Methods : New shortwave infrared albedo measurements for snow specific surface area retrival, *Journal of Glaciology*, 58(211).

Morrow, B.H. (1999). Identifying and Mapping Community Vulnerability. *Disasters* 23(1) ,1–18.

Nolin, A. W. and J. Stroeve,(1997) The changing albedo of the Greenland ice sheet: Implications for climate modeling, *Annals of Glaciology*, 25, 51-57.

Otterman, J.(1974). Baring high-albedosoils by overgrazing: a hypothesised desertification mechanism. *Science* ,86 ,531–33

O.H.K, Spate, (1957) India and Pakisthan: A Regional geography.

Painter, Thomas , H., Rittger, Karl, McKenzie, Ceretha., Slaughter, Peter., Davis, Robert E. and Dozier, Jeff. (2009) . Retrieval of sub pixel snow covered area, grain size, and albedo from MODIS, *Remote Sensing of Environment*, 113 ,868 –879.

Pandey, Pritima. ,. Kulkarni, A. V, G. Venkataraman .(2012).Remote Sensing Study of Snowline Altitude at the End of Melting Season, Chandra-Bhaga Basin, Himachal Pradesh, 1980-2010. *Geocarto International*, DOI:10.1080/ 1010604 . 2012.705336.

Perovich, D.K . (2007). Light reflection and transmission by a temperate snow cover. *Journal of Glaciology*, 53(181).

Pitman A.J. and Narisma G.T. (2005), the role of land surface processes in regional climate change: a case study of future land cover change over south western Australia, Meteorology Atoms Phys. 1-14

Punia, M, Joshi, P. K. and Porwal, M. C. (2010) Decision tree classification of land use land forest coverindelhi ,India.*ELSEVIER,ESWA* 5449.No.of P 7 , Model 5

Rao, K. S., and Pant, Rekha.(2001). Land use dynamics and landscape change pattern in a typical micro watershed in the mid elevation zone of central Himalaya, India. Agriculture, Ecosystems and Environment ,86, 113–123.

Robinson, D.A, Dewey, K.F and Heim, R.R., Global Snow cover Monitoring: An Update , *Bulletin of the American Meteorological Society*. 74, sept.

Rees, W. Gareth .(2006).*Remote Sensing of Snow and Ice*, CRC Press, Taylor & Francis Group, Cambridge University England.

Rittger, Karl, Painter, Thomas H and Dozier, Jeff. (2012). Assessment of methods for mapping snow cover from MODIS, Advances in Water Resources.

Renssen, Sonja van .(2012).The greenhouse-gas gang*Nature Climate Change* ,2. march

Roy ,A and Srivastava, V.K .(2012). Geospatial approach to identification of potential hotspots of land-use and land-cover change for biodiversity conservation, *Current Science*,102 (8)25 April.

Sagan ,C., Toon,O.B. Pollack ,JB. (1979).Anthropogenic albedo changes and the earth's climate. *Science*,206,1363–68

Saha, A. K. (2001). Land Cover Classification Using IRS LISS III Image and DEM in a Rugged Terrain : A Case Study in Himalayas, 33–40.

Saha, A.K ,Arora,M.K., Csaplovics, E.. (2 June 2005). Land Cover Classification Using IRS LISS III Image and DEM in a Rugged Terrain: A Case Study in Himalayas, *Geo carto International*, 20.

Sangewar, C.V. and Shukla, S.P.(2009). An inventory of Himalayan Glaciers, Special Publication No.34, *Geological Survey of India*. 588.

Schaepman-Strub, G., Schaepman, M. E., Painter, T. H., Dangel, S., & Martonchik, J. V. (2006).Reflectance quantities in optical remote sensing—definitions and case studies.*Remote Sensing of Environment*, 103(1), 27–42. doi:10.1016/j.rse.2006.03.002.

Selvan, M.T and Kodi, Malar P. (2012). Application of Remote Sensing techniques to study Hyro-Meteorological changes on the dynamics of glaciers, Bhagirathi basin,Garhwal Himalaya, ARPN *Journal of Engineering and Applied Sciences*,7(3) March.

Semwal, R. , Nautiyal, S., Sen, K., Rana, U., Maikhuri, R ., Rao, K. , & Saxena, K. (2004). Patterns and ecological implications of agricultural land-use changes: a case study from central Himalaya, India. Agriculture, *Ecosystems & Environment*, 102(1), 81–92. doi:10.1016/S0167-8809(03)00228-7

Seto, K. C., Reenberg, A., Boone, C. G., Fragkias, M., Haase, D., Langanke, T.,Simon, D. (2012). Urban land teleconnections and sustainability. Proceedings of the National Academy of Sciences of the United States of America,109(20), 7687–92. doi:10.1073/pnas.1117622109

Shreve, C.M. Gregory S., Thomas H.(2009). Indices for estimating fractional snow cover in the western Tibetan Plateau. *Journal of Glaciology*, 55(192)

Slaymaker, O., Spencer, Thomas. And Embleton-Hamann, C. (2009).*Geomorphology and Global Environmental Change*. Edited book. Published by Cambridge University Press.

Singh, P., Arora, M., &Goel, N. K. (2006).Effect of climate change on runoff of a glacierized Himalayan basin. *Hydrological Processes*, 20(9), 1979–1992. doi:10.1002/hyp.5991

Singh, R.k., Srivastava, D. and Sangewar, C.V.(2008). *Glacier Inventory-basin wise classification of the glaciers and Data cards.* In Raina, V.K. and Srivastava , D. (Eds), *Glacier Atlas of India.*Geological Society of India. Bangalore, 65-185.

Sobrino, J. A., & Kharraz, M. H. El. (1999a). Combining afternoon and morning NOAA satellites for thermal inertia estimation: 2. Methodology and application, 104(1998), 9455-9465.

Srivastava, Deepak (Draft), A Status report on Gangotri Glacier, Centre of Glaciology, Wadia Institute of Himalayan Geology, Dehradun.

Singh. S, Srivastava S.K, Srivastava VK, Roy A ,Aggarawal SP, Nayak R Diwivedi RS and Roy PS,(2010) Human Dimensions of climate change : A few initiatives, Earth observation applications in climate change studies. A Report.

Deborah S. K. Thomas, Brenda D. Phillips, William E. Lovecamp, Alice FothergillvDi Gregorio, A. and Jansen, L.J.M. Edited book (1998).Land Cover Classification System (LCCS): Classification Concepts and User Manual. *Social Vulnerability to Disasters,* Second Edition For software version 1.0. GCP/RAF/287/ITA Africover - East Africa Project in cooperation with AGLS and SDRN. Nairobi, Rome.

Tierney, K. 2006. *Social Inequality: Humans and Disasters*. In R.J. Daniels, D.F. Keitl, and H. Kunreuther (eds), On Risk and Disaster: Lessons From Hurricane Katrina. Philadelphia: University of Pennsylvania Press.

Tiwari,K.&Khanduri, Kamlesh.(2011).Land Use / Land cover change detection in Doonvalley (Dehradun Tehsil), Uttarakhand: using GIS&Remote Sensing Technique. *International journal of Geomatics and Geosciences,*2(1).

Tiwari, P. C. (2000) .Land use changes in Himalaya and their impact on the plains ecosystem: Need for sus-tainable land use. *Land Use Policy*, 17,101–111.

Tiwari,P.(2008). Land Use Changes in Himalaya and Their Impacts on Environment, Society and Economy: A Study of the Lake Region in Kumaon Himalaya, India, *Advances in Atmospheric Sciences*,25,(6), 1029–1042.

Turner II, B.L. D. Sanderson Skole, S.,Fischer G., Fresco L. and Leemans,R. (1995).Land Use and Land Cover Change, Science/Research Plan, IGBP Report No. 35, HDP Report No. 7, IGBP and HDP, Stockholm and Geneva, 20-25.

Unesco/IAHS/WMO(1970) Seasonal snow cover. In Technical Papers in Hydrology.Paris: Unesco/IAHS/WMO.

UNEP, “Land Degradation,” State of the Environment in Bangladesh, 2001.

Wendler, G and Kelley, J. (1988). On the Albedo Of snow in Antarctica: A contribution to I.A.G.O. *Journal of Glaciology*, 34 (116).

Wakeel ,A., Rao, K.S. , Maikhuri, R.K. and Saxena, K.G.,2005: Forest management and land use/cover changes in a typical micro watershed in the mid elevation zone of Central Himalaya, India, Forest Ecology and Management 213, 229-242.

William B. Meyer and B. L. Turner II(1992), Human Population Growth and Global Land-Use/Cover Change, Annual Review of Ecology and Systematics, 23 (1992), 39-61.

Wakeel, A. Rao K.S, Maikhuri R.K and Saxena K.G.(2005) . Forest Management and Land use/cover changes in A typical Micro Watershed in the mid elevation zone of central Himalayas, India. *Forest Ecology and Management,* 213, 229-242.

W. B. Meyer and B. L. Turner II, (Eds.) (1994) .*Changes in Land Use and Land Cover: AGlobal Perspective,* The Press Syndicate of University of Cambridge, UK.

W. B. Meyer and B. L. Turner(1992) .Human Population Growth and Land Use/Cover Change. *Annual Review of Ecology and Systematics*, 23, 39-61.

Zubair, A. O., (2006). Change detection in land use and Land cover using remote sensing data and GIS (A case study of Ilorin and its environs in Kwara State),Thesis, University of Ibadan, Nigeria.