Impact of Climate Change in Snow and Glacier Retreat With People's Perception and Adaptation Strategies
(A Case Study of Langtang Valley)

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Submitted By

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CENTRAL DEPARTMENT OF GEOGRAPHY

RECOMMENDATION LETTER

This is to certify that the thesis submitted by Ms. Bhabana Thapa, entitled **"Impact of Climat Change in Snow and Glacier Retreat With People's Perception and Adaptation Strategies (A Case Study of Langtang Valley)** has been prepared under my supervision in the partial fulfillment of the requirements for the degree of Master of Arts in Geography. I recommend this thesis to the evaluation committee for examination.

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Approved by:

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September, 2012	**Thesis Committee**

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Abstract

Climate change studies in Himalayan regions have focused mainly on glacier melting, retreating, Glacial Lake Outburst Flood (GLOF). Most glacier studies in Nepal show glaciers are undergoing rapid deglaciation. But somehow the impact of climate change and adaptation strategies of local peoples have not been studied in detail in Langtang valley. Hence, this research has been carried out to investigate the contribution of climate change and effects on people's adaptation strategies in the region which are most vulnerable to climate change. This research paper deals with various time series satellite imagery, temperature data, precipitation data, water discharge data and social survey. Analyzing the temperature data from 1987 to 2009 it is found that the average daily temperature is 3.2°C with standard deviation of 1.27. The temperature is found to be in increasing trend of 0.119°C/year. Global warming has serious consequences like snow melting, glacier lake outburst flood (GLOF) and overall land use/ land cover change. The study also reveals that the total snow coverage area was continuously decreased in Langtang valley. In 1988, the total snow covered area was 43.16 percent and in 2000 total snow covered area was 42.67 percent which was decreased by 272.9 ha. In 2009 snow covered area was 38.72 percent which was decreased by 2196.5 ha between 2000 to 2009. Yearly snow melting rate has been 0.21 percent per year according to data available between 1988 to 2009. The result suggested that the glaciers are retreating rapidly and people are facing several problems due to the hydro-ecological changes in Langtang valley and trying their best to tackle with the changing environments. Rapid glacier melting disrupted rural livelihoods by posing a threat to agriculture, biodiversity and health. Change in rainfall and temperature resulted in changes in plant behavior like early flowering, shift in vegetation line and loss of some valuable species. Extreme climate events are destroying crops, depleting water resources, causing losses in livestock, cropland, and agricultural productivity. These changes indicate that unpredictable climate variability will be a major obstacle for subsistence-based livelihoods in Langtang valley.

Key Words: Climate change, land use/ land cover change, rainfall, temperature, adaptation strategies.

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ABBREVIATIONS AND SYMBOLS

CBS	Central Bureau of Statistics
CNRCC	China National Report on Climate Change
DEM	Digital Elevation Model
GIS	Geographic Information System
GLOFs	Glacier Lake Outburst Floods
HKH	Hindu Kush Himalaya
ICIMOD	International Center for Integrated Mountain Development
IPCC	International Panel for Climate Change
M m^3	Million meter cubes
RCA	Rainfall Contributing Area
SCA	Snow Coverage area
SGHU	Snow and Glacier Hydrology Unit
USGS	United State Geological Survey
UNDRO	United Nations Disaster Relief Co-Ordinate
TU	Tribhuvan University
ASL	Average sea level
km^2	Squire Kilo Meter
mm	Mili Liter
SAGUN	Strengthened Actions for Governance in Utilization of Natural Resources
ADAPT	Association for Development of Environment and People in Transition
NAPA	National Adaptation Plan of Action

CHAPTER I

INTRODUCTION

1.1 Background

Various studies suggest that warming in the Himalayas has been much greater than the global average of 0.74° in the last 100 years (IPCC, 2007; Du et al., 2004).Warming in Nepal was 0.6°C per decade between 1977 and 2000 (Shrestha et al. 1999). The analysis of observed temperature and precipitation data in Nepal shows that temperature in Nepal is increasing at a rather high rate in comparison to other mountains of the world. As a result, rainfall is increasing, numbers of rainy days are decreasing and rainfall burst is occurring frequently. Such change in precipitation pattern in recent years is the direct cause of climate change in the Himalayan region (Shrestha, 2010). With rising temperature, areas covered by permafrost and glaciers are decreasing to a great extent in much of the region. Moreover, in many areas a greater proportion of total precipitation appears to be falling as rain than here-to-fore. As a result, snow begins melting earlier and winter tends to be shorter: this affects river regimes, natural hazards, water supplies, and people's livelihoods. Such extreme events are already observed in many parts of Nepal and can cause devastating effect on fragile Himalayan ecosystem like Langtang Valley (Shrestha et al. 1999).

The Fourth Assessment Report of the Inter Governmental Panel on Climate Change (IPCC) compiled current knowledge on various aspects of climate change, including the key indicators, based on research conducted during the last few years (IPCC, 2007). One of the most visible impacts of climate change in the Himalayan region is the retreat of glaciers (WWF, 2005), which are the reliable sources of fresh water to many people living downstream to meet their needs for water supply, irrigation, hydropower and navigation. Himalayan glaciers cover about 17 % of the global mountain i.e. around 33,000 sq.km (Eriksson et al. 2009), and stored about 12,000 $km^3$of fresh water (Thompson, 2007). There are about 3,252 glaciers with coverage of 5,323 sq. km areas and an estimated ice reserve of 481 km^3 present in Nepal (Mool et al., 2001). Thus, there is a research need to examine the impact of climate change and effect of the glacier.

1.2 Statement of the Problems

The scientific evidence shows that the effects of globalization and climate change are being felt in even the most remote Himalayan environments (Shrestha, 2007). The effect of the global warming on the glaciers and ice reserves of Nepal has serious implications for the fresh water reserve and consequently for low flows (IPCC, 2007). Any significant change in glacier mass and ground water storage will impact on water resource in a regional scale. Precipitation is an important link in the water cycle. Increase in temperature and precipitation in Himalayas accelerates the process of ice/snow melting as well as enhances flooding event from direct runoff whereas dry season discharge i.e. base flow is decreased. The change in climatic parameters is projected to have adverse effect on water storage capacity of the Nepalese Himalayas. The major concern is rapid reduction of glaciers in much of the Himalayan region and shifting upwards of snow line (Fujita, 2006).

Therefore, it is very necessary to study about climate change and its impact on local people. Many attempts have been made to conduct researches on climate change and its impact. Most of these searches have focused on climate change. Recently researches have been started to study climate change and biodiversity, but so far, few research has been carried out in Nepal. Hence, this study is carried out to investigate the contribution of climate change and effects on people's adaptation strategies in the region which are most vulnerable to climate change.

1.3 Research Questions

This research is primarily aimed to address the following research questions:

- What are the indicators of the climate change on the Langtang valley ecosystem?
- What are the factors responsible for increasing glacier retreat?
- What are the people's adaptation strategies in the region which are most vulnerable to climate change?

1.4 Objectives of the Study

The overall objective of this study is to find out the effect of climate change on land use/land cover. The specific objectives of this study are:

- To analyze the climatic condition of Langtang Valley.

- To analyze the impacts of climate change on snow and glacier environment.
- To analyzed the land use/ land cover pattern of Langtang Valley.
- To identify the effect of climate change and adaptation strategies of local people.

1.5 Significance of the Study

Climate change is affecting people around the globe, and this is especially evident at the top of the world around Mount Everest and the high peaks of the Himalayan mountain range. The greater Himalayan region has the largest concentration of snow and ice outside the two poles. Warming temperatures cause rapid melting of the glaciers, severely affecting the people downstream. Ten river systems originating in the Himalayas bring water to a mountain population of around 200 million, while the vast water basins downstream are home to a further 1.3 billion people. In total 1.5 billion people - a fifth of the world's population - depends on the Himalayan Rivers for their water supply (Bajrachyarya, 2010). This study will help to understand about glacier in Nepal, and it will be helpful to identify the general scenario of snow and glacier in the climate change context. Mainly this paper will be a baseline study for further research in this region, and research in the context of climate change, impact, associated vulnerability and adaptation strategy in the alpine areas.

1.6 Limitations of the Study

The main limitation of this study is use of secondary sources of data which is 15 m and 30 m resolution image. *This study is based on both primary and secondary attributes and spatial data*, and based on the quality of imaginary, rectification, interpretation and analysis of the satellite image. This study incorporates the secondary information based on earlier studies. *So, this study is limited to the accuracy of the data used and different map digitizing and processing error.*

CHAPTER – II

LITERATURE REVIEW

2.1 Review of Literature

The first investigations on glacierization and the movement of glaciers in the Langtang region were done in the 1960s. Since then, some glaciers were monitored sporadically (Watanabe & Higuchi, 1987). A continuous observation series for Yala Glacier between 1982 and 1989 is given by Yamada *et al.* (1992). A glacier inventory was established by Shiraiwa & Yamada (1991). Historic glacier positions were studied and dated by Shiraiwa & Watanabe (1991). The initiation was made by the Japanese Glacier Research Group (1968-1973)and Geological Expedition Nepal (Higuchi 1976 as cited in Ghimire 2004/2005). Glaciers may be retreating worldwide due to global warming, but they still cover about 10% of earth's land and hold about 77% of earth's freshwater (29,180,000 cubic kilometers) (www.globle greenhousewarming.com). Without the water from mountain glacier, serious problems are inevitable and the UN's Millennium Development Goals for fighting poverty and improving access to clean water will be jeopardizes (United Nations Environment Program, Global Outlook for Ice and Snow, 2007).

Resent observation has shown many glacier in the Himalayas retreating rapidly (Ghimire 2004/2005). The Himalayan region abounds in glaciers. Most of the big glaciers lie in the eastern Himalayas. As the western Himalayas receive only a small amount of rainfall, barring the formation of vast snowfields, the sources of some of the big rivers of Nepal are in fact glaciers (www.thehimalayantimes.com). Meteorological observations have been made for different surface covers (grass, debris-free glacier and rock-covered glacier ice in Langtang Valley, Nepal Himalayas. Change in the daily mean lapse rate over debris-covered ice shows a significantly larger fluctuation compared with over debris-free ice. An analysis of the daily mean lapse rate reveals that a "low" or "high" lapse rate appeared under dry or wet conditions on the debris-covered area even though the opposite result was expected for the lapse rate of a free atmosphere. It is considered that less evaporation under dry condition would bring about high surface and then warm air temperatures. Many small glaciers at low altitudes have disappeared entirely and many larger ones have lost around half of their volume. Some have formed huge glacial lakes at the foot of the glacier, threatening downstream communities in case of an outburst", (www.RaOneOnline.com).

Shiraiwa and Watanabe (1991) proposed the first glacial chronology for the Langtang Himal, based on radiocarbon and relative dating methods (Fig. 1, Table 1). They divided the glacial succession into six stages: Lama (oldest), Gora Tabela, Langtang, Lirung, and Yala I and II (youngest).The Lama Stage is defined by the U-shaped valley extending down the Langtang Valley to 2600m asl. The Gora Tabela stage is defined by a weathered till that extends down to 3200m asl. Based on the timing of glacier advances of similar extent in other regions of the Himalaya, Shiraiwa (1993) speculated that the Lama Stage is equivalent to the early Last Glacial, and the Gora Tabela Stage is equivalent to the Last Glacial Maximum (LGM). The remaining stages are defined by morphostratigraphy, relative dating methods, and seven radiocarbon dates obtained by Shiraiwa et al. (1990) and five radiocarbon dates undertaken by Watanabe et al. (1998). The Holocene chronology is summarized in Watanabe (1998): Langtang Stage (3650–3310 14C yr BP), corresponding to the greatest advance during the Holocene, followed by three smaller advances, Lirung Stage (2800–2000 14C yr BP) and two recent advances, Yala I (0550 14C yr BP) and Yala II(1910 AD).

Shiraiwa and Watanabe (1991) logged 12 sections from fan/terrace surfaces and moraines throughout the Langtang Khola Valley, focusing on the broad, relatively flat surfaces on the north side of the valley between Thyangshap and Sindum. Their results show that the sections comprise primarily bouldery diamicts of glacial origin, commonly lodgement and ablation tills, that have been reworked by fluvial activity. This reworking is expressed in the bedded sand units that commonly cap these glacial diamicts, and the terrace expression of their surfaces.

Shiraiwa (1993) used a steady-state glacier model of the Langtang Valley to reconstruct the climate for the Gora Tabela Stage (summer precipitation reduced to 200 mm, increased winter balance to 400mm and reduced air temperature 6 1C) and for the Langtang Stage (contemporary summer precipitation of 400 mm, increased winter balance to 300mm and decreased air temperature 4 1C). The model indicates that glaciers during the Gora Tabela Stage were supported by a non-monsoonal climate, demonstrating that Himalayan glaciers may advance during global cooling periods (cf. Sarkar et al., 1990; Owen et al., 1998). A more limited advance is described during this time period in the Khumbu Himal (Finkelet al., 2003).

Heuberger and Ibetsberger (1997) disputed the proposed Langtang Stage of Shiraiwa and Watanabe (1991), suggesting that such an extensive valley glaciation at this time was impossible based on the relatively limited extent of other Himalayan glaciers during this period. However, significant advances of glaciers during the Mid-Late Holocene have been defined in Garhwal (Sharma and Owen, 1996; Barnard et al., 2004b).

Although the regional differences exit, growing evidence showed that the glaciers of the Himalaya are receding faster than the world average (Thompson, 2007) and are thinning by 0.3-1 m/year (Dyurgerov and Meier 2005). In the last half century, 82 % of the glaciers in western China have retreated (Liu et al. 2006). On the Tibetan Plateau, the glacial area has decreased by 4.5% over the last twenty years and by 7 % over the last forty years (CNRCC, 2007). Most glaciers studied in Nepal are undergoing rapid deglaciations. The reported rate of glacial retreat ranges from several meters to 20 m/year (Fujita et al.2001a; Fujita et al. 1997; Kadota et al. 1997).

Based on prior studies, Fort (1996) estimated the equilibrium line altitude (ELA) depression during the Langtang Stage to be 600m below the present ELA of 5320 m. Baumler et al. (1997) substantiated the dating of Shiraiwa et al. (1990) by producing equivalent dates for the Langtang Stage by dating organic material that overlies till associated with the Langtang Stage within the Sindum terrace (3140780 14C yr BP) and buried soils that overlie till linked to the Lirung Stage (25007111 14C yr BP, 2020785 14C yr BP, 11507120 14C yr BP; Table 1).

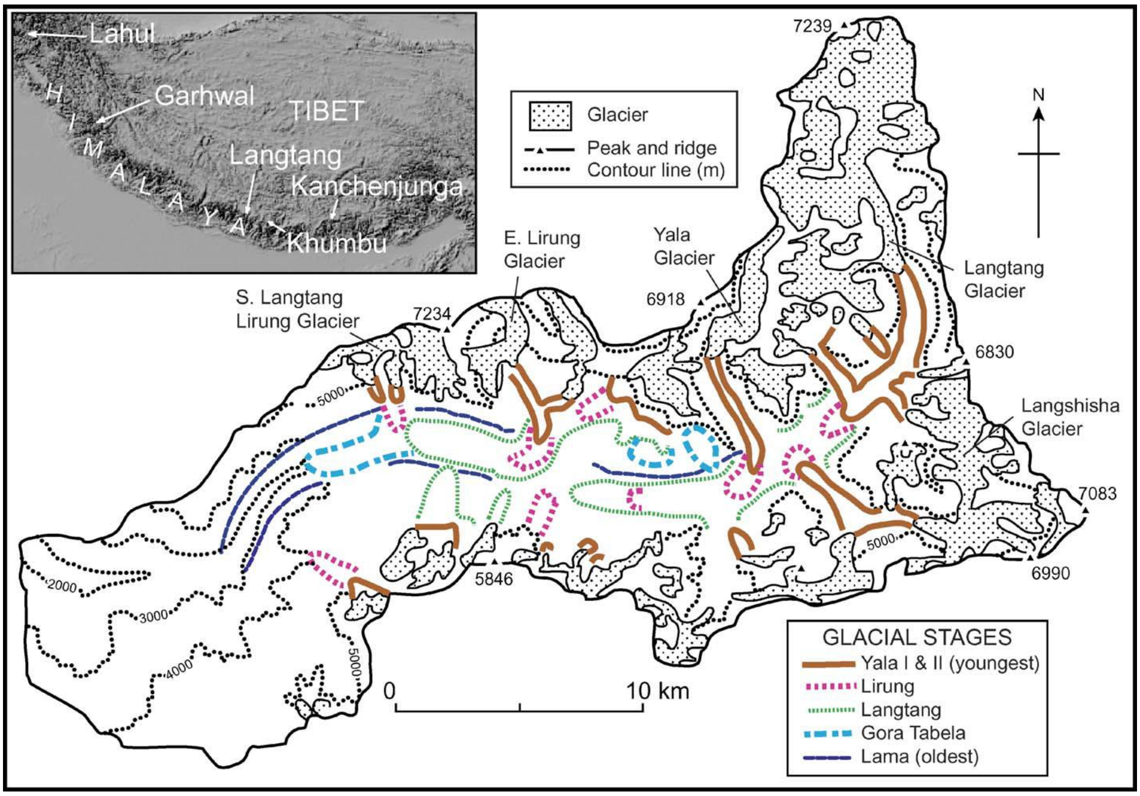


Fig. 1. Existing Langtang glacial chronology, modified from Shiraiwa and Watanabe (1991).

This can be described through the following table:

Table 1 : Existing Langtang glacial chronology

2164 *P. L. Barnard et al. / Quaternary Science Reviews 25 (2006) 2162–2176*

Table 1
The ^{14}C dating results and glacial chronology of Shiraiwa et al. (1990) = S, Baumler et al. (1997) = B, and Watanabe et al. (1998) = W

Glacial Stage	Time	Evidence	Sample no.	Location	Material	^{14}C date (yr BP)	Lab no.
YalaII	1910 A.D.	^{14}C dating	S1	Lirung Glacier, inner moraine	Organic layer	40±130	NUTA-740
Yala I	<550 yr BP	^{14}C dating	S2	Langshisha, valley train	Buried A-horizon	550±70	GaK-14029
			B1	Lirung moraine (precise location NA)	soil	1150±120	N/A
Lirung	2800-2000 ^{14}C yr BP	^{14}C dating	W1	Sindum	buried soil	1980±60	Beta-81006
			B2	Lirung moraine (precise location NA)	soil	2020±85	N/A
			B3	Lirung moraine (precise location NA)	soil	2500±111	N/A
			W2	Sindum	buried soil	2530±100	Gak-15792
			W3	Sindum	buried soil with charcoal	2800±90	Beta-94734
			S3	Tangdemo, slope deposit	Buried A-horizon	2800±110	GaK-10996
			S4	Mundro, till	Buried A-horizon	2850±140	NUTA-739
			S5	Lharung Chu, till	Superposed A-horizon	2980±110	GaK-14028
Langtang	3650-3310 ^{14}C yr BP	14C dating	B4	Sindum terrace	soil	3140±80	N/A
			W4	Sindum	layers of pure charcoal	3190±100	Gak-15793
			W5	Sindum	layers of pure charcoal	3310±80	Gak-15794
			S6	Mundro, till	Buried A-horizon	3650±320	GaK-10997
			S7	Mundro, till	Wood, not in situ	3860±110	GaK-14027
Gora Tabela	LGM	weathered till to ~3200 m asl	none	N/A	N/A	N/A	N/A
Lama	Last Glacial	U-shaped valley to ~2600 m asl	none	N/A	N/A	N/A	N/A

Watanabe et al. (1998) used radiocarbon to date charcoal fragments and soils within debris cones in the Langtang Valley. They showed that major debris cone sedimentation was initiated immediately following the termination of the Langtang (3310 14C yr BP) and Lirung (2000 14C yr BP) Stages. Based on the incision of the debris cones, they were able to calculate Late Holocene sediment denudation rates in the Langtang Valley that ranged from 3.2 to 15.6 mm/a. Debris flow was the dominant means of sediment transport onto the debris cones, but modification by debris avalanche, rock fall, glaciers and fluvial erosion was also common (Watanabe et al., 1998).

Shrestha et al. (1999) reported temperature increase of 0.06 °C to 0.12 °C per year in most of middle mountain and Himalayan regions while Siwalik and Tarai region showed warming trend of less than 0.03 °C /year between 1971 – 1994.

These prior studies suggest that periglacial processes are particularly prevalent and important in this high mountain environment. Many other workers have also recognized that the alluvial/debris flow fans within the Himalaya are the result of rapid sedimentation during periods of deglaciation (Derbyshire and Owen, 1990; Owen et al., 1995; Owen and Sharma, 1998; Barnard et al., 2004a, b, 2006). These findings are similar to studies completed in other glaciated environments that illustrated the significant role of periglacial processes in landscape evolution (Ryder,1971a, b; Church and Ryder, 1972; Ballantyne and Benn,1994; Ballantyne, 1995, 2002, 2003).

Gurung and Bajracharya (2012) assessed the effects of climate change on glacial retreat and its associated hazards (e.g. GLOFs), but these studies gave more focus on the effects of climate change on Himalayan vegetation, as well as plant succession on recently deglaciated soils. Mountain communities are highly dependent on natural resources for the ecosystem services that they perform: provisioning services (genetic resources, food, fiber, fresh water, etc.); regulating services (regulation of climate, water and human diseases); supporting services (productivity, soil fertility and nutrient cycling); and cultural services (spiritual enrichment, recreation, aesthetics, etc.) (ICIMOD, 2009). Therefore, understanding the effects of climate change on Himalayan soil and vegetation dynamics is important for assessing impacts on mountain livelihoods, as well as for implementing effective conservation strategies.

SAGUN Program,(2009). The impact of climate change was severe on biodiversity and livelihoods of communities in the study areas. Drought and floods disrupted rural livelihoods by posing a threat to agriculture, biodiversity, health and infrastructure. Major impacts were observed in agriculture and natural resources like forests, wetlands and pastures. Frequent flooding washed away thousands of hectares of productive agricultural land, destroyed crop yields, damaged houses and infrastructure, took human and livestock lives, and contributed to outbreak of diseases. Similarly, drought resulted in decline in crop productivity, loss of local crop species, drying of water sources (wells, ponds, and springs), and outbreak of pests and diseases. Extreme climate events forced thousands of people to leave their homes, destroyed wildlife habitat and increased human pressure on forest resources due to reallocation and resettlement. Change in rainfall and temperature resulted in changes in plant behavior like early flowering, shift in vegetation line (i.e. expansion of habitat of crops and species), and loss of some valuable species and NTFPs (Non Timber Forest Product). These changes indicate that unpredictable climate variability will be a major obstacle for subsistence-based livelihoods in rural areas of Nepal.

According to (Tiwari, Awasthi, and Ball, 2011), the study shows that adaptation measures such as use of water source, community forest management, planting trees and grasses in the farm land, crop diversification were practiced by local people in their farm land as well as communal land. Natural resource degradation, poverty are already severe problems in this region, and there will be more severe problems in future if present scenario continues, particularly because small farmers do not have adequate resources to adopt to cope with CC impact. The study showed that Mid-mountain region is less vulnerable through climate change than other regions. Furthermore, no any policies and programs have been formulated for adaptation strategy in this region. It is suggested that policy and program should formulate holistic approach and develop low cost technology for adaption to CC impact and improve livelihood of the local communities.

Increase in temperature and precipitation in Himalayas accelerates the process of ice/snow melting as well as enhances flooding event from direct runoff whereas dry season discharge i.e. base flow is decreased. The change in climatic parameters is projected to have adverse effect on water storage capacity of the Nepalese Himalayas. The major concern is rapid reduction of glaciers in much of the Himalayan region and shifting upwards of snow line.

2.2 Research Gap

Many attempts have been made to research on climate change and its impact. Most of these researches have focused on the extreme events like flood, drought and snow line. Climate change studies in Himalayan regions have focused mainly on the glacier melting, retreating, Glacial Lake Outburst Flood (GLOF), its trend and impact of climate change. Recently researches have been started to study about the adaptation strategies of local people in the context of changes in glacier and periglacier environment but so far, few research has been carried out in Nepal. Hence, this study is carried out to investigate the people's adaptation strategies in the region which are most vulnerable to climate change, so the above research is more relevant for this research.

CHAPTER - III

RESEARCH METHODOLOGY

3.1 Research Methodology and Sequence

The whole research work has been divided into three major parts. First part considers the pre-field work which includes literature review, proposal development, map collection, inventory sheet development and field preparation. The second part is related to field work. During the field work, primary and secondary data were collected and field observation was made. The third part of the study is the analytical work including literature review, digitizing satellite image, verification of field report, and result analysis. The flow chart of research methodology and sequence are shown in figure 3.2.

3.2 Methodological Framework

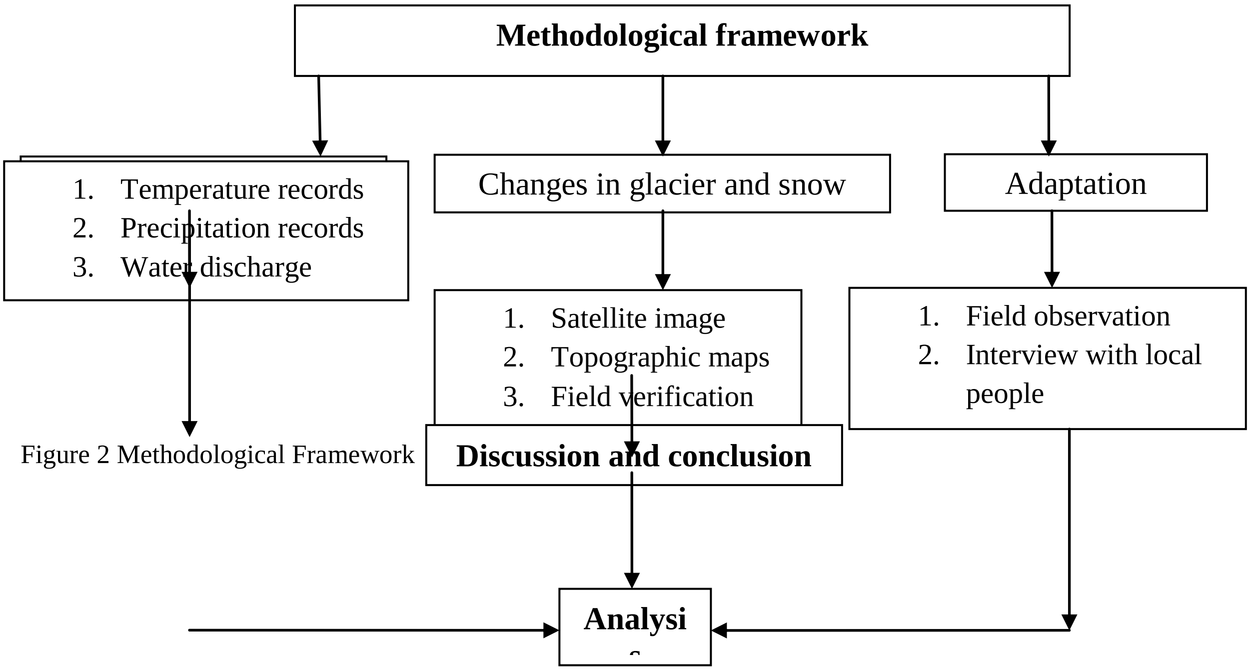


Figure 2 Methodological Framework

3.2.1 Pre Field Work

The study started with a review of previous research about glacier retreat and related aspects. The main findings are incorporated in the research proposal and formulating the major objectives to address the existing research problem. Langtang Valley is selected as the study area. Satellite imageries are used as the main base image to identify the glacier situation in the field, which was made available by ICIMOD Nepal, Kathmandu. Before going to the field, image processing and image interpretation were done which is discussed in detail in data processing section. Inventory sheet for data collection are prepared to collect information of climate change and effect of local people like the socio economic impact, biodiversity, forest, agriculture, water etc.

3.2.2 Field Work

The field work was divided into two parts, primary data collection and verifying the available data. A primary data collection of field study of one 15 day was conducted from May 11 to 29. And other related secondary data are collected from the various sources available libraries and wed site.

3.2.3 Post Field Work

At first, I digitized the three times map. Land use/cover map was digitized in the Arc GIS 10 environment. In GIS each changes was separated and numbered with its unique futures during the field survey. All attribute information of the Langtang valley is entered in excel format and then converted in to dbase file for the GIS format and joined the attribute table. After completion of the GIS Map work, Land use/cover e map analysis was done. Calculate the precipitation, temperature and discharge data and to make a appropriate diagrams and charts.

3.3 Data Sources

3.3.1 Primary Data

The primary data of Langtang valley are collected from the house hold survey. All individual buildings were visually observed and had filled the related questionnaires from every household.

3.3.2 Secondary Data

The secondary data are collected from various sources. The base map of the Langtang valley and toposheet are collected from Topographic Department of Survey Nepal. Some other relevant information of the Langtang valley is collected from the ICIMOD, FRA office, Central library T.U. and Department library of Central department of Geography T.U. Beside these other published and unpublished books, journals, reports, newspapers, and dissertations related to this tropic were reviewed.

Table 2 Sources of data

S.N.	Description	Source	Map scale	Year
1	Digital layer map in GIS	LRMP	1:25,000	1978
2	Toposheet	Topographical survey branch	1:25,000	1996
3	Satellite Image	Landsat	15m / 30m	1988, 2000, 2009
4	Primary data	Field survey		May 11- 29, 2012

3.4 Method of Data Collection and Processing

This research was conducted in Langtang valley. Temperature and precipitation records published by DHM were collected for Dhunche and Kyanjin meteorological stations as well as other 22 surroundings stations. Satellite images and aerial photographs of last 30 years was collected. Available temporal satellite image (1988, 2000, 2009) is analyzed to identify the retreat rate of glaciers. At first Geo-referencing the Landsat Image 1988, 2000 and 2009 then projection matching, digitizing, error correction, smoothing and classify the image. After calculate the glacier, snow and other land cover area land use/cover map was done. Then projection matching of 1996 topomap and merge the toposheets like sheet no 288510, 288511, 288515, 288516, 288514a, 288514b, 288514c, 288514d. Household survey and group discussion also carried out for the perception and response survey to address the issues of climate change and its impact on adaptation patterns like – biodiversity, livestock grazing, agriculture, forest products, health and sanitation, infrastructure development, drinking water, and related hazards.

To study the impact of climate change on snow and glacier, following data were collected and analyzed to get the results.

- Hydro-meteorological data, i.e., temperature, precipitation etc. in the study area.
- Topographic data, i.e., contour, settlement, drainage pattern etc.
- Remote sensing data i.e. snow cover and land cover extant of the study area.
- Household survey and group discussion.

3.5 Data Processing Tools

The available data from primary and secondary sources has been processed by using descriptive statistical techniques. All spatial data has been analyzed in ERDAS IMAGINE 9.2, ArcGIS 10, and ArcView GIS 3.2a. Microsoft excel format to calculate the daily climatic data and data coding from household survey.

3.5.1 ERDAS IMAGINE 9.2

The present study ERDAS IMAGINE 9.2 tool to do geo-reference, digitizing, projection matching, error correction, smoothing, edge matching and cutting the main base image of the research area.

3.5.2 Geographic Information System (GIS)

Geographic information system is a set of tools for collecting, manipulating, storing, and displaying geo referenced data. It provides various capabilities like data input, used to prepare the different map (land cover map, change map, drainage map etc), beside this, it is used for editing and digitizing the shape map based on field survey. In this study, the researcher has used Arc view GIS 3.2a and ArcGis 10 software to prepare various maps.

3.5.3 Microsoft Excel

All the finding data of social survey and climate like precipitation, temperature etc are tabulated in the Microsoft excel. After completed to the tabulation then these data are making a appropriate bar diagram and suitable charts.

3.6 Data Analysis and Presentation

All the data have been analyzed and presented to fulfill the objectives. The raw data collected from the field survey are edited and then processed through data processing, editing, coding followed by classification and tabulation. In this research, some statistical tools like co-relation, percentage, average, ratio etc. have been used to analyze the data. To illustrate the research work, necessary tables, chart, diagrams and map has been used for the clarity of the data presented. The required data for this research are acquired as described below.

3.6.1 Hydro-Meteorological Data

The hydro-meteorological data like temperature and precipitation are acquired from the Department of Hydrology and Meteorology (DHM) Nepal. The data acquired from the DHM are daily meteorological data, i.e., temperature, precipitation at Kyanjin Station (3920 amsl)

3.6.2 Remote Sensing Data

For the delineation of snow cover and the land use pattern, the satellite images were used. Many commercial vendors acquire and distributed the satellite image with required spatial and temporal resolutions. LandSat 7 ETM+ consist of 30 to 15 m spatial resolution. These data are also provided free of charge by the International Center for Integrated Mountain Development (ICIMOD).

3.6.3 Preparation of Area Elevation Map

DEM model was prepared from the interpolation of contour and indicate spot height layer. ERDAS IMAGINE 9.2 software was calculated DEM. And the from DEM elevation range, seven elevation range at the interval of one thousand meter was produced from 1300-7200m.

3.6.4 Social Data Analysis

Data and information of all completed survey questionnaire were checked, sorted out and finalized. The computer programme based database sheet has been designed and the data entry has been made on Microsoft Office Excel programme. Information has been generated as required to meet the objective of the study. The method of analysis of the collected data has been based on both types such as quantitative and qualitative. Table, diagrams and graphs are used in the text wherever appropriate.

CHAPTER – IV

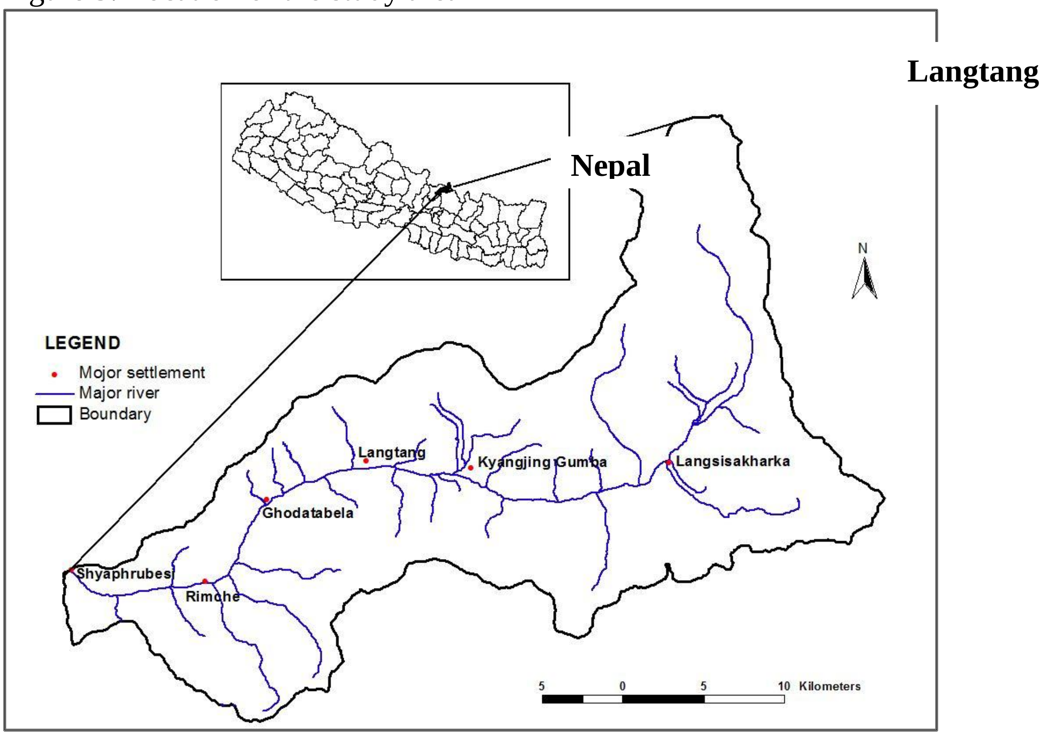
PROFILE OF STUDY AREA

The profile of study area intends to provide framework of understanding the overall condition of the study area. For understanding the natural resource, climatic condition, socio economic impact and physical integration of different places and region of the entire study area, a short description about biophysical and socio-economic condition has been described in the following section.

4.1 Spatial Setting

Langtang valley is located in some 60 km north of the Kathmandu. Geographically it is located between $85^{0}20^{'}$-$85^{0}47^{'}$E and $28^{0}5^{'}$-$28^{0}22^{'}$N, which covers 555.37 km^2 area. Langtang valley is an east–west running valley that nestles between two alpine ranges in the Nepal Himalaya. Elevations range widely from 1,300m at the valley's mouth to over 7,200m at its highest point, Mt. Langtang-Lirung. The high peaks and ridges of the Langtang Himal, which rise above 6,000 m, constitute the northern divide of the valley and act as a natural border between Nepal and the Tibetan Autonomous Region of China.

Figure 3: Location of the study area



Map source: Topographical Survey Department, 1994

4.2 Physical Setting

4.2.1 Topography and Drainage

Langtang valley is a mountain area with an altitude range 1300m at the valley mouth to over 7200m at its highest point, Mt. Langtang-Lirung. The altitude is gradually increased from the valley to mountain. The Langtang valley contains a number of glacier, debris, rock glacier, forest and narrow rivers.

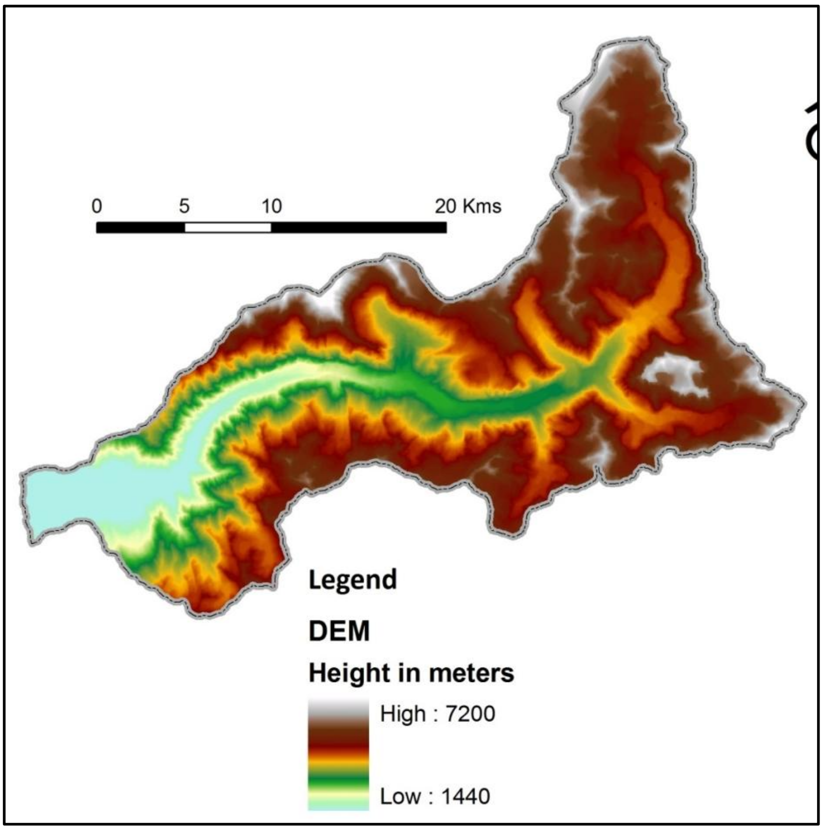
The southern divide is lower and provides the only way into the valley other than at the western end. At an altitude of 5,122 m, the Gangja-La pass serves as a gateway to the Helambu region to the south. Langtang is the longest glacier of Nepal. The Langtang Himal forms the western portion of a complex of mountains which also includes the Jugal Himal, home of Shisha Pangma. This complex lies between the Sun Kosi valley on the east and the Trisuli Gandaki valley on the west. Langtang Lirung lies near the Trisuli Gandaki, and north of the Langtang Khola. Langtang Lirung is the highest peak of the Langtang Himal, which is a sub range of the Nepalese Himalayas, southwest of the Eight-thousander Shisha Pangma.

Table 3: Distribution of Elevation Zones, Langtang valley

Elevation class(m)	Area (km)	Percent
1500 and Below	14.76	0.03
1501 - 2500	1513.77	2.73
2501 - 3500	3831.45	6.90
3501 - 4500	11708.65	21.08
4501 - 5500	27525.06	49.56
5501 - 6500	10458.86	18.83
Above 6500	484.85	0.87
Total	**55537.40**	**100.00**

Source: Department of Survey, 1996.

Figure 5 Digital Elevation Model (DEM) in Langtang valley



Source: Department of Survey, 1996.

.2.2 Climatic Condition

The valley’s climate is driven by the summer monsoon, which brings 80 percent of the year’s moisture in the form of rain on the valley’s terraces and plains and snow in the high mountains. From mid-October to mid-December and from mid-February until mid-April the weather is usually clear but cold at higher elevations. From mid-April to mid-June, it is warm but often cloudy with thunder showers, spring flowers are at their best. Summer monsoon lasts until the beginning of October. During the winter month’s daytime temperatures are low and snow may occur even at low levels. The summer rains are vital for crops and grasses during the short, single growing season, but associated erosion patterns also create ideal conditions for landslides and avalanches. Ono and Sadakane (1986) say that avalanches are one reason why the south-facing valley wall is not covered by forest, offering a refreshing alternative to claims that unforested slopes are the result of local misuse. Humidity and cloud cover increase with the monsoon (Timmerman and Platje 1989), and most afternoons a thick cloud, which is so reliable you can almost set your watch by it, is blown up the valley, shrouding everything in its path in mist. The cloud cover has the effect of keeping temperatures down in summer while the lack of it allows for more sunshine hours – and thus warmer temperatures – in winter. This means that the settled part of the valley does not normally experience extreme temperatures either way, which is to say it gets neither very hot nor very cold. Instead of the bitter cold of drier areas, it is the dampness in Langtang that bites.

4.2.2.1 Air Temperature

Figure 3 shows the average value of temperature for the period from 1988 to 2009 at the SGHU (Snow and Glacier Hydrology Unit) station (3920 m ASL.). The pre monsoon season, from March to mid-June, is characterized by gradual increase of air temperature. The monsoon season, from mid-June to the end of September, is dominated by positive values of air temperature. In this season, diurnal variation of the air temperature is generally very small due to a thick cloud cover (Shiraiwa et al. 1992). The monsoon season ends in the end of September and is followed by the post monsoon season, and the air temperature decreases gradually during. Mean monthly air temperature was calculated in this study area 2.3 °C in the dry season (October to June) and 9.2 °C during the monsoon season. The temperature remains below 0 °C for the months of December to middle of February. The temperature goes maximum during the monsoon season (June to August).

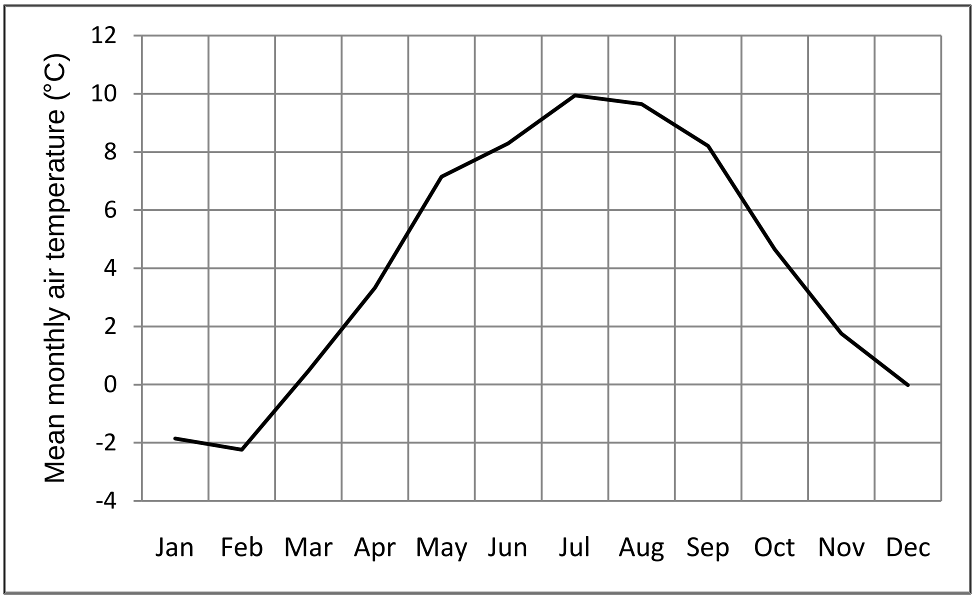


Figure 5 : Mean monthly air temperature (1988 to 2009) at SGHU station (3920 m ASL.)

4.2.2.2 Precipitation

The highest annual precipitation falls during monsoon season i.e. 74% in the period from 1988 to 2009 with average annual precipitation of 722.05 mm with daily average of 1.97mm at SGHU station. From June to August, total precipitation is large and it occurs almost every day. The SGHU station is located at the bottom of the valley at an altitude of 3920 m ASL, where less precipitation falls from the cumulus clouds as compared to stations along the mountain slopes as reported by Seko (1987) and Ueno et al. (1990).

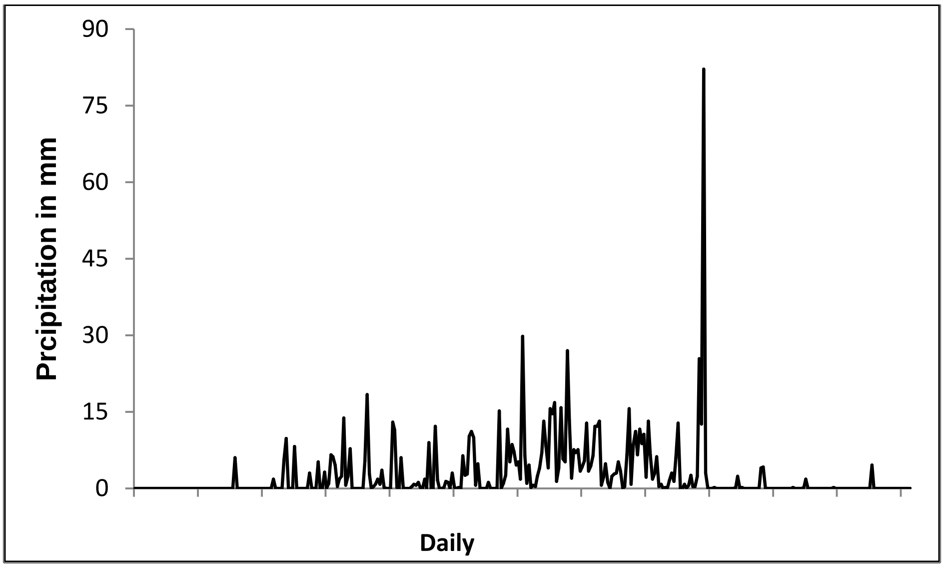


Figure 6: Seasonal variation of daily sums of precipitation at SGHU station (3920 m ASL), 2006

The precipitation data (1988 to 2009) analyzed for Langtang showed that most of the rainfall occurs in pre monsoon and monsoon seasons with 18.74 and 74.65% respectively. In winter and post monsoon only 4.09 and 2.5% of rainfall takes place in winter, 18.74% in pre monsoon and 2.5% in post monsoon seasons.

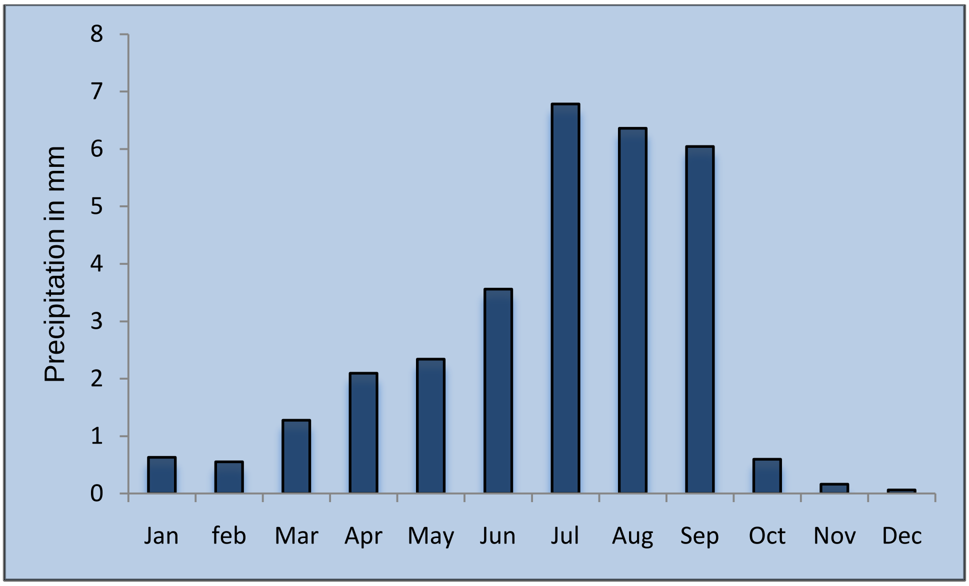


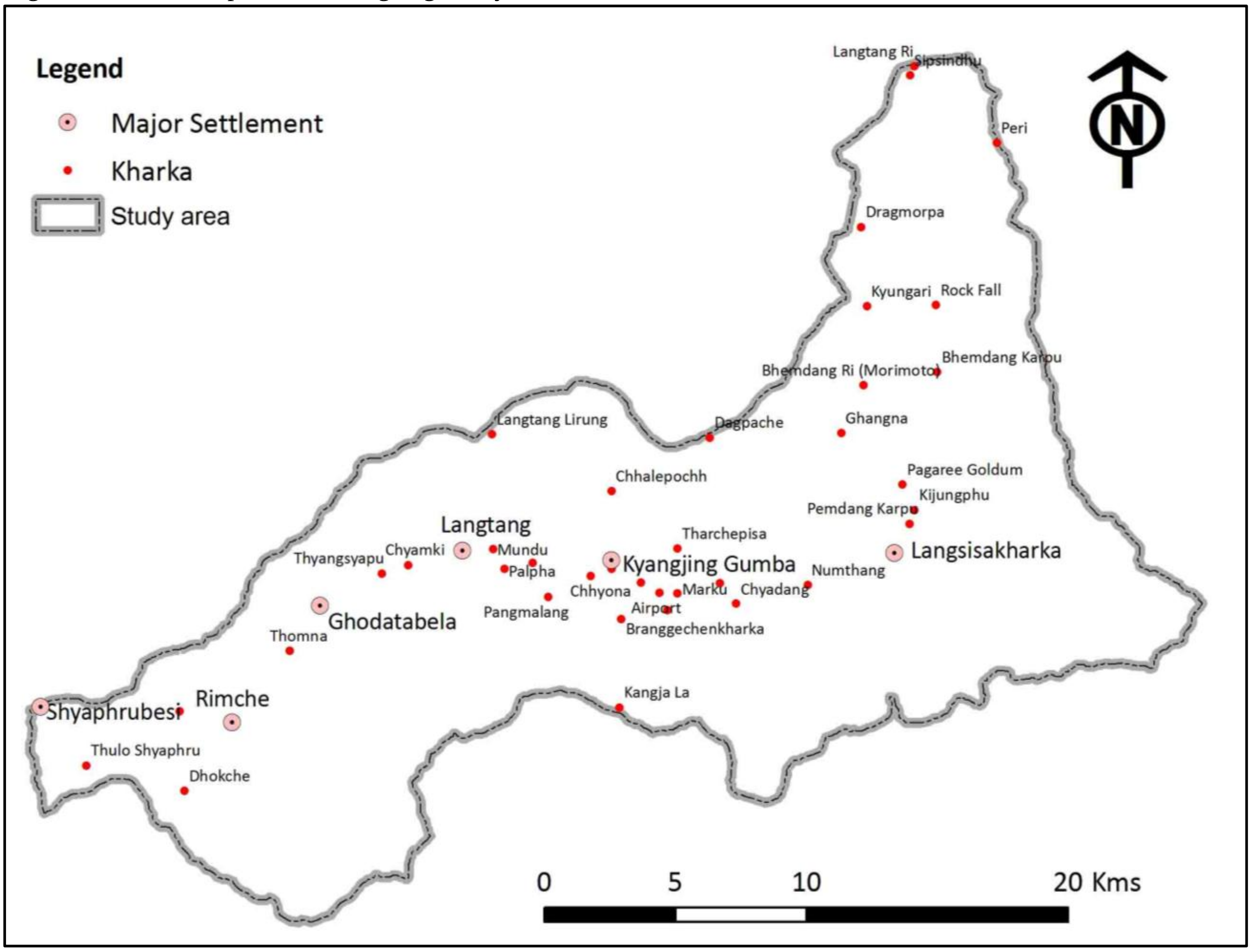
Figure 7: Daily mean precipitation of SGHU station (3920m ASL), as mean values from 1988 to 2009

Seko (1987) and Shiraiwa et al. (1992) observed that the amount of precipitation in an altitude of 5090 m ASL is almost 1.5 times higher than at the SGHU station (3920 m ASL) during the monsoon periods of 1986 and 1990. From June to September, precipitation amounted to around 820 mm at 5090 m and to 540 mm at SGHU station in 1990. From December to March, the amount of precipitation at 5090 m is twice as high as at 3920 min 1986. Based on these findings, a linear precipitation gradient can be estimated as 4.4 %/100m (Calculated from the previous measurements made by Seko & SGHU station data) (Ueno et al. 1990).

4.3 Social Settings

About 45 villages are situated within the park boundaries. In total about 3000 households depend on park resources, primarily for wood and pasture lands. Culturally the area is mixed, which is the home of several ethnic groups. The majority of people are Tamang, an ancient Nepalese race. The Tamangs, traditionally farmers and cattle breeders, are especially well known for their weaving. Their religion is related to the Bon and the pre-Buddhist doctrines of Tibet. Over the centuries the dependence of people on natural resources has influenced the environment. Their settlements, cultivation patterns, livestock grazing and daily use of resources which, in combination with the diversity of flora and fauna and views to make Langtang an attractive national park.

Figure 8: Settlement pattern of Langtang valley



Source: Department of Survey, 1996.

CHAPTER – V

RESULT

This chapter intends to examine the land cover/land use patterns with spatial emphasis to snow and glacier.

5.1 Land cover/Land use Change

Land use/land cover change has several consequences on climate, food security human health urbanization, biological diversity, trans boundary, migration and environment, water availability and quality ecosystem functioning and more and thus a significant cause of local as well as global change (Skole,1998, Turner et al.1995,Watson,1997,Goudie,1997).

Table 4: Coverage status of land use categories by year, Langtang valley

Land use categories	1988		2000		2009	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Glacier lake	19.1	0.03	20.1	0.04	48.2	0.09
Snow	23971.8	43.16	23698.9	42.67	21502.4	38.72
Glacier	5030.3	9.06	5042.2	9.08	5162.8	9.30
Rock/barren	7836.7	14.11	7984.8	14.38	9771.8	17.59
River	438.1	0.79	438.1	0.79	431.7	0.78
Bush	1780.0	3.21	1342.6	2.42	1871.8	3.37
Sand	342.4	0.62	342.4	0.62	351.8	0.63
Forest	6879.6	12.39	6721.1	12.10	6823.1	12.29
Alluvial Fan	19.2	0.03	19.2	0.03	33.5	0.06
Grass	9220.1	16.60	9927.8	17.88	9540.3	17.18
Total	55537.4	100.00	55537.4	100.00	55537.4	100.00

Snow, grass and rock/barren are the predominant categories in the Langtang valley as evidenced by the land use statistics shown in table 4. However, there has been change in proportionate area shown by their categories in the year 1988, 2000 and 2009. In 1988, both covered 43.16, 16.60 and 14.11 percent respectively of the Langtang valley area – at total area of 55537.4 ha. By 2000, snow coverage decreased to 42.67 percent while grass land increased slightly to 17.88 percent, and rock/barren has also slightly increased to 14.13 percent. Glacier lake and glacier has also increased by 0.03 percent to 0.09 percent and 9.06 percent to 9.30 percent between 1988 to 2009. It is a drastic change of glacial lake (which intends to supra glacier lake). By 2009, snow coverage had continuously decreased to 38.72

percent while grass land coverage was reduced to 17.18 percent and rock/barren land is highly increase 17.59 percent.

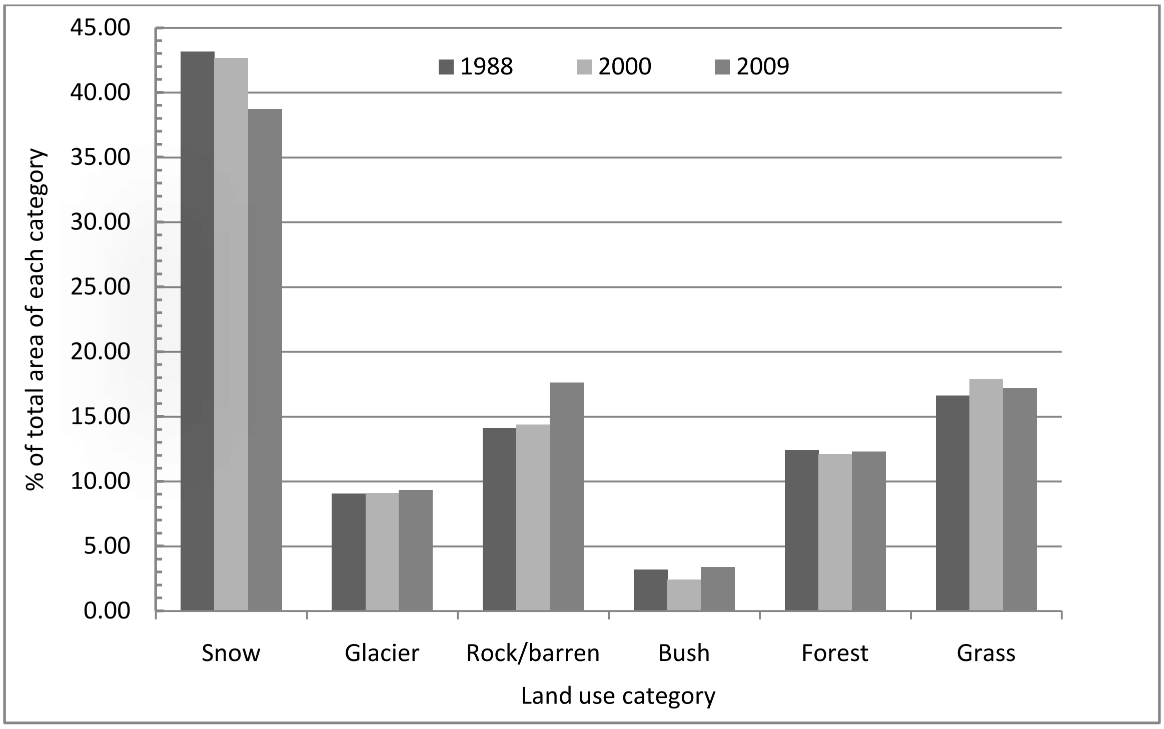


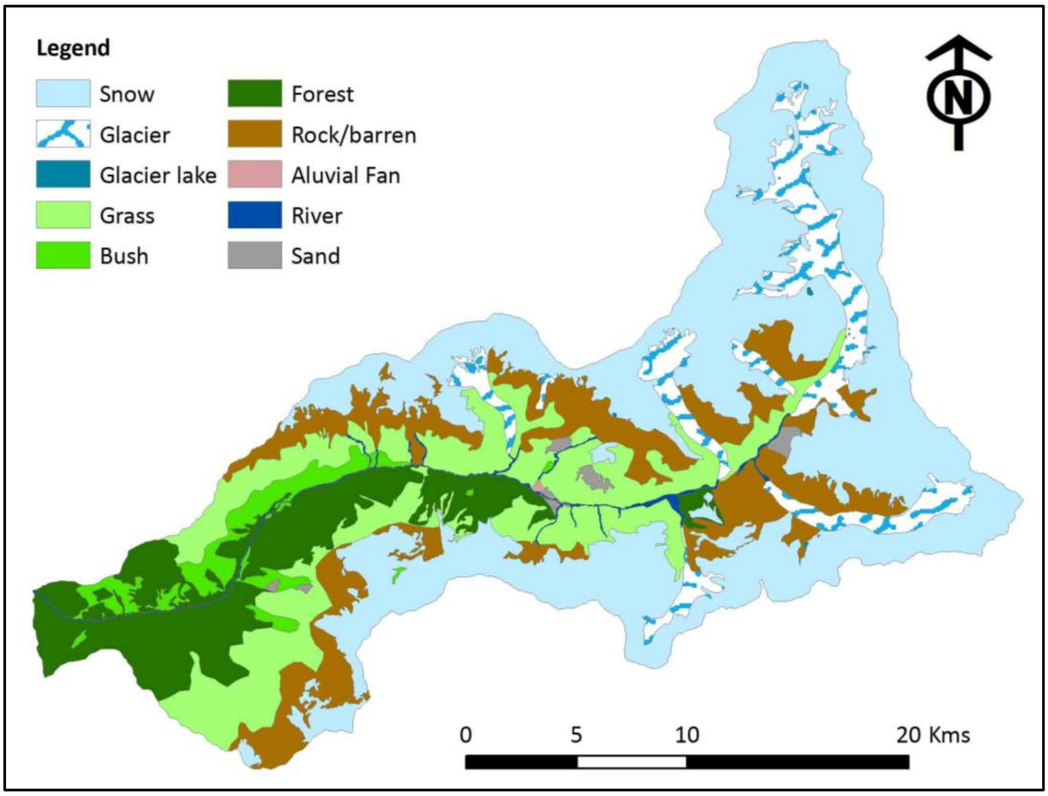
Figure 9: Coverage of land use categories by year, Langtang valley.

The coverage of bush remained to be at around 3.21 percent in the years 1988 and in 2000 it declined sharply to 0.78 percent but in 2010 again total area of bush is slightly increased by 0.95 percent. Forest experienced a decrease from 12.39 percent in 1988 to 12.29 percent in 2009. Grass coverage increased to 16.60 percent in 1988 and 17.88 percent in 2000 but in year 2009 the grass coverage is slightly decreased in 0.7 percent. Others sand coverage, alluvial fan and river have been not significantly changed.

From this analysis it can be interpreted that the main reason for the slight increment in glacier has been due to the increasing temperature. It is not due to the snow fall but due to the existing snow melting. If this was the result of snow fall, the glacier would move forward but the size is spreading wider due to melting of existing snow. Due to the same reason the rock barren has also been increasing day by day.

5.2 Langtang Valley 1988

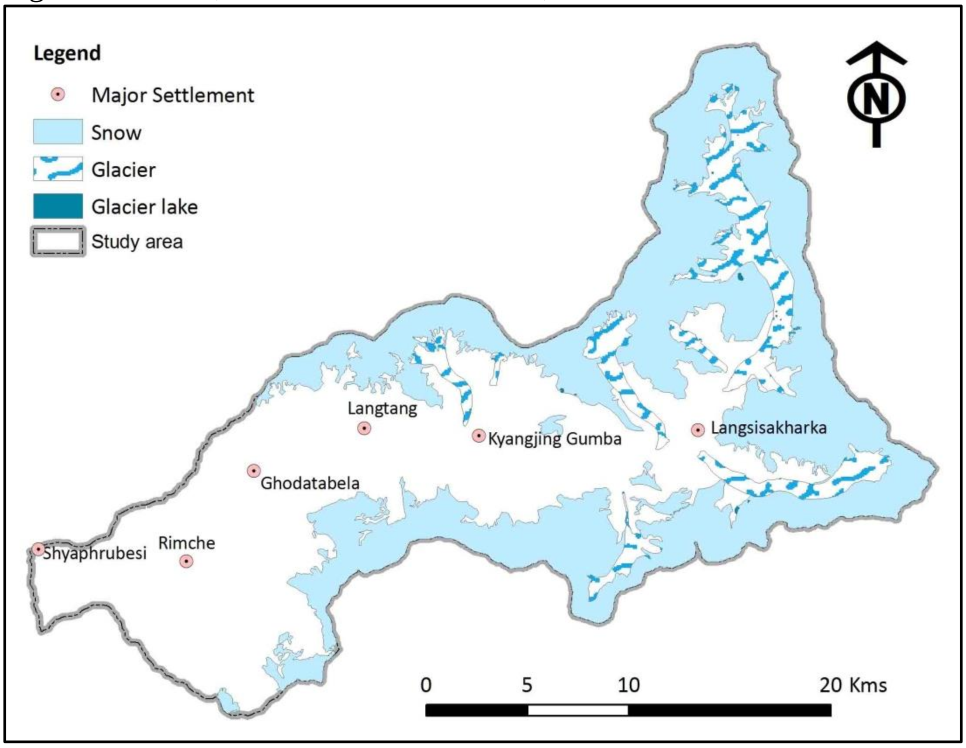
Figure: 10 Land use/ Land cover map 1988



Source: Landsat TM, 1988

5.3 Langtang Valley 1988

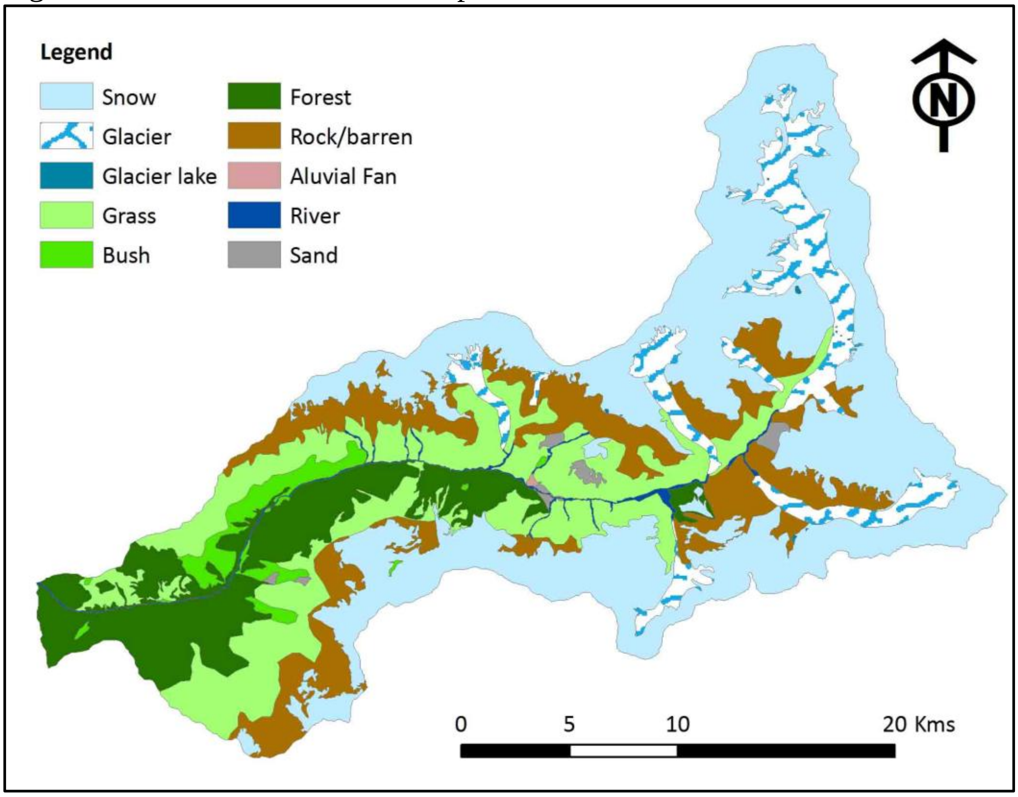
Figure: 11 Snow, Glacier and Glacier lake, 1988



Source: Landsat TM, 1988

5.4 Langtang Valley 2000

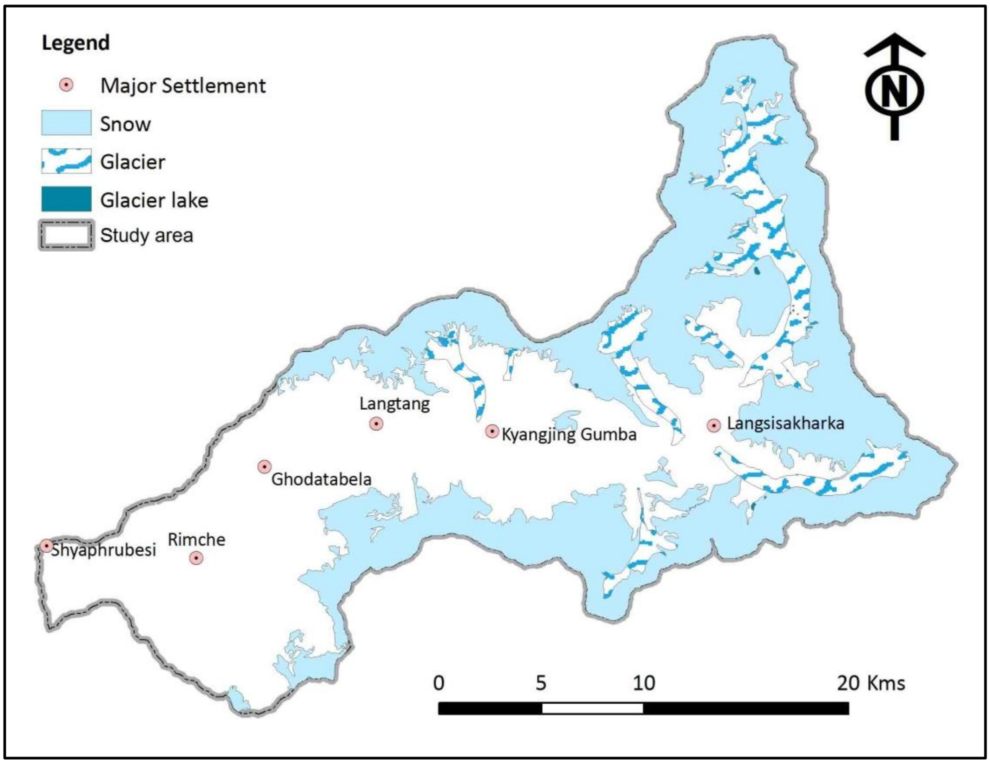
Figure: 12 Land use/ land cover map 2000



Source: Landsat TM, 2000

5.5 Langtang Valley 2000

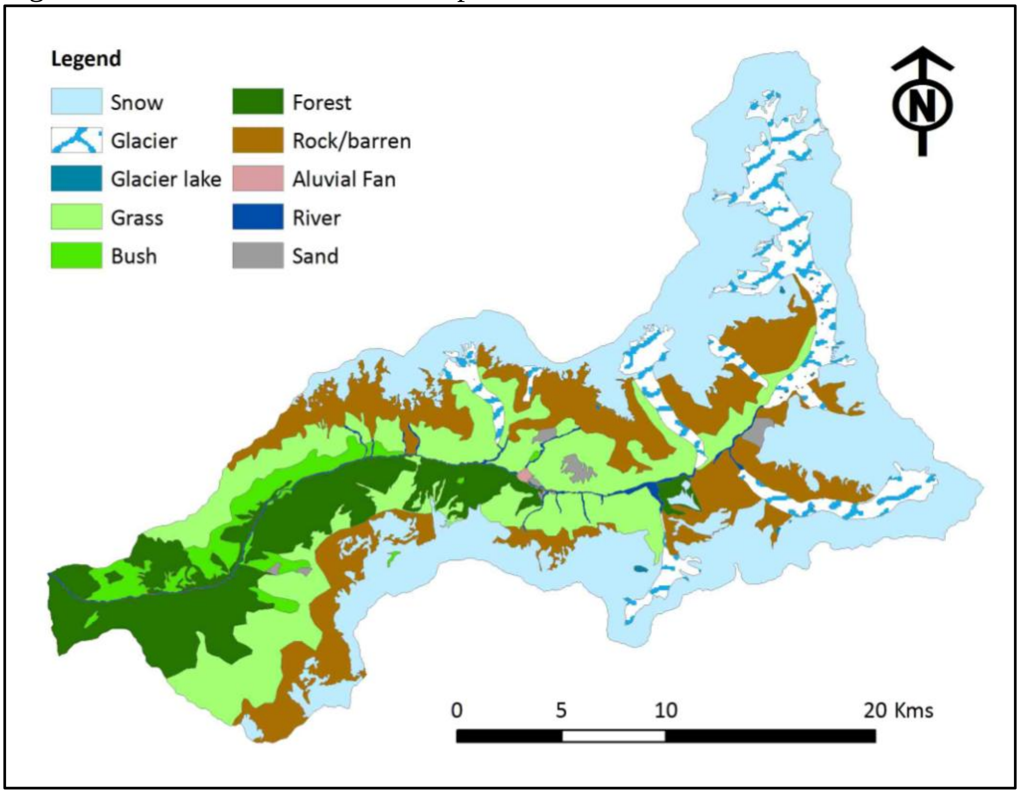
Figure: 13 Snow, Glacier and Glacier lake, 2000



Source: Landsat TM, 2000

5.6 Langtang Valley 2009

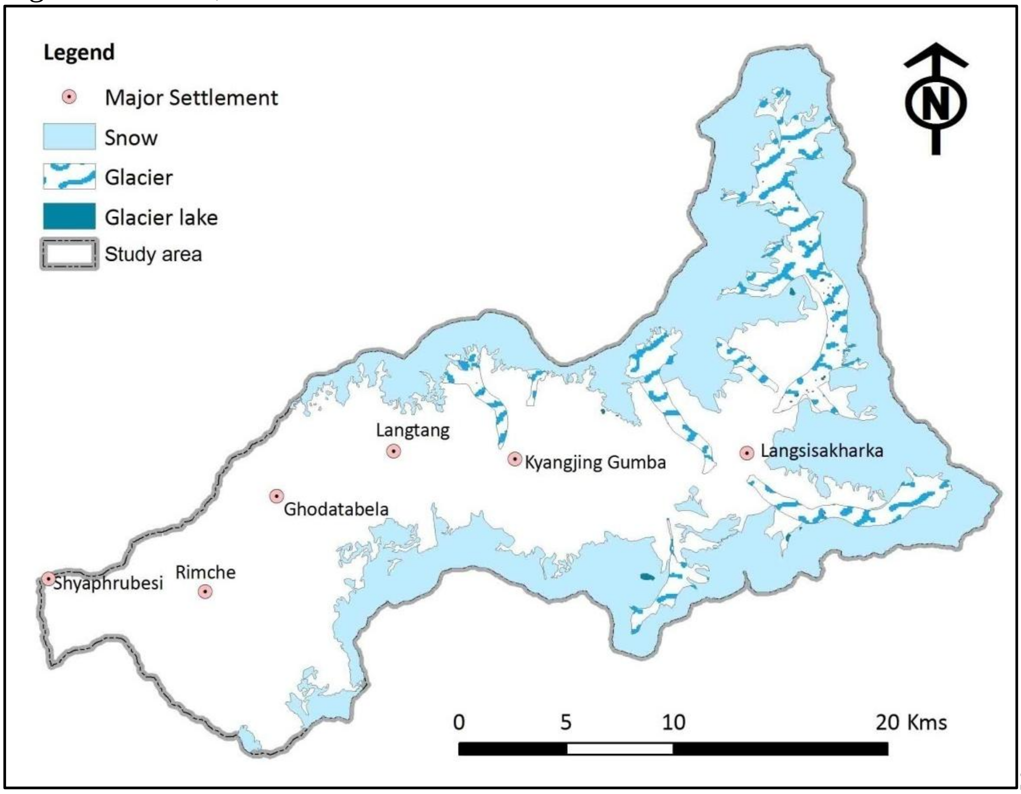
Figure: 14 Land use/ land cover map 2009



Source: Landsat ETM, 2009

5.7 Langtang Valley 2009

Figure: 15 Snow, Glacier and Glacier lake 2009



Source: Landsat ETM, 2009

The major change shows snow coverage area. The trend line of snow coverage is given below:

Figure 16: Snow covered area of 1988-2009.

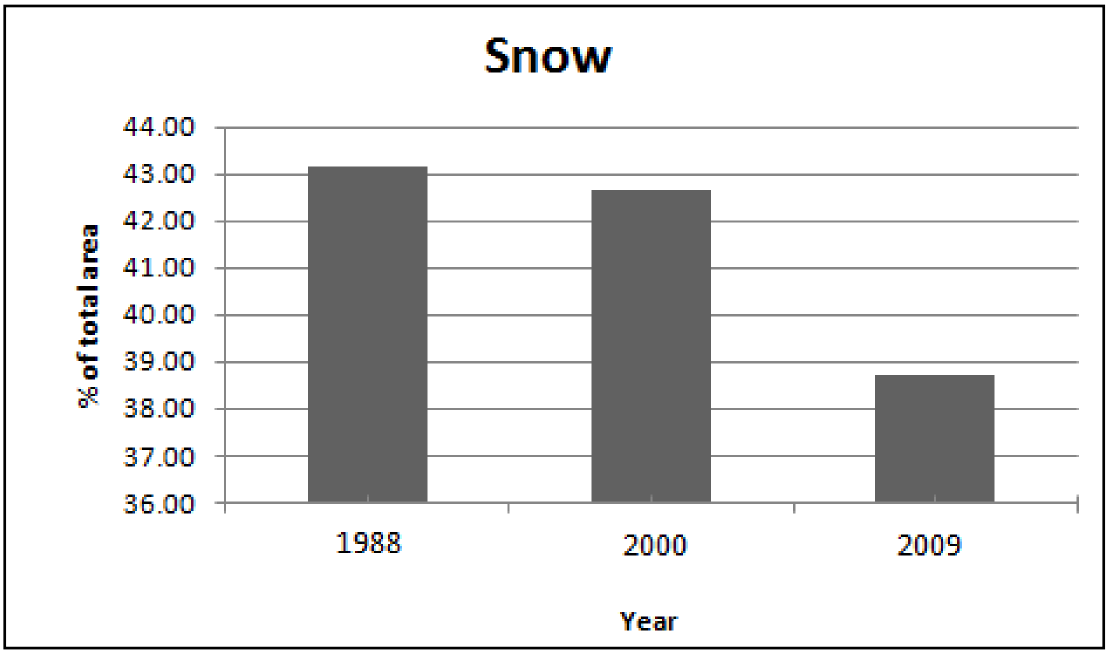


Figure 16 clearly shows that a snow coverage trend is continuously decreasing. In 1988, the total snow covered area was 23971.8 ha (43.16%) and in 2000 total snow covered area was 23698.9 ha (42.67%) which is decreased by 272.9 ha. In 2009 snow covered area is 21502.4 ha (38.72%) which was decreased by 2196.5 ha between 2000 to 2009.

The snow and rock/barren land are land cover categories of Langtang valley. The snow land alone shares about 38.72 percent of the total area, whereas the rock/barren land shares 17.59 percent. Other land use categories include grass, forest, glacier, bush, sand, glacier lake and alluvial fan.

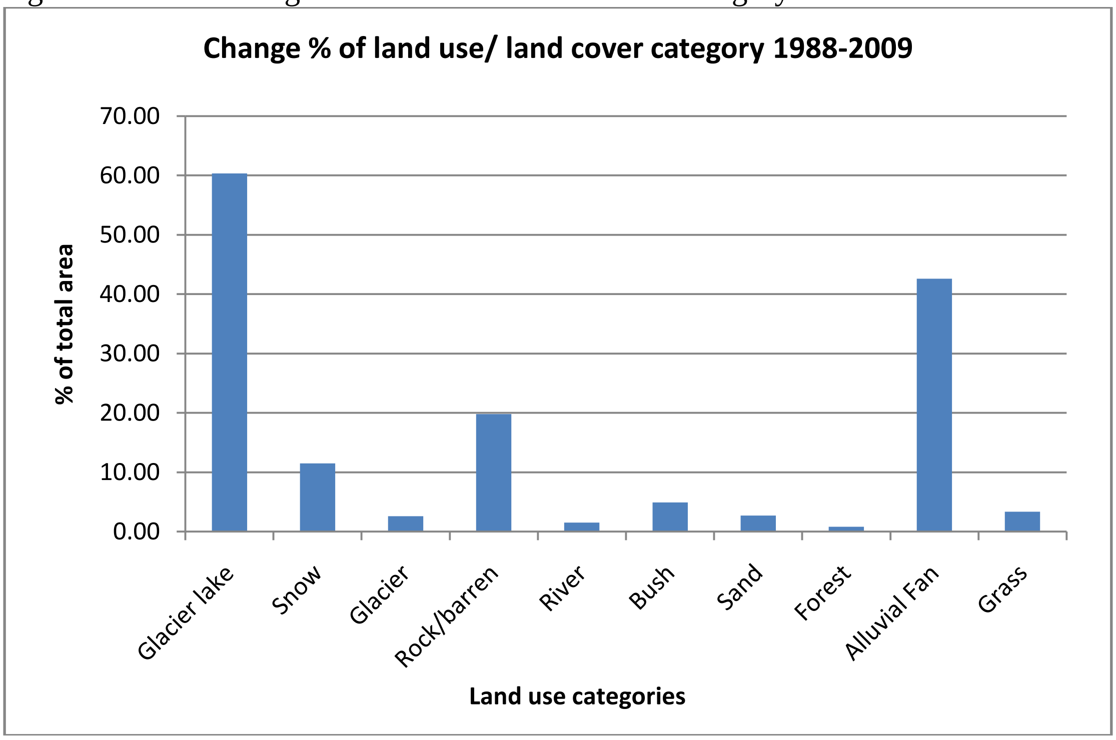
Changes have occurred in glacier lake, snow, rock/ barren, alluvial fan, grass, bush, glacier, grass and forest coverage. There was an increase of 24.57 percent in bush, 7.86 percent in grass, 5.34 percent in glacier lake, 2.30 percent in forest, 1.89 percent in rock/barren and 1.14 percent in snow between 1988 and 2000, while a no change of coverage in sand and alluvial fan between the same two years (Table 4).

Table 5: Magnitude in change (%) in land use categories by year, Langtang valley

Land use categories	1988-2000		2000-2009		1988-2009	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Glacier lake	1.0	5.34	28.1	139.36	29.1	60.34
Snow	272.9	1.14	2196.5	9.27	2469.4	11.48
Glacier	11.9	0.24	120.6	2.39	132.5	2.57
Rock/barren	148.1	1.89	1786.9	22.38	1935.1	19.80
River	0.0	0.00	6.4	1.47	6.4	1.49
Bush	437.4	24.57	529.2	39.41	91.8	4.91
Sand	0.0	0.00	9.5	2.76	9.5	2.69
Forest	158.5	2.30	101.9	1.52	56.6	0.83
Alluvial Fan	0.0	0.00	14.3	74.23	14.3	42.60
Grass	707.7	7.68	387.5	3.90	320.2	3.36

According to table 5, between 2000 to 2009 glacier lake had highly increased which is 139 percent. Similarly there was an increase of 74.23(28.1 ha) percent in alluvial fan, 39.41 percent in bush, 22.38 percent in rock/barren, 9.27 percent in snow, 3.90 percent in grass , 2.76 percent in sand, 2.39 percent in glacier,1.52 percent in forest and 1.47 percent in river between 2000 and 2009 (Table 3).

Figure 17: Total Changes % of Land use/ land cover category 1988 to 2009.



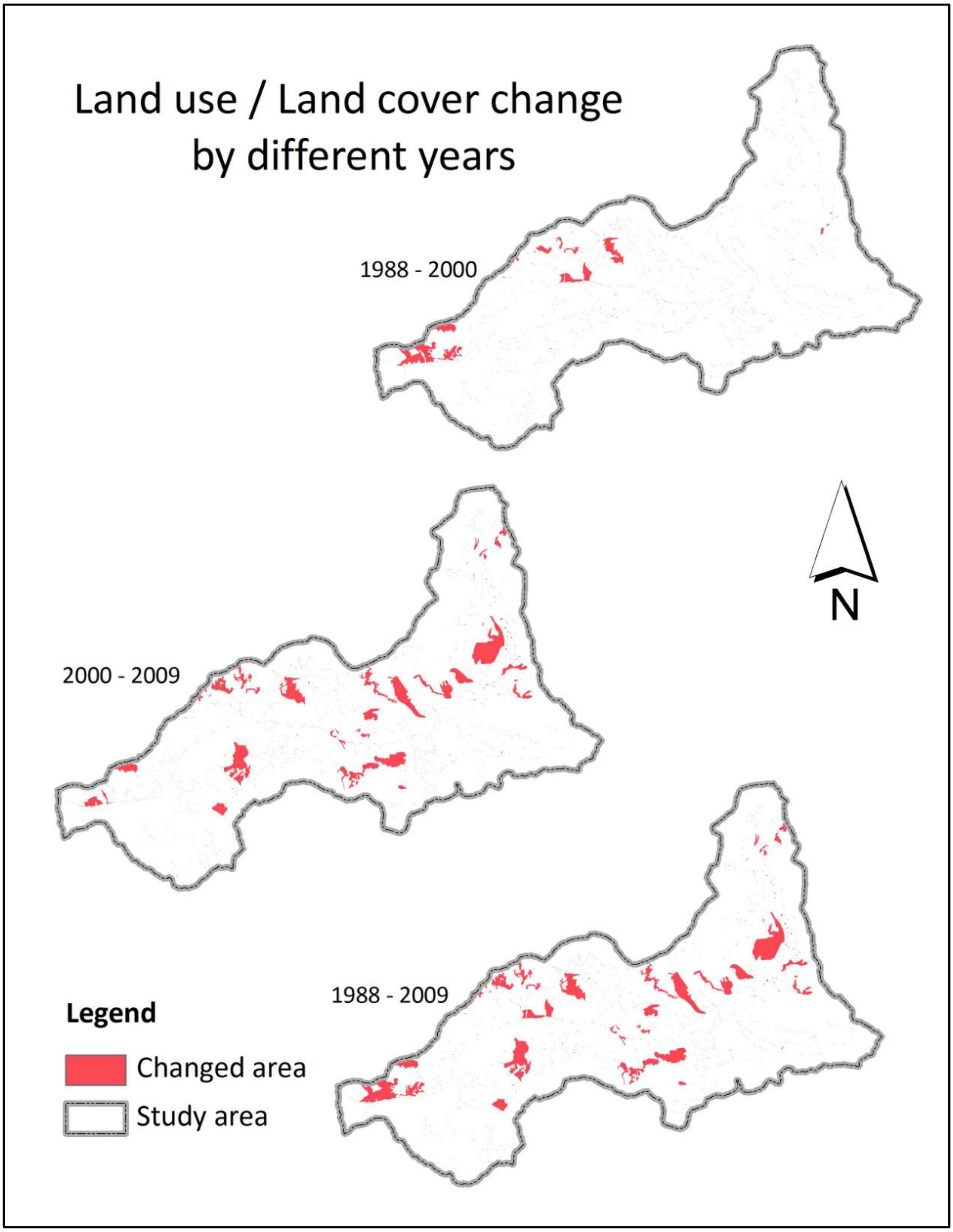
Over the last 21 years, the area of glacial lake has increased at 60.34 percent while that of snow increased at 11.48 percent. A remarkable change has occurred in glacial lake and snow over the past years. Table 3 depicts that the glacial lake had increased by an area of 29.1 ha, or by 60.34 percent during 1988-2009, while the rock/barren increased by 19.80percent (1935.1ha) during 1988-2009, similarly the glacier, grassland, sand, bush land, river area and alluvial fan had increased by 2.57 percent, 3.36 percent, 2.69 percent, 4.91 percent, 1.49 percent, 42.60 percent during the same years (1988-2009). Thus, over the past 21 years (1988-2009) the forest land declined by 1.52 and 0.83 percent respectively.

Table 6 : Overall Changes % of Land use category by year, Langtang valley.

Change/No change	1988 - 2000		2000 - 2009		1988 - 2009	
	area	**%**	**area**	**%**	**area**	**%**
Change	1112.6	2.0	3019.4	5.4	3055.6	5.5
No Change	54424.8	98.0	52518.0	94.6	52481.8	94.5
Total	**55537.4**	**100.0**	**55537.4**	**100.0**	**55537.4**	**100.0**

It is interesting to note that the patterns of change in 1988 to 2000 changed by 2 percent and in 2000 to 2009 changed by 5.4 percent. Overall change of 1988 to 2009 is 5.5 percent.

Figure: 18 Land use/land cover change in 1988-2009.



Source: Landsat imagery 1988, 2000 and 2009.

5.2 Climatic Condition

5.2.1 Temperature

The temperature data are available for the period of 1987 to 2009. The data from the automatic recording type are available from June 2002 to May 2009 only in electronic version from SGHU of Department of Hydrology and Meteorology. The average annual temperature is shown in figure 5.1 which shows a rising trend.

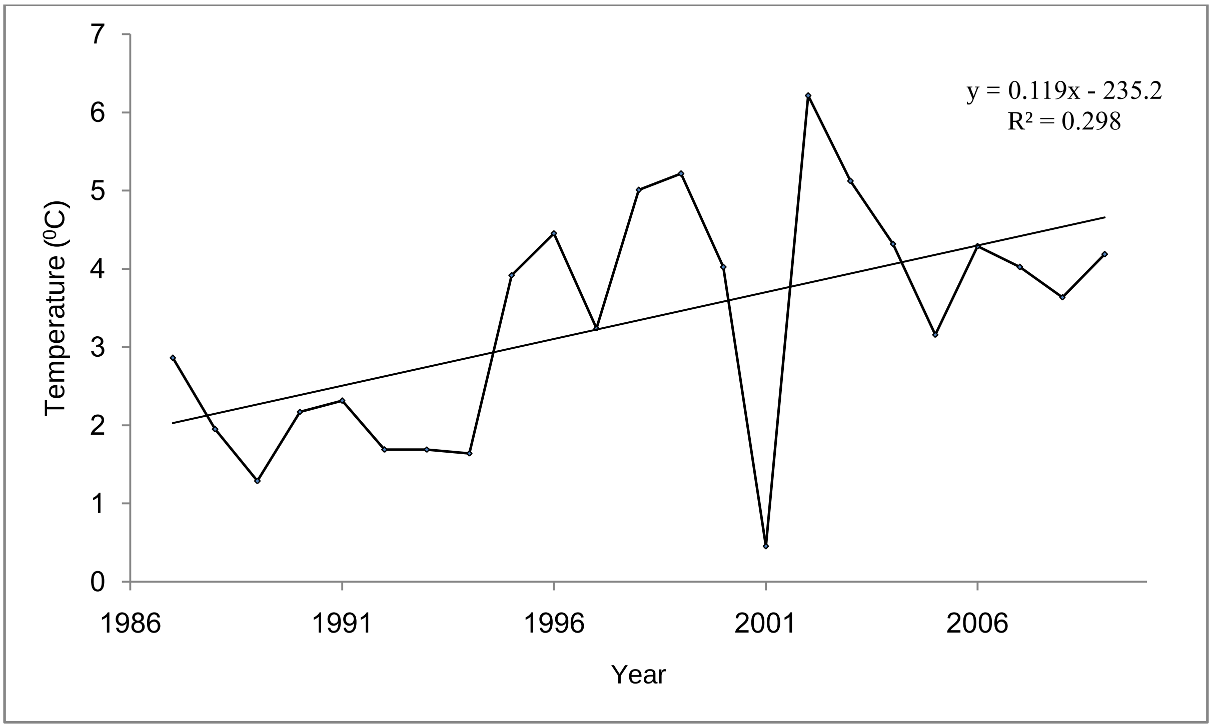


Figure: 19 Annual average temperature

The analysis of temperature data from 1987 to 2009 shows that the average daily temperature is 3.20℃, with standard deviation of 1.27. The fig 19 shows clearly increasing trend of temperature accorded at Kyanjin station (3920m ASL), at the rate of 0.119℃ per. The average annual temperature shows positive correlation with year i.e. 0.54.

5.2.2 Precipitation

Similarly, the daily rainfall data analysis of Kyanjin station indicates that the average precipitation from the year 1987 to 2009 is found to be 722.05 mm with a daily average of 1.97 mm. From this data, it clearly shows that the precipitation is also in an increasing trend with 15.44mm per year. There is a lot of fluctuation in rainfall but in general trend is increased. The annual precipitation shows positive correlation with year i.e. 0.44.

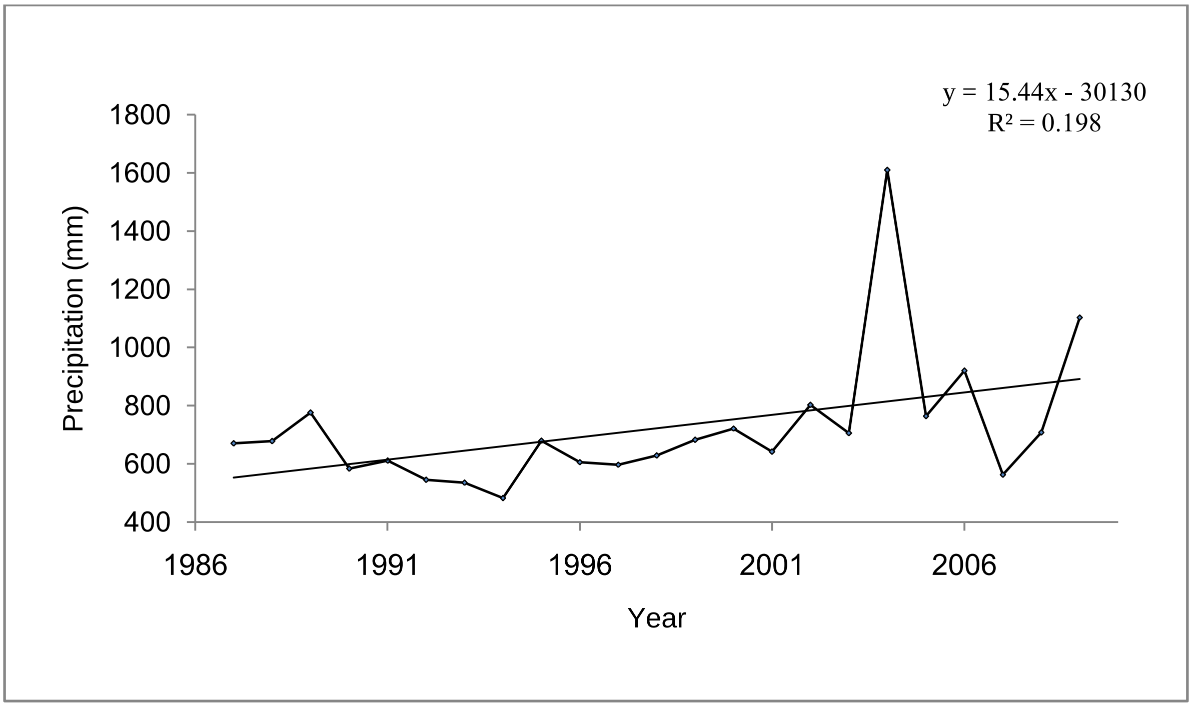


Figure: 20 Annual average precipitation at Kyanjin station

5.2.3 Annual Discharge

From the analysis of discharge data for 25 years, it is found that the average annual discharge trend has slightly increased at the rate of $0.017m^3/s$ with standard deviation of 0.067. The average annual discharge has weak positive correlation with year i.e. 0.05.

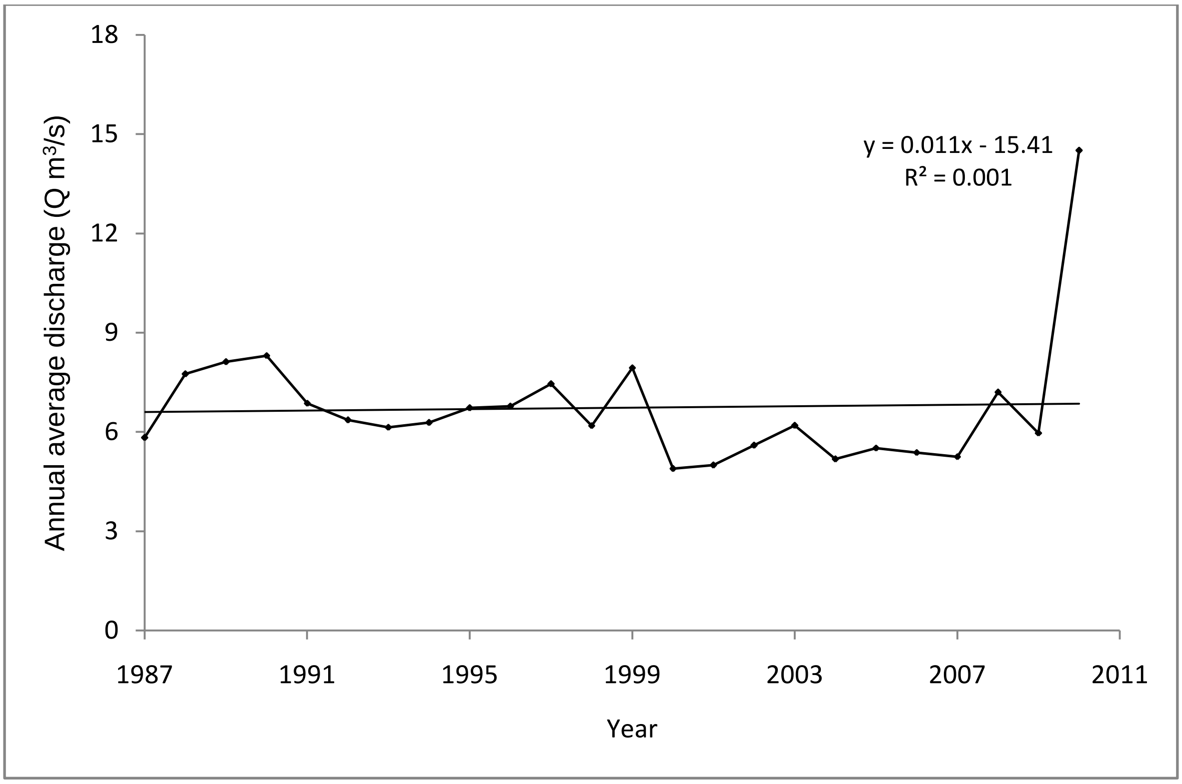


Figure: 21 Average annual discharge of Langtang

5.3 Adaptation

Adaptation to climate change refers to adjustment in nature or human system in response to actual or expected climatic condition.It is well known fact that climate change has significant implications for the environment, ecosystems, water resources and virtually every aspect of human life. One of the most important and immediate effects of global warming would be the changes in local and regional water availability. Such effects may include the floods and droughts, rainfall patterns, extreme weather events, and the quality and quantity of water availability, these changes, in turn, influence the water supply system, sediment transport and deposition, and ecosystem conservation. Some of these effects may not necessarily be negative, but they need to be evaluated as early as possible because of the great socio-economic importance of water and other natural resources (Jiang Tao et al, 2007).

This research paper impact of climate change in Langtang valley is trying to explore the causes of climate change in Langtang valley and its impact on people. As cited in methodology section this research is based on the information gathered from 34 randomly selected household in Langtang area. In order to eliminate the errors in getting information people have been asked questionnaire based on age range basis, which includes three age range group starting from 20 to 40, 40 to 60 and 60 to above years old. Both men and women were used as informants to ensure the accuracy of information.

According to the field survey and informants the primary cause for the climatic change in that region is due to global warming as snow areas are most sensitive to temperature. Langtang valley was a small mountainous valley having a couple of houses. Majority of people would engage in agriculture and livestock rising. Potato and buck wheat were the major crops grown in this valley. Abundant water resources for agriculture and drinking water had made living easy early days. Many wild animals and seasonal birds were other beautiful aspects of this valley. Snowy year, thick snow layer on rivers, cold wintery days in all seasons were the characteristics of this valley. Ever since the global temperatures began to rise gradually, the causes of snow area has decreased in the case with Langtang valley.

Table 7 People perception about adaptation

Impact	Yes	No
Cropping season shifting	24	10
Frost occurring months are changing/shifting	14	20
Water sources is drying	32	2
Grasses growing	28	6
Bird species disappeared	22	12
Animal increasing	18	16

This field survey reveals, once a very small pastoral village has now become a tourist destination as the melting of snows dragged attention to the people. Those small houses are now changing into big hotels and restaurants. According to table 7 people are now shifting their primitive agricultural activities to the hospitality industries as their crops could not grow efficiently due to drying of water resources. Potatoes, major crops for this belt can't get efficient water due to melting of snows and lack of frost. People can't grow other cereal crops as well because red monkeys basically migrated from hilly region for suitable habitat, destroy baby crops. Thus growing crops is now challenging. Animals like reindeers, peacocks, yaks that prefer cold climate have disappeared and new sorts of animals from hilly belt have moved to this place. However, grass for animals has now become sufficient as the frost and snow vanished forever. That is why people are now down to livestock raising. Climatic change in this area signifies certainly some sort of changes in living of people and the way they perform for living. In the early days, people of this region had to travel a lot for collecting grass for their cattle but now as the grass level has increased people don't have to struggle for grass. This has resulted in increase in animals which ultimately makes life easier in this region. This is significantly positive for people.

People are now experiencing more hot weather than past. Drinking water is now becoming more challenging because water resources are drying out. Thus they have to travel too far for drinking water. If it continuous then it might be more critical in coming future. Tourists and visitors are now growing. As a result it is becoming more polluted day by day.

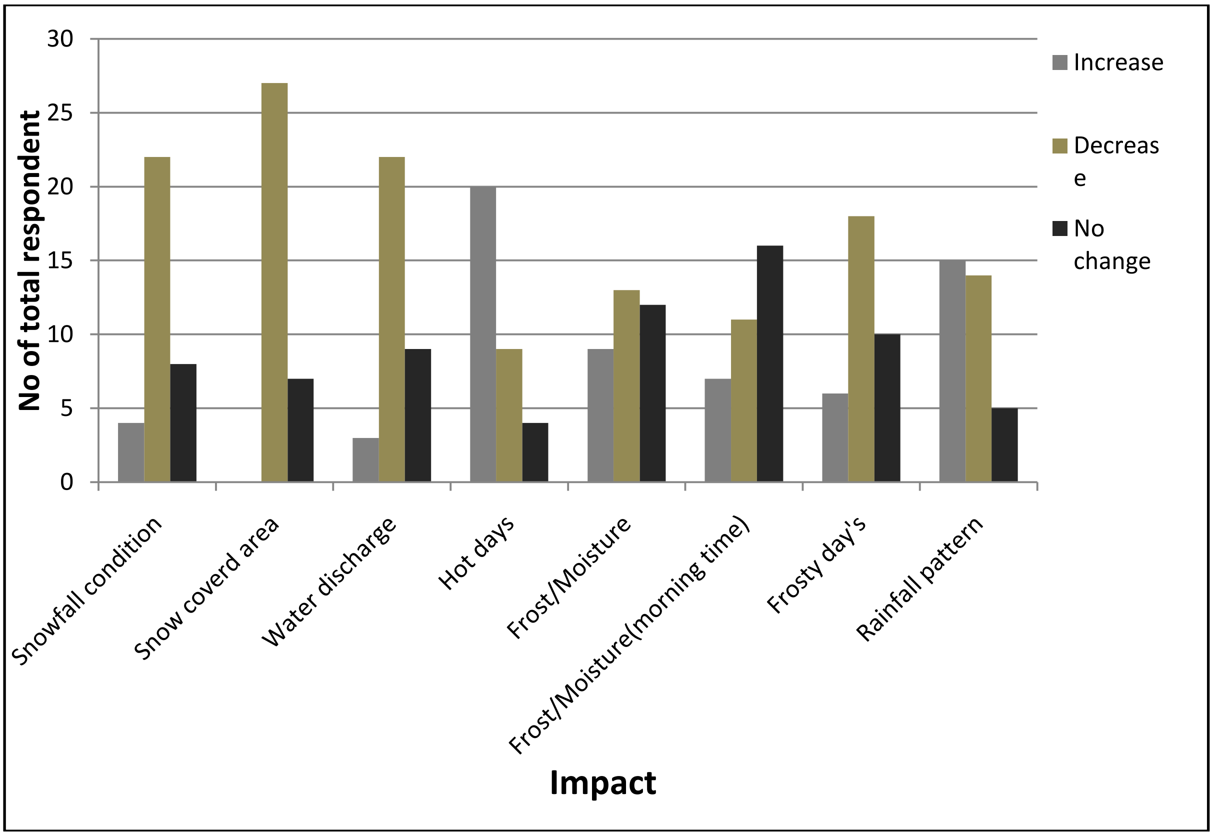
Major concern lies in the way that the snow is melting because it is so fast and accelerating. If it keeps going in the same rate and then we can't expect for a greater future of this region because of the potential glacier movement.

Table 8 People perception about climate change

Impact	Increase	Decrease	No change
Snowfall condition	4	22	8
Snow covered area	0	27	7
Water discharge	3	22	9
Hot days	20	9	4
Frost/Moisture	9	13	12
Frost/Moisture(morning time)	7	11	16
Frosty day's	6	18	10
Rainfall pattern	15	14	5

There are lots of changes in climate in this region since decades as many indications have been spotted in (Table 6). For an example there is decrease in snowfall which means increase in temperature as snow falls mostly caused by falling in atmospheric temperature. Many snow covered areas in the past have been disappearing due to increase in surface temperature. There are certainly, some changes in climate in this region as less rainfall has caused decrease in water discharge level which is really significant in terms of showing in climate changes in this particular area. Similarly, increase in hot days, decrease in frosting in morning indicates somehow weather has changed in this region. These indications provoke a massive change climatic in this belt.

Figure: 22 Status of climatic indicators by local people.



These figures above indicate that there are quite a lot positive changes due to climatic changes in this region. Increased living standards due to tourism industries, shifting of cropping seasons, increased numbers of cattle, and increase in numbers of hot days have immerged prosperous livings in this region. However, the growing population and increasing pollution by internal and external tourists, decreasing water resources might bring devastating consequences in the coming future.

CHAPTER – VI

DISCUSSION

In mountain regions, climate varies at short distances due to strong topographic forcing. Also the amplitude of such changes is high at high elevations due to the relatively greater sensitivity to climate change (Diaz and Bradley, 1997, Shreshta et al., 1999). In the Himalayan region, climate, especially precipitation, varies at local and meso scale levels owing to complicated relief, direction of ridges, degree of slope, sunny or shady aspects of slope and forest cover (Barros et al., 2004). Instrumental weather records from the western Himalayan region for the past century show increasing trend in temperature at the rate of around 0.6°C/100 years. However, no such long-term trend has been noted in precipitation. With the rise in temperature of the region, glaciers are retreating at an alarming rate. It is predicted that at this present rate of retreat, glaciers in the region will vanish within 40 years and the flow of Himalayan Rivers will eventually diminish, resulting in widespread water shortages (WWF Nepal Program, 2005). The result showed, land use/cover change t*able no. 4 the land use/land cover pattern of 1988, 2000 and 2009. According to that table Langtang valley* has three predominant land use categories –snow, grass and rock/barren land between 1988 and 2010 (Figure 1). In 1988, both covered 43.16, 16.60 and 14.11 percent respectively of the Langtang valley area – at total area of 55537.4 ha. By 1988 to 2009 snow coverage decreased to 4.44 percent while glacial lake increased by 0.06 percent.

The outputs of the analysis on temperature trend revealed a faster warming trend in Langtang area (i.e. 0.119 ºC/ year) than the global average (0.011-0.022ºC/ year). The annual maximum temperature in southern lowland areas of Nepal has increased by 0.04ºC/ year while those in northern high altitude regions has increased by 0.06-0.12ºC/ year for the same period (Shrestha, 2000, Shrestha, 1997) developed climate change scenarios with reference to Nepal which reported that the stations at higher elevations showed more increase in temperature than at lower elevations in a scenario with doubling of CO_2. Temperature rise in Langtang is almost same as in the higher ranges as reported by Shrestha (2001). So, from this we can say that temperature is rising significantly. We found clear trend of increasing in precipitation with annual increase of 15.44 mm. Shrestha et al. (2000) found that there was no long term trend in all Nepal annual precipitation series for 1948-1994. Nayava (2004) pointed out that the number of rainy days was decreasing for the period 1971-2000 at 17 rain gauge stations across Nepal while the intensity of rainfall was increasing for the same period. Chaulagain

(2003) reported that annual rainy days at the Jiri station (2003mASL) in eastern Nepal was decreasing by 0.4% per year while the rainy days with daily precipitation of more than 50 mm were increasing by 2% per year. These findings suggest a clear change in precipitation pattern. Impact of climate change on river discharge increased in the rate of 4.5% rise in the average temperature.

Result suggested that the glaciers are retreating rapidly and people are facing several problems due to the hydro-ecological changes in Langtang valley and trying their best to tackle with the changing environments. Rapid glacier melting disrupted rural livelihoods by posing a threat to agriculture, biodiversity and health. Change in rainfall and temperature resulted in changes in plant behavior like early flowering, shift in vegetation line and loss of some valuable species. Extreme climate events are destroying crops, depleting water resources, causing losses in livestock, cropland, and agricultural productivity. The Intergovernmental Panel on Climate Change (IPCC) has confirmed global climate change impacts every aspect of nature and human life, and is predicted to continue. Climate change threatens biodiversity, including some of the most valuable biodiversity hotspots of Earth, risking not only major changes in species compositions, but also highly significant and irreversible biodiversity losses that will result in the loss of ecosystem since our analysis showed that many people in the Himalaya region and in the river basins downstream are being forced to adapt to a new reality (Oxfam Research Reports, 2011). Climate change is increasing uncertainty and the risk for extreme droughts interspersed with extreme floods that are challenging food security, housing, infrastructure, business and even survival (IPCC 2007). The findings of the current study, thus, support the results of the previous studies.

CHAPTER – VII

SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Summary

This research has been carried out to investigate the contribution of climate change and effects on people's adaptation strategies in the region are most vulnerable to climate change. This study deals with various time series satellite imagery, temperature data, precipitation data, water discharge data and social survey. The study shows that the analysis of temperature data from 1987 to 2009 it is found that the average daily temperature is 3.2°C with standard deviation of 1.27. The temperature is found to be in increasing trend of 0.119°C/year. Global warming has serious consequences like snow melting, glacial lake outburst flood (GLOF) and overall land use/ land cover change. The study also reveals that the total Snow coverage area was continuously decreased in Langtang valley. Yearly snow melting rate is 0.21 percent per year according to data available between 1988 to 2009. Result suggested that the glaciers are retreating rapidly and people are facing several problems due to the hydro-ecological changes in Langtang valley and trying their best to tackle with the changing environments. Rapid glacier melting disrupted rural livelihoods by posing a threat to agriculture, biodiversity and health. These changes indicate that unpredictable climate variability will be a major obstacle for subsistence-based livelihoods in Langtang valley.

7.2 Conclusion

This research was carried out in the remote and rugged Himalayan region i.e. Langtang Valley. In this study changes in Himalayan landscape have been observed from Landsat imageries of 1988, 2000, and 2009. The temperature data recorded at Kyanjin stations shows the definite rise, which conforms to the global warming trend. There is a fluctuating pattern in precipitation between 1988-2009, but there seems somewhat increasing trend of precipitation over these years, but not as definite as temperature.

As there is increase of precipitation trend, temperature is increased. Social research is based on the information gathered from 34 randomly selected households in Langtang area. In order to eliminate the errors in getting information people have been asked questionnaire based on age range basis.

The major and significant results obtained from this research study are outlined as follows:

- The analysis of temperature data from 1987 to 2009 shows that the average daily temperature is 3.2°C with standard deviation of 1.27. The temperature is found to be in increasing trend of 0.119°C/year.
- The annual average precipitation is found to be 722.05mm. The precipitation is also in increasing trend of 15.44mm/year.
- River volume also increases at the rate of 2% in winter, 6% in summer and 5% in annual with 1°C temperature rise.
- It is interesting to note that the patterns of change in 1988 to 2000 changed by 2 percent and in 2000 to 2009 changed by 5.4 percent. Overall change of 1988 to 2009 is 5.5 percent.
- Snow coverage trend is continuously decreasing. In 1988, the total snow covered area was 23971.8 ha (43.16%) and in 2000 total snow covered area was 23698.9 ha (42.67%) which is decreased by 272.9 ha. In 2009 snow covered area is 21502.4 ha (38.72%) which is decreased by 2196.5 ha between 2000 to 2009.
- Glacial lake increased by 0.03 percent to 0.09 percent between 1988 to 2009. It is a drastic change of glacial lake.
- The coverage of bush remained to be at around 3.21 percent in the years 1988 and in 2000 it declined sharply to 0.78 percent but in 2010 again total area of bush is slightly increased by 0.95 percent. Forest experienced a decrease from 12.39 percent in 1988 to 12.29 percent in 2009. Grass coverage increased to 16.60 percent in 1988 and 17.88 percent in 2000 but in year 2009 the grass coverage is slightly decreased by 0.7 percent. Others sand coverage, alluvial fan and river have been not significantly changed.
- Extreme climate events are destroying crops, depleting water resources, causing losses in livestock, cropland, and agricultural productivity.
- Continuous decrease in water resources which has led people to struggle for getting drinking water from nearer rivers. This may indicate further harder life in future for getting drinking water unless there is some programme managed for drinking water. This is really a serious problem.

7.3 Recommendations

This study analyzes the impact of climate change on various fields in available data. So using effective water resource management, plans and strategy can be developed. Moreover, it can be used for sustainable development and management of any area. For more accurate and effective study the following recommendations are made:

- Denser network of meteorological stations should be established in higher altitude to measure temperature, rainfall and snowfall, evapotranspiration and insolation to understand climatic trend.

- Advanced remote sensing technology (high temporal, spatial, and spectral resolution) should be used to examine the climate change and its impact on water resources, forest ecology, agriculture, and livelihood of the people.

- Research on climate change impact, vulnerability and the adaptations should be carried out on similar environment of Himalayas and elsewhere using long term temporal data about snow and glacier, glacial lake, temperature and precipitation in order to collate and correlate the findings at regional as well as global scale.

- Rigorous and robust methodology about understanding the climate change risk and vulnerability, adaptation measures should be developed so that appropriate policy measures and strategies can be devised to reduce climate change risk/vulnerability by increasing improved adaptation measures.

- Government policies must be developed to support and facilitate local adaptation strategies and to increase long-term resilience, not just disaster management. Focusing especially on the agricultural sector, there are a number of specific priorities that must be addressed. The most important changes must come in the form of water management.

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Central Department of Geography

Tribhuvan University, Kirtipur

Questionnaire Survey

1. Personal information:

Name: Age: Sex:

Address: Occupation: Religion:

Education:

Illiterate	Literate	Primary	Lower secondary	Secondary	Higher Secondary	Bachelor's	Master's

2**. Family Description:**

S.N	Name	Age	Sex	Marital status	Occupation

3. How long have you been staying in this area?

....

4. Do you have land used for agriculture? If yes,

< 10 Ropani 20 – 30 Ropani ☐ > 20 Ropani ☐

5. Do you think the cropping season is shifting?

Yes ☐ No ☐

6. Is your crop production increasing? If yes, what do you think is the reason?

………………………………………………………………………………………………
………………………………………………………………………………………………

7. How far do you have to go for livestock herding?

……………………………………………………………………………………………..

8. Have you heard about climate change? If yes, share your perception/ views towards climate change?

…………………………………………………………………………………………………..
…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

9. Do you think climate change has impact on your life? If yes, how do you think it has impacted?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

10. What do you think can be the adaptive measures of climate change?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

11. Do you think snowfall is increasing with compare to previous years?

Increasing ☐ Decreasing ☐ No Change ☐

12. Do you think snow covered areas are increasing?

Increasing ☐ Decreasing ☐ No Change ☐

13. Have you observed the snow above the river?

Yes ☐ No

☐

14. Do you think the snow thickness in river is decreasing than previous years?

Yes ☐ No ☐

15. Can people walk on the layer of snow above the river?

Yes ☐ No ☐

16. Do you think the water discharge in the river is increasing?

Increasing ☐ Decreasing ☐ No Change ☐

17. What problems do you have to face due to it?

Drinking water shortage ☐ Flood ☐ Walking trail degradation☐

18. What are the frequent natural disasters occurring in this area?

i. Landslide ☐
ii. Flood ☐
iii. Drought ☐
iv. Lightning ☐
v. Erosion ☐
vi. Hail/ windstorms ☐
vii. Others ☐

19. Do you think the hot days are increasing compare to the previous years?

Increasing ☐ Decreasing ☐ No Change ☐

20. The amount of frost/ moisture is decreasing or increasing nowadays?

Increasing ☐ Decreasing ☐ No Change ☐

21. Has the amount of frost increased in morning times at recent times?

Increased ☐ Decreased ☐ No Change ☐

22. From which month did the frosty days start in previous years?

………………………………………………………………………………………………….

23. Do you think the frosty days are decreasing compared with the previous years?

Increasing ☐ Decreasing ☐ No Change ☐

24. How many months do the frost usually occur?

………………………………………………………………………………………………….

25. Do you think the frost occurring months are changing/ shifting?

Yes ☐ No ☐

26. What are the sources of drinking water in your community?

…………………………………………………………………………………………………

27. Do you have your own tap? If no, how far do you have to go to fetch water?

…………………………………………………………………………………………………

28. The water source is drying or not?

Yes ☐ No ☐

29. What is the condition of pastureland at present times?

Good ☐ Bad ☐ Same ☐

30. Has the trail towards pastureland converted to muddy or same as previous years?

……………………………………………………………………………………………..

31. What are the species of grass found in this area?

1.)…………2)…………..3)………………4)…………………5)…………….

32. Has old variety of grasses started to disappear? If yes, which species has disappeared?

1.)…………2)…………..3)………………4)…………………5)…………….

33. Has new variety of grasses found in pastureland?

1.)…………2)…………..3)………………4)…………………5)…………….

34. Do you notice the grasses growing in areas where previously snow occurs?

Yes ☐ No ☐

35. Do you think the rainfall pattern is changing? If yes,

High Intensity ☐ Low Intensity ☐ Drought ☐

36. What kind of problems do you have to face during livestock grazing?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

37. Have you seen any new bird species in this area? If yes, can you name the new bird species?

1.)…………2)…………..3)………………4)…………………5)…………….

38. Do you think any bird species has disappeared?

Yes ☐ No ☐

39. Do you think the number of animals is increasing?

Yes ☐ No ☐

40. Do you see any new disease in this area? If yes, what are the new diseases seen recently in this place?

1.)…………2)…………..3)………………4)…………………5)………

☐41. What is the present condition of the forest?

Good☐ Bad☐ No change ☐

42. Have you noticed loss of species of mammals,birds, reptiles or trees due to forest fire?

Yes ☐ No ☐

43. What should be done to conserve biodiversity in the National Park?

……………………………………………………………………………………………

………………………………………………………………………………

44. Was there any effect in community due to forest fire?

Yes ☐ No ☐

45. If yes, what type of impact community experienced due to forest fire?

1.)…………2)…………..3)………………4)…………………5)…………….