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Climatic Variability and Impacts on Biodiversity at Local Level: A case Study from Kanchanjanga Conservation Area, Nepal

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Impacts of climatic variability on biodiversity and livelihood aspects were examined in Kanchanjanga Conservation Area (KCA) Nepal. The area is characterized with unique gene pool, cultural, archeological, and historic values. Field reconnaissance survey, interaction with local communities and institutions were carried out for obtaining the necessary information. Linear trend analysis of climatic data in specific temperature and rainfall were analyzed for past 20 years. Major findings of the study were

- 1) Retreating of glacial lakes were evident, which may bring glacial lake outburst and flood; although no major river flow system was affected,
- 2) Blankets of snow/ice sheets were reported melted,
- 3) Habitat of snow leopard was affected and population balance between snow leopard and blue sheep was disturbed,
- 4) Forest and agro biodiversity, agriculture productivity were affected adversely due to unusual rainfall pattern, pests and diseases,
- 5) No major river flow system was affected. It was observed that interagency coordination for awareness generation, planning and implementation of climate change coping strategies specially focusing for biodiversity conservation felt urgent. Similarly it is suggested that trans-boundary issues are needed to be considered to address the issues of animal migration.

Keywords: biodiversity, climate change, KCA, climatic variability, trend analysis

INTRODUCTION

The global climate system is a consequence of and link between the atmosphere, the oceans, the ice sheets, living organisms, soils, sediments, rocks and changes continuously over a timescale. However, the climate in certain location varies between more or less extreme states and events called the climate variability, such as severe droughts, heavy rainfall, or unusually hot or cold weather.

Recently, the occurrence of extreme weather or climatic events has been used to indicate overall climate change.

Over the past few decades, human activity has significantly altered the atmospheric composition, leading to climate change of an unprecedented character. The average surface temperature of the earth has increased between 0.3°C and 0.6°C over the past hundred years and the increase in global temperature is predicted to increase between 3.5° Celsius (C) and 5.5°C by 2100 for the Indian sub continent (IPCC, 2001a) and even greater increase is predicted for the Tibetan Plateau (Lal, 2002). Annual warming in the Himalayan region between 1977–1994 was 0.06°C (Shrestha *et al.*, 1999). As per the third assessment report of the IPCC, the spatial average annual mean warming over the Asian region is projected to be as much as by 3°C by 2050 and about 5°C by the

2080s as a result of continued green house gas emission. Multiple consequences globally or locally are experiencing around the globe. For instance, a 1°C rise in temperature will cause alpine glaciers worldwide to shrink as much as 40% in area and more than 50% in volume as compared to 1850 (IPCC, 2001b). Food and Agriculture Organization (FAO) has also estimated that climate change and its implications can reduce crop yields up to 30% in the South Asian region.

Located in the eastern Himalayan region, Kanchanjanga Conservation Area (KCA) is an extraordinarily high mountain chain, encompassing many varied cultures and an extensive diversity of flora and fauna (Table 1). This study was carried out to know the climate change impacts mainly on freshwater, biodiversity, vegetation and livelihood.

Table 1. Biodiversity status in KCA

SN	Particulars	Species Number	Remarks
1	Angiosperms	835	
2	Gymnosperms	9	
3	Birds	253	Wood snipe is in endangered stage
4	Mammals	58	Musk Deer, Red Panda are in endangered stage
5	Flowering plants	2000	
6	Orchids	48	

(Source: Carpenter, 1996)

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MATERIALS AND STUDY METHODS

Salient features of the study area

Kanchanjunga Conservation Area, covering an area of 2,035 km² is located in Taplejung district, the north eastern part of Nepal, bordering India's Sikkim to the east and Tibet Autonomous Region of China to the north (Figure 1). The KCA covers more than 56% of the total district area. KCA region includes Mt. Kanchanjunga (8,586 m), the third highest mountain in the world and it is also home to 14 mountain peaks over 7,000 m and one of the longest glaciers on the earth. In support of World Wildlife Fund (WWF)'s Living Planet Campaign, then His Majesty's Government of Nepal (HMG/N) declared Kanchanjunga area as a "Gift to the earth" in April 1997, followed by conferring it a full-protected area status and declaring it a conservation area in July 1997. KCA is the only protected area of Nepal managed by local communities. The KCA region falls within WWF's "Global 200 Eco regions" and eco-region based conservation of eastern Himalaya.

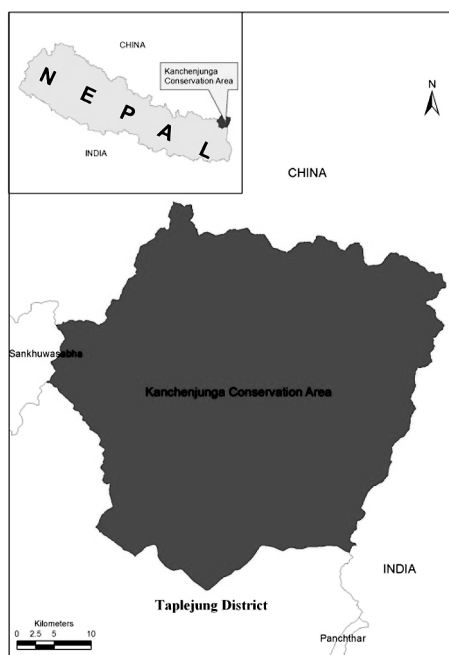


Fig. 1. Location map of the study area, Kanchanjunga Conservation Area (KCA).

Topography

The altitude of the KCA region varies from 1,200 m asl (Thiwa Khola) to 8586 m asl (Mt. Kanchanjunga). Below 4,000 m, topography is characterized with narrow V-shaped valleys with steep side slopes. The three main rivers (Tamur, Ghunsa, and Shimbuwa) and their tributaries drain the area. These rivers cut deeply into the mountains, creating deep gorges. The different valleys are distinct from one another in that they possess varied forest types and floristic elements. Existing glaciers extend over an area of 400 km² and altitude range of almost 5,000 m. About 65% of the area is covered by rock and ice, 14.1% by forests, 10.1% by shrubland, 9.2% by grassland, and 1.6% by agricultural land.

Flora, Fauna and Bioclimatic zones

The specific climatic conditions in combination with varied topographic nature in KCA give rise to diverse ecological habitat of very rich flora and fauna. There are some rare and endangered species eg. *Uncia uncia* (Snow leopard), *Ursus thibetanus* (Himalayan black bear), *Moschus chrysogaster* (Musk deer), *Ailurus fulgens* (Red Panda), *Canis lupus* (Grey wolf). Other important mammals of this area includes Common leopard (*Panthera pardus*), Blue sheep (*Pseudois nayaur*), and Common langur (*Semnopithecus entellus*). The region reportedly hosts 2,000 species of flowering plants, 48 types of orchids, 137 types of non timber forest products, 253 species of birds, 58 species of mammals, extensive Himalayan larch forest (*Larix griffithiana*), Juniper forest (*Juniperus indica*), at least 252 species of migrant and resident birds, eight of which are considered to be at risk in Nepal (Carpenter, 1996).

Along the landscapes four bio-climatic zones comprise distinct vegetation belts (Dobremetz and Shakya, 1975; Shrestha, 1994; Shrestha and Ghimire, 1996), viz.

- a) Subtropical bioclimatic belt (1,000–2,000 m),
- b) Temperate bioclimatic belt (2,000–3,000 m),
- c) Subalpine bioclimatic belt (3,000–4,000 m), and
- d) Alpine bioclimatic belt (>4,000 m).

Socio-economic conditions

The agriculture, forest and livestock rearing are closely linked to the livelihood of the local communities. The area accommodates about 1,050 households with culturally diverse ethnic groups including Sherpa, Limbu, Rai, Gurung, Tamang, Sarki, Damai, Kami, Brahmin, Samal and Tibetan refugees. In lower altitude, communities of mixed ethnicity practice a mixture of shifting cultivation, harvesting of forest products. The higher altitude settlements are agro pastoral and, due to the short growing season, the rearing of Yaks and their hybrids predominates. In these higher regions, the seasonal movement of livestock between mountain and lowland pastures is evolved as an adaptation to the alpine environment. In the lower altitude communities, the cardamom as a cash crop is becoming one of the most important income generating activities.

STUDY METHODS

Multidisciplinary team members comprising experts on agriculture, forestry, flood/erosion hazards, social, and hydrology have examined the impacts of climate change on various aspects. Field reconnaissance survey was carried out in March and April 2009 along the route (Fig. 2), target group discussions were done with the local community groups along the route. Intensive review of secondary information was done to understand the state of climate change impacts along Himalayan arc.

Statistical analysis of the climatic data

In order to understand the climatic variability, monthly minimum, monthly maximum temperature records were obtained from the Taplejung Station located

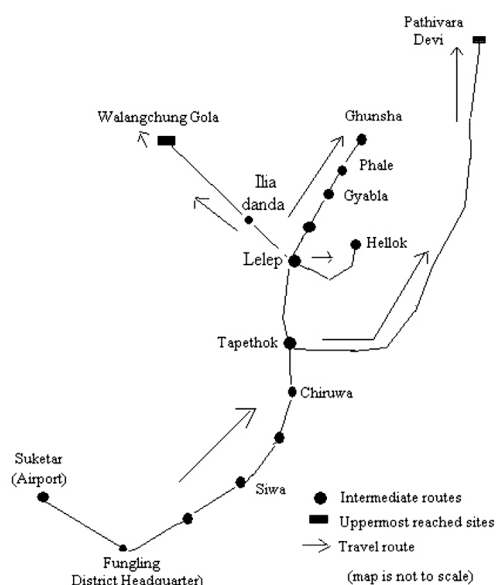


Fig. 2. Routes of the field survey.

at 1,732 m asl and monthly rainfall records were examined for 20 years (1988–2007). The local people reported that they were observing the changing scenario since past 15–20 years.

Simple statistical analysis such as mean, range, standard deviation, and coefficient of variation, are calculated. Based on the time series records of temperature available for 20 years (1988–2007), linear trend line equations are computed by using the following relationships;

$$Y = a + bx \quad (1)$$

Thus, for a given time t , the estimated value Y_e of Y (temperature axis) can be written as;

$$Y_e = a + bx \quad (2)$$

The value of a and b was computed by using the following equations (3) and (4), respectively;

$$\sum Y = na + b \sum x \quad (3)$$

$$\sum xy = a \sum x + b \sum x^2 \quad (4)$$

$$\text{and, } x = 2(t - 1997.5) \quad (5)$$

Where, the number of data n is 20 (Climatic data series of 20 years), year 1997.5 is middle year of the data series, and t is the corresponding time.

RESULTS

Snow/Ice and Glaciers

In the uppermost part of KCA region (mainly above 3,000 m) a substantial proportion of the annual precipitation falls as snow. In the higher ridges, snowfall builds up as ice sheets from year to year to form glaciers that provide long term reservoirs of water which has supported the life of various flora and fauna. In case the Thanjen glacier bursts, many communities will be affected

because of their location close to Ghunsha village. The length and breadth of the Aemtachhi glaciers has increased compared to 10–15 years back.

Climatic variability

In order to know the climatic conditions (temperature and rainfall) in the study area trends were examined for 20 years (1988–2007) and results are shown below in Figures 3, 4, 5a and 5b.

The above figures reveals that both monthly maxi-

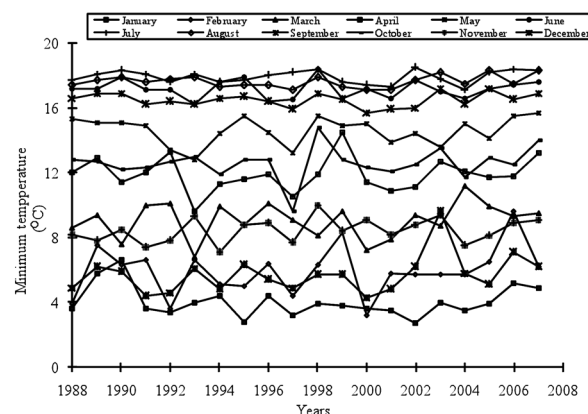


Fig. 3. Average monthly minimum temperature pattern in KCA region, Nepal (1988–2007).

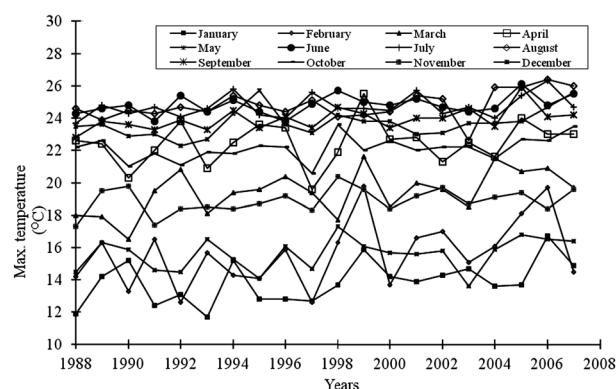


Fig. 4. Average monthly maximum temperature pattern in KCA region, Nepal (1988–2007).

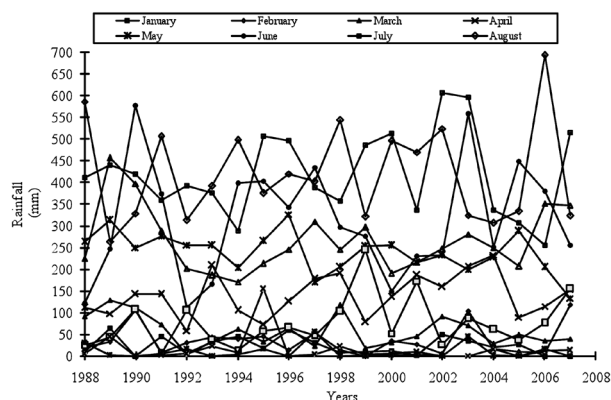


Fig. 5a. Average monthly rainfall pattern in KCA region, Nepal (1988–2007).

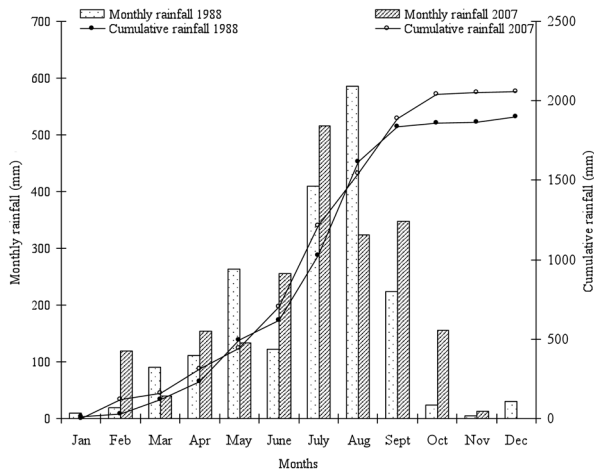


Fig. 5b. Comparison of monthly rainfall (left axis) and cumulative pattern (right axis) between 1988 and 2007.

imum and monthly minimum temperature records are higher in the year 2007 compared to the 20 years before i.e. in the year 1988. For instance, the monthly maximum temperature, for the January 1988 was 11.9°C, while it increased to 14.9°C for the January 2007. Similarly, for monthly minimum for the January, it was 3.6°C and 4.9°C, for the years 1988 and 2007, respectively. We conclude that since past 20 years (1988–2007) the monthly maximum and monthly minimum temperature are in rising trends for the all months (Figs. 3–5).

Comparison of the rainfall patterns between 1988 and 2007 (Fig. 5) indicated that cumulative rainfall pattern was slightly higher in 2007 (1,896.9 mm and 2,055 mm, for 1988 and 2007, respectively) and annual rainfall amount was fluctuating in every 2–3 years. According to the local officials and communities, there was no rainfall in the year 2008 monsoon season and the temperature was also rising (feeling hot).

Forest conditions

There was massive forest fire in the KCAu region in 2008. It was revealed that about 300 hac. of forest area was affected across Yamphuden, Illahadanda, Amilesha, Lelep, Hellok, which damaged the pasture land, Nigalo (*Drepanostachyum* sps.), and also *Pinus* plantation area. Decreasing population of *Michalia champaca*, excessive growth of *Alnus nepalensis* may cause threat to biodiversity loss.

The damaging scale of forest fire was in larger extent, and could be due to dryness and warmth environmental conditions. Impacts were observed on biodiversity, and habitats due to the forest fire. The area is also rich in medicinal plants and non-timber forest products. Major species of such includes Chiraito (*Swertia* sps.), Kutki (*Picrorhiza scrophulariiflora*), Jatamashi (*Valeriana jatamasi*), Nirmashi (*Parnassia nubikola*) (also known as Bishma), Sunpati (*Rhododendron anthopogan*), Thulo okhati, Bish (*Aconitum* sps), Micopila (mainly in Gola), Lokta (*Daphne bholua*) and Argeli (*Daphne sureil*) (used in local paper preparation), Lout Sallo (*Taxus baccata*— used in cancer control medicine), and

Hattighar. These species are very useful for the local communities and their population is also increasing gradually. The species Champ (*Michalia champaca*) is using extensively, so its population is in decreasing trend. Uttis (*Alnus nepalensis*), Malingo (*Thamnocalamus spathiflorus*), and Cardanom (*Amomum aromaticum*) are increasing vigorously. Uttis is the pioneer species of eroded land and can be grown easily in diverse condition. Cardanom is becoming very popular for cash income which the local communities are cultivating extensively and *Swertia* species is also becoming popular as cash crops.

Biodiversity and impacts of climate change

Kanchanjunga mountain region hosts a series of climatically different zones over short distances and elevations supporting different microhabitats and niches. The early arrival and the late departure of the monsoon cause a prolonged wet season and very humid summer conditions. These specific climatic conditions in combination with varied topographic nature give rise to rich flora and fauna. For instance, out of total 36 species of *Rhododendron*, 24 species are available in the KCA region alone. As there was reporting of early flowering, the color and sizes of *Rhododendron* flowers, we presume they have been affected by recent climatic variability.

According to local respondents, the population of blue sheep, red panda, and snow leopards was increasing as they appeared more frequently along the trekking routes. However, balancing the population between snow leopard and blue sheep is becoming challenging. The melting of the snow and no snowfall events have both beneficial and adverse effects for the Snow leopards' habitat because in one hand, snowmelt can open new grassland areas (supportive), and reduced snow blanket can cause unfavorable situation for their habitat (disturbance). The local communities also said that the population of Dhedu monkey was in declining trend, because they rarely observed the wild animals as compared to few years ago. The reasons why their population decreased, and factors disturbing their habitats are not clearly known.

The detail consequences felt by the local people due to climate change is summarized in Table 2.

Climatic variability

Salient features

In the study site of KCA June–August were the warmest months (monthly maximum temperature range 24.73–24.81°C, while January is the coldest one (maximum 13.8°C). While higher fluctuations in temperature (maximum 12.6 to 19.8°C), and minimum (3.2 to 9.6°C) were observed in February and less variation in June/July. The fluctuation in the temperature supports for frequency and magnitude of extreme weather events, which ultimately supports for global warming. To know the trend analysis of the time series temperature pattern, linear trend analysis is computed by using the $Y=a+bx$ relationship and the obtained results are summarized in Table 3.

Climate change evidences, vulnerable entities

From Figs. 3 and 4 and Table 3 it can be concluded that the temperature is in increasing trend and the rain-fall pattern is also fluctuating. These climatic changes are

influencing on ecosystem's (aquatic and terrestrial) leading to vulnerability. Although frequent occurrence of slope failures and GLOF events were not observed, some landslides have occurred sporadically in some locations.

Table 2. Response on effects of increased temperature on plants and animals

Species, Type / Events	Responses	Remarks
Domestic animals (cattle)	• Itching, water bodies appearances in body parts	• Water bodies disappear suddenly, may be due to excessive hot (according to local respondent).
Alainchi	• No uniform maturity since last two years	• Major income source, dominates other herbs and shrubs plants.
Orange	• Early flowering	• Warmer weather condition.
Deciduous fruits (Apples, Aru, Alupokhada)	• Late flowering	• Seedling distribution and plantation of Apples started since past 5 years.
Chanp and Gurans	• Early flowering	
Lokta and Argeli	• Low natural growth	• Started seedling production in nursery and plantation in wide areas.
Trees trunk	• Started dying	• Might be due to decreases in soil moisture, available water in root zone especially in soil-rocky terrain.
Fire proneness	• Increased	• Due to warmth and increased dryness.
Snow fall	• Nil in the winter since last year.	• Scenic beauty of mountain decreased, due to no blanketing.
Life cycle of crops/ Food security	• Deviated	• Life cycle Cardamom was affected, (no uniform maturity), low production, and appearance of rhizome rot). • The dryness has hampered wheat production. The growth of wheat plant was stunted, with fewer tillers. • Decreased water availability in the root zone has affect fruiting/flowering of the agricultural crops. • Maize cultivation was affected due to drought, Taplejung district is already food deficit area, hence further decrease on agricultural production and cash crops may create acute problem to the life. • No rainfall in regular time/normal time.

Table 3. Computation of the linear trend equations

Month	Temperature	Value of a	Value of b	Trend equation ($Y_e = a + bx$)
January	Maximum	13.88	0.053	$Y_e = 13.88 + 0.053x$
	Minimum	4.04	-0.013	$Y_e = 4.04 - 0.013x$
February	Maximum	15.62	0.074	$Y_e = 15.62 + 0.074x$
	Minimum	5.92	0.033	$Y_e = 5.92 + 0.033x$
March	Maximum	19.16	0.06	$Y_e = 19.16 + 0.06x$
	Minimum	9.06	0.018	$Y_e = 9.06 + 0.018x$
April	Maximum	22.47	0.023	$Y_e = 22.47 + 0.023x$
	Minimum	11.89	0.008	$Y_e = 11.89 + 0.008x$
May	Maximum	23.70	0.031	$Y_e = 23.70 + 0.031x$
	Minimum	14.59	0.005	$Y_e = 14.59 + 0.005x$
June	Maximum	24.81	0.02	$Y_e = 24.81 + 0.02x$
	Minimum	17.17	0.0006	$Y_e = 17.17 + 0.0006x$
July	Maximum	24.73	0.021	$Y_e = 24.73 + 0.021x$
	Minimum	17.92	0.001	$Y_e = 17.92 + 0.001x$
August	Maximum	24.81	0.034	$Y_e = 24.81 + 0.034x$
	Minimum	17.62	0.006	$Y_e = 17.62 + 0.006x$
September	Maximum	23.94	0.03	$Y_e = 23.94 + 0.03x$
	Minimum	16.49	0.0006	$Y_e = 16.49 + 0.0006x$
October	Maximum	22.12	0.02	$Y_e = 22.12 + 0.02x$
	Minimum	12.59	0.011	$Y_e = 12.59 + 0.011x$
November	Maximum	18.9	0.02	$Y_e = 18.9 + 0.02x$
	Minimum	8.45	0.02	$Y_e = 8.45 + 0.02x$
December	Maximum	15.61	0.02	$Y_e = 15.61 + 0.02x$
	Minimum	5.7	0.035	$Y_e = 5.7 + 0.035x$

Y_e = expected value of temperature, $x = 2$ ($t-1997.5$), x axis denotes for different time (years).

Table 4. Overview of climate change evidences, vulnerable elements

Parameter	Impacts/evidences	Vulnerable entities/elements
Snow/ Glaciers	Melting snow cover due to temperature rise. No snow fall since past two years.	Janu south, Yalung, Thanjen, Aemtachhi glaciers, adjoining areas of Dudh Pokhari, Yamphudin, and Ghunsa, respectively. Lowering albedo prone to radiative melting.
Freshwater	Disappearance of few water sources, Historic evidences of lake burst eg. Nangma, Chherching, Availability/supply of water, in river basins/tributaries are sometimes increasing.	Water availability in major rivers (eg. Tamor River, Ghunsa Khola, Gola), Nangma, Cherching, Tamor, Shirpokhari lakes. River pollution, hygienic problems.
Bio-diversity	Population of Blue sheep, Red Panda, and Snow leopards are increasing. Early flowering of Rhododendron, and appearance of fruits. Started dying back of tree trunk, showing signs of fragmentation and degradation, climate warming can increase suitable habitats for the water weeds.	Rhododendron species (c.f. the KCA hosts 24 species of Rhododendron out of total 36 species), agro-ecosystem pattern.
Agriculture	No uniform maturity in Alainchi. Itching/waterbodies appearing in cattle. Early flowering in orange. Low natural growth in Lokta and Argeli. Late flowering in Apples, Aru, Alupokhada. Appearance of some diseases and pests. Stunted growth of wheat with less tillers. Affecting maize cultivation due to drought.	Alainchi, cattles, Lokta, deciduous fruits, maize, apples, and other cash crops.

Glaciers burst, snow fall decreasing, melting of snow blankets, soil quality deterioration/land degradation due to excessive grazing, and life cycle change of some species (e.g. early fruiting, flowering), and appearance of some diseases in plant, animal are some of the impacts of climate change experienced by the local communities, and are summarized in Table 4.

DISCUSSION

The mountain landscape is one the most dynamic and complex ranges in the world due to tectonic activity, and they are vulnerable to global warming and increasing human activities (Bandyopadhyay and Gyawali, 1994). Uncertainties about the rate and magnitude of climate change and potential impacts prevail, but the above mentioned facts revealed that it is gradually and powerfully changing the ecological and socioeconomic status of the Kanchanjunga region.

The present study aimed to investigate the vulnerability states of community resources based on empirical evidences from field observation and interview with local people. For the study area, the time series data and other systematic climate change related data were not sufficiently available. As the KCA people have long experience on past unusual events (Glacial lake outburst, drought, etc.), hence, participatory vulnerability analysis has provided sufficient climate change related evidences. The past study evidences have shown ecological response due to climate change like advances in timing of spring events (change in bird species, excessive invasive plant species) and appearances of epidemic disease (Walther *et al.*, 2002). In the study area too, there was similar observation about the appearance of new water bodies. The study carried out in Churiya region (Paudel, 2011)

has also suggested about the change in floral feature (leaf color change) in recent years. Communities have adapted themselves and developed resiliency to face some extreme unusual events. It means they have wealth of experience on how to deal with some extreme events. But some additional techniques, suggestions from external institutions will encourage the local communities to cope with unusual events. This study revealed some insights on the vulnerability state and impacts of climate change, which are as follows.

- 1) The temperature was deviated positively during the course of 20 years (1988–2007), while the annual cumulative rainfall during was fluctuated in every 2–3 years interval.
- 2) Glaciers were among the most sensitive indicators of climate change, advancing substantially during climate cooling and retreating during climate warming. Glaciers grow and collapse, both contributing to natural variability and greatly amplifying externally forced changes eg. Nagma, Tamor Shirpokhari.
- 3) Decreasing snow fall, and melting of blankets of snow/ice sheets affecting mountain albedo and habitat of Snow leopard. Upto now there is no change in major river flow system, however; after few years if the climatic situation remains unusual, freshwater system/hydrological system may also affected.
- 4) Population balance between Snow leopard and Blue sheep is becoming matter of serious consideration.
- 5) Forest biodiversity, agro biodiversity, agriculture productivity are being affected. For instance, early flowering, early maturity, appearances of some pests/diseases (e.g. water bodies in cattle) are some evidences of climate change related consequences.
- 6) Forest fire was observed in the site. Hence, precautionary measures should be taken to minimize the

fire damage. For this, awareness campaign, forest line constructions are suggested.

- 7) Interagency coordination for awareness generation, planning and implementation of climate change coping strategies are becoming essential and WWF is required to facilities for this process.
- 8) As KCA is characterized with its outstanding peculiar features, the National Adaptation Plan of Action (NAPA) should incorporate KCA for identification of hotspots, and develop plan of action and monitoring schemes.
- 9) Trans boundary issues should be taken into consideration to address the issues of migration, habitat management and other related consequences. In addition, this study is recommending some activities, projects to conserve the outstanding significance and consideration on such matters are essential.

CONCLUSION

In present context of ecosystem based adaptation, climate change related issues should be deal in the integrated and coordinated way through incorporating local, national, regional, global scenarios. The data base related with climate change and other associated impacts are very limited to conclude, however; there are some evidences about the climatic variability trends (e.g. minimum temperature increasing throughout the months) and such evidences should be measure periodically and causative effects should be monitored closely.

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