Assessment of Climate Change Impacts on Water Resources and Vulnerability in Hills of Nepal

(A Case Study on Dhare Khola Watershed of Dhading District)

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Kabindra Dhakal
(Principal Researcher)
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EXECUTIVE SUMMARY

Nepal's temperature is rising faster than the global average, and rainfall is becoming unpredictable. Water resource is projected to become one of the most pressing environmental problems with high impacts from climate change in hills and mountains of Nepal. Drying water sources, ground water depletion is likely due to long dry seasons, irregular rains, and high intensity rainfall leading to high run-off and less infiltration. Rural communities in hills and mountains of Nepal are experiencing the impact on water resource due to climate change. The study was done to identify the actual impact of climate change in water resources and suggest the necessary adaptive measures to combat the subsequent adversaries in Dhare Khola Watershed of Dhading district.

Participatory tools and methods along empirical field studies were used to collect data from the field. Both qualitative and quantitative research techniques were applied to gather the information related to objectives. The major elements of this methodology include the use of primary and secondary data, household questionnaire survey, focal group discussion, key informant interviews and field observations.

Assessment parameters	Tools used
Historical trend analysis: Changes, risk and impacts	FGD, KII
Climate Risks and Hazards	FGD
Vulnerability Assessment	FGD and group discussions
Comparative analysis of impacts across different groups	Household survey
Assessment of coping strategies and adaptation measures	FGD and household survey

Average yearly and five year moving mean yearly temperature and rainfall of thirty years data (1979 to 2008) on temperature and rainfall of the nearest meteorological station (Dhunibeshi, index no. 1038) and non-climatic indicators based on community perceptions of climate variability were documented to assess climatic variability scenario. The primary information was collected through in-depth interviews with key informants as well as focus group discussions with farmers and members of forest user groups taking gender, social class into consideration in assessing impacts, vulnerability and adaptation planning. Participatory Well Being Ranking in users groups of Community Forests stratified by Resources Identification and Management Society-Nepal was used for the class differentiation (poor and well off). Acquired data were analyzed using Microsoft Excel 2007 (quantitative information) and using bar and chart graphs (qualitative information). Adaptation options were recognized after analysis of the impact on water resource, livelihood vulnerability, and coping strategies that the community acquired, effectiveness of these strategies, preliminarily identified adaptation options, community resilience to cope

with the hazards and risks and institutional arrangement and groups' dynamics and external support.

The climatic data interpretation showed that temperature and rainfall trend increased. And non climatic indicators on community's perception also illustrated the climatic variability n the area. Drying of the water resources was the major impact of climate change and was the topmost hazard in the area in community ranking. Sixty percent of sources were dried and substantial decreased in water volume in Dhare khola. Drying of such water sources caused problems for the availability of drinking water, irrigation water and in business too. Most of the water holes in the forest areas dried up and caused adverse effects on biodiversity.

More than thirty five percentage of poor have high impact due to water hazard in the area, whereas only thirty two percent in well off were facing high impact of this hazard. Less water use, lessening livestock in dry seasons, covering the water sources with tin plates, developing the water storage system, lifting water from far spring source, rain water harvesting were some coping strategies in well off families. In some poor families, collections of water from next source, digging temporary *kuwa* were common coping strategies for deinking water. Shifting cropping pattern, rain water harvesting and developing the water storage system in well off families were some coping strategies to overcome inaccessibility of irrigation water. Likewise, collecting kitchen waste water and urine of livestock have also been developed in few poor and well off families. Lower percentage of poor has high effectiveness on acquiring coping strategies. But in well off families this was more than thirty percent.

Kebalpur VDC-9, inhabitant poor and marginalized groups in the area was found more vulnerable to this hazard. Production and human system were most vulnerable sectors due to this hazard. . Lack of effective external support and formal institutional arrangement to deal with such climatic hazard/risk, community came across with low resilience capacity. Both the intervention and facilitating adaptations measures are required to be developed considering bottom up and top down approach simultaneously.

Awareness and sensitizations in groups, institutions and providing technical and financial support to them, sustainable water resource management, strengthening agriculture system**,** research and development, technology transfer and financing are some recommended adaptation measures.

ACRONYMS

DHM	:	Department of Hydrology and Meteorology
ENSO	:	El Nino- Southern Oscillation
FAO	:	Food and Agriculture Organization
FGD	:	Focal Group Discussion
GCM	:	General Circulation Model
GLOF	:	Glacier Lake Outburst Flood
HMGN	:	His Majesty Government of Nepal
IPCC	:	Intergovernmental Panel on Climate Change
KII	:	Key Informants Interview
MFSC	:	Ministry of Forest and Soil Conservation
MoEnv	:	Ministry of Environment
NAPA	:	National Adaptation Program of Action
NGO	:	Non-governmental organizations
NTFP	:	Non timber forest products
PWBR	:	Participatory Well Being Ranking
RIMS-Nepal	:	Resources Identification and Management Society-Nepal
UNFCCC	:	United Nation Framework for Climate Change Convention
VDC	:	Village Development Committee
WWF	:	World Wildlife Fund

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INTRODUCTION

1.1 Background

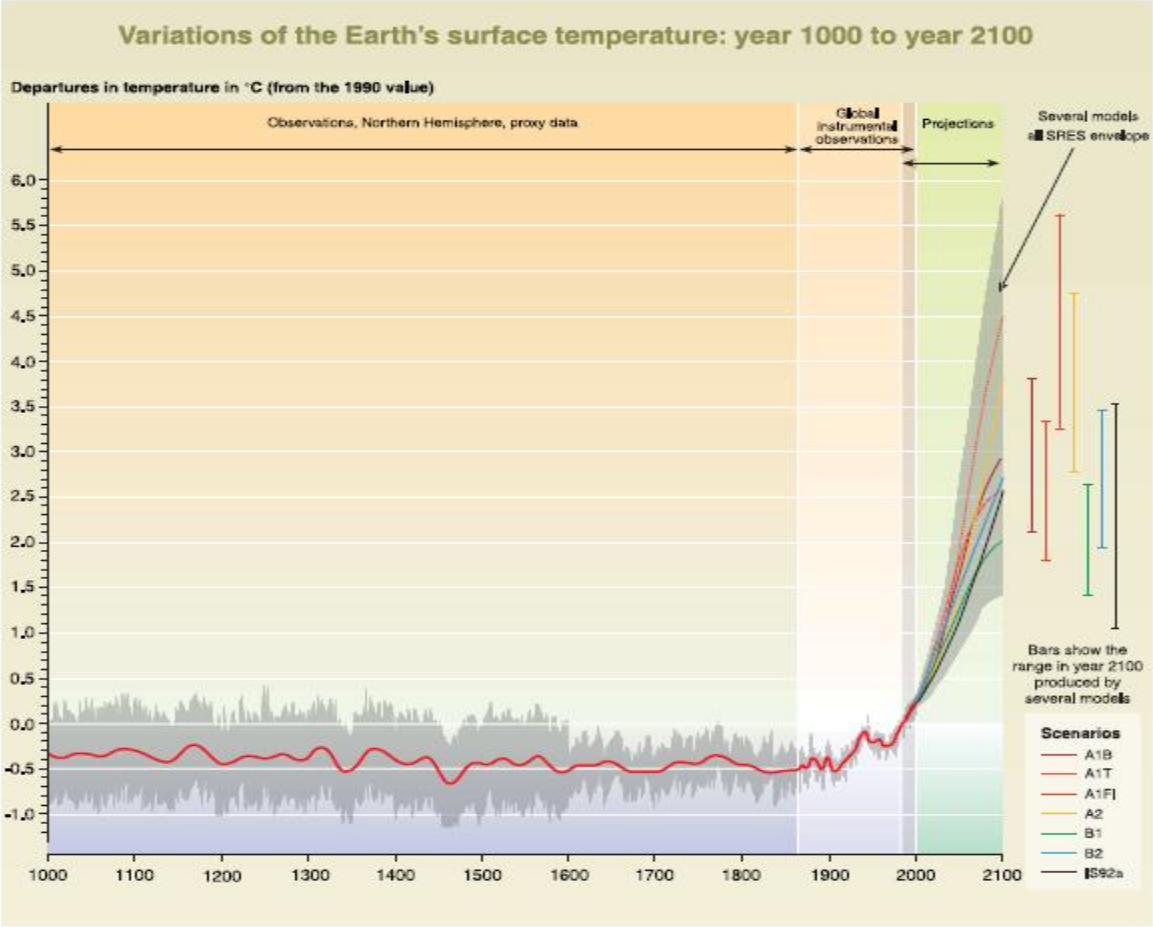
Nepal is situated on the southern slopes of the central Himalayas and occupies a total area of 147,181km^2. The country is located between latitudes 26^{o}22' and 30^{o}27' N and longitudes 80^{o}40' and 88^{o}12' E. The average length of the country is 885km from east to west and the width varies from 145km to 241km, with a mean of 193km north to south. Hills and high mountains cover about 86% of the total land area and the remaining 14% are the flatlands of the Terai, which are less than 300m in elevation. Altitude varies from some 60m above sea level in the Terai to Mount Everest (Sagarmatha) at 8,848m, the highest point in the world.

Nepal's climate is influenced by the Himalayan mountain range and the South Asian Monsoon (NCVST, 2009). Pre-monsoon (March to May), monsoon (June to September), post monsoon (October to November), and winter (December to February) are the four distinct seasons characterized in Nepal (MoEnv, 2010). Average annual rainfall is approximately 1800 mm but there are marked spatial and temporal variations both north- south and east- west and the monsoon rain is most abundant in the east and declines westwards, while winter rains are higher in the northwest and declines south- westwards (Practical Action, 2009). Eighty percent of the precipitation that falls in Nepal comes in the form of summer monsoon rain, from June to September and the southern flanks of the Himalayas, such as at Pokhara, receive a higher amount of rainfall (3,345mm), while the rain-shadow areas of Dolpa, Jomsom, and Mustang receive considerably less (295mm) (HMGN/MFSC, 2002). Temperature varies with topographic variations and increases from north (Mountains) to south (Terai) (MoEnv, 2010) and the average temperature decreases by 6 ^{0}C for every 1000 m gain in altitude (Jha 1992). In Terai, winter temperatures are between 22-27^{o}C, while summer temperatures exceed 37^{o}C and in the mid-hills, temperatures are between 12-16^{o}C.

1.2 Climate change: An Overriding Issue

Climate change refers to the variations in the Earth's global climate or in regional climate over time. United Nation Framework for Climate Change Convention (UNFCCC) defines it as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere". The Intergovernmental Panel on Climate Change (IPCC 2007) concludes that increased global temperature since the twentieth

century is very likely due to increased anthropogenic Greenhouse Gas (GHG) emissions from burning of fossil fuel and forest conversion. The climate change is real and happening now. The planet is already experiencing its impact on biodiversity, freshwater resources and local livelihood (WWF, 2006).



(Source: IPCC 2001 a)

Figure 1: Variations in the Earth´s Surface Temperature (1000-2100)

Using the current temperature trends, the average temperature may rise by 1.4-5.8^0 C by 2100 in comparison to 1990 (IPCC, 2001a). This is certain disaster for a fragile ecosystem such as mountains (WWF, 2006). Climate change is emerging as one of the most profound ecological and social concerns in our time (Y2Y, 2007). The ecological axiom 'adapt, migrate or die' takes a particular relevance and urgency as scientists continue to study the potential scope of climate change. In the face of warming temperatures many species will be forced down to one of the three paths (Y2Y, 2007).

According to the Third Assessment Report of the IPCC, developing countries are expected to suffer the most from the negative impacts of climate change. This is due to the economic importance of climate- sensitive sectors (for example, agriculture and fisheries) for these countries, and to their limited human, institutional, and financial capacity to anticipate and respond to the direct and indirect effects of climate change. The vulnerability is highest for least developed countries in the tropical and subtropical areas. Hence, the countries with the fewest resources are likely to bear the greatest burden of climate change in terms of loss of life and relative effect on investment and the economy.

1.3 Climate Change: Trends, Scenarios, and Key Vulnerabilities in Nepal

It is now apparent that dealing with climate change is unavoidable. And Nepal cannot remain untouched by this global phenomenon (Lamichhane & Awasti, 2009). Nepal's temperature is rising faster than the global average, and rainfall is becoming unpredictable. Although Nepal is responsible for only about 0.025% of the total annual GHG emissions of the world (Karki, 2007), it is already experiencing an increasing trend and the associated effects of climate warming. It is experiencing increase in dry periods, intense rainfall, floods, landslides, forest fires, glacial retreats and Glacier Lake Outburst Flood (GLOF) threats (Shrestha, 2007). Being a developing country, Nepal is more vulnerable to the effects of climate change due to its high dependence on climate-sensitive sectors such as glaciers, agriculture and forestry, and its low financial adaptive capacity (Karki, 2007). There have been more than 13 reported cases of Glacier Lake Outburst events in Nepal Himalayas since 1964 causing substantial damage to the people's lives, livestock, land, environment and infrastructure (Rana et al., 2000).

1.3.1 Climate Change Trend

Various studies suggest that the pattern of temperature increase in Nepal. Regional mean maximum trends in Nepal from 1997-2000 (Table 1) shows the increasing temperature trends in the higher elevation in the northern part of the country compare to the lower elevation in the south and show the warming trends of 0.06^{0}C per year (Shrestha et al., 1999). The finding is also supported by Liu & Chen (2000) (Figure 2). As a result of this, significant glacier retreat as well as significant areal expansion of several lakes was documented in recent decades with an extremely high likelihood that such impacts are linked to rising temperatures (OECD, 2003).

Table 1: Regional mean maximum temperature trends in Nepal from 1977- 2000 (^{0}C per year)

Regions	Seasonal				Annual
	Winter (Dec- Feb)	Pre- monsoon (March - May)	Monsoon (June- Sept)	Post monsoon (Oct- Nov)	(Jan- Dec)
Trans-Himalaya	0.12	0.01	0.11	0.1	0.09
Himalayas	0.09	0.05	0.06	0.08	0.06
Middle mountain	0.06	0.05	0.06	0.09	0.08
Siwaliks	0.02	0.01	0.02	0.08	0.04
Terai	0.01	0	0.01	0.07	0.04
All Nepal	**0.06**	**0.03**	**0.051**	**0.08**	**0.06**

(Source: ICIMOD, 2007; Updated after Shrestha et al. 1999)

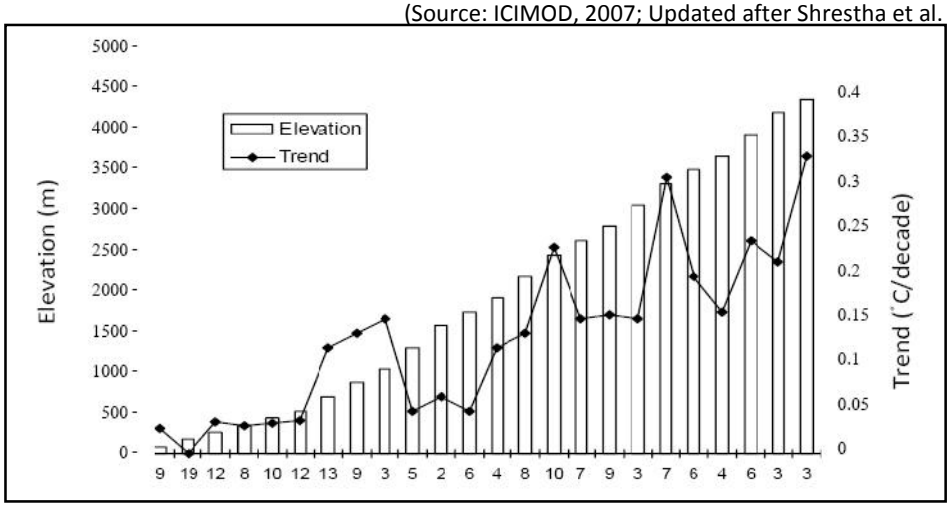


Figure 2: Variation in Temperature Increase at Different Elevations (*Source: Liu and Chen 2000*)

1.3.2 Climatic Projection

A very few studies on climate change projections for Nepal have been published in recent years. In the study conducted by OECD, the temperature and precipitation projection of Nepal for the years 2030, 2050 and 2100 were projected and assessed based upon over a dozen recent general circulation models (GCMs) and showed a significant and consistent increase in temperatures (Table 2). The increase in temperature seems to be larger in winter months compared to summer months. While regarding the precipitation, it projects the overall annual increase. Considering this analysis, it can be estimated that the warming trend already observed in recent decades will continue to 21st century and the intensification in summer monsoon can lead to the increasing risk of flooding and landslide.

Table 2: GCM estimates of temperature and precipitation changes for Nepal

	Temperature change (^{0}C) mean (standard deviation)			Precipitation change (%) Mean (standard deviation)		
Year	**Annual**	**DJF**	**JJA**	**Annual**	**DJF**	**JJA**
Baseline average				*1433 mm*	*73 mm*	*894 mm*
2030	1.2 (0.27)	1.3 (0.40)	1.1 (0.20)	5.0 (3.85)	0.8 (9.95)	9.1 (7.11)
2050	1.7 (0.39)	1.8 (0.58)	1.6 (0.29)	7.3 (5.56)	1.2 (14.37)	13.1 (10.28)
2100	3.0 (0.67)	3.2 (1.00)	2.9 (0.51)	12.6 (9.67)	2.1 (25.02)	22.9 (17.89)

(DJF= December, January, February; JJA- June, July, August) *(Source: OECD, 2003)*

1.3.3 Impacts of climate change, its Ranking and Vulnerabilities

The ongoing climate change and changes projected to occur are likely to have impacts on different sectors of Nepal. Agriculture, forestry, water and energy, health, urban and infrastructures, tourism, industry and overall livelihoods and economy are the sensitive sectors to climate change (MoEnv, 2010). Impacts that are most certain, most severe, and most likely to become severe in the first half of the 21st century are ranked the highest while ranking of impacts and vulnerabilities in resources (OECD, 2003).

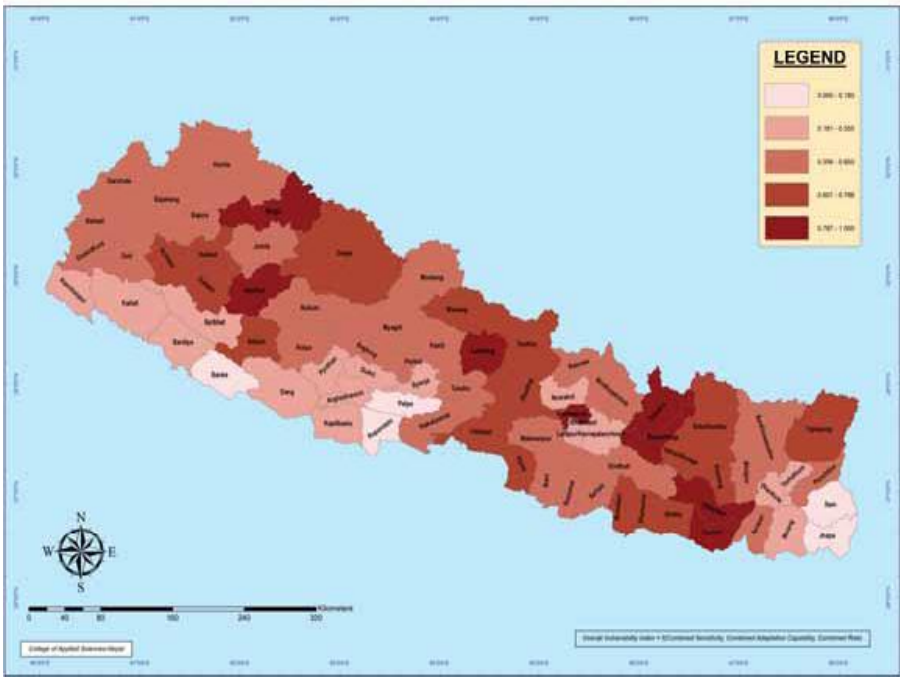
Water resource and hydropower ranks highest among others due to various reasons followed by agriculture (Table 3).

Table 3: Priority ranking of climate change impacts for Nepal

Resource Ranking	Certainty of impact	Timing of impact (urgency)	Severity of impact	Importance of resource
Water resources and hydropower	High	High	High	High
Agriculture	Medium- low	Medium- low	Medium	High
Human health	Low	Medium	Uncertain	High
Ecosystem/ Biodiversity	Low	Uncertain	Uncertain	Medium- high

(Source: OECD, 2003)

The overall vulnerability map for the districts of Nepal from GIS based vulnerability map was developed (Fig 3) (MoEnv, 2010). Based on this vulnerability assessment, National Adaptation Program of Action (NAPA) to climate change reported Nepal as highly vulnerable to climate change and suggest more than 1.9 million people are under high vulnerable to climate change and 10 million are increasingly at risk. People living mid and far western regions are amongst the most vulnerable. Poor people are more vulnerable to loss of physical, human, social, natural and financial capitals.



[0.787-1.000 (very high), 0.601-0.786 (high), 0.356- 0.600(moderate), 0.181-0.355 (low), 0.000-0.180 (very low)]

Fig 3: map of districts showing relative overall climate change vulnerability (*Source: MoEnv, 2010*)

1.4 Climate Change Impact on Water

According to IPCC special report (1997), changes in climate could exacerbate periodic and chronic shortfalls of water, particularly in arid and semi-arid areas of the world. Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems Developing countries are highly vulnerable to climate change because many are located in arid and semi-arid regions, and most derive their water resources from single-point systems such as bore holes or isolated reservoirs. These systems, by their nature, are vulnerable because there is no redundancy in the system to provide resources, should the primary supply fail. Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits. By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress. Areas in which runoff is projected to decline face a clear reduction in the value of the services provided by water resources. Increased annual runoff in some areas is projected to lead to increased total water supply. However, in many regions, this benefit is likely to be counter

balanced by the negative effects of increased precipitation variability and seasonal runoff shifts in water supply, water quality and flood risks

Effects of climate change on water resources could yield manifold Implications either due to too much and /or too little water. Climate induced water stressed directly affects agricultural productivity, malnutrition, human health and sanitation while too much water impacts human settlements, infrastructure and agricultural land (MoEnv, 2010). Changes in water supply, changes in its demand and changes in resources availability are some impacts of climate change impacts on water resources (Nicol & Kaur, 2009). According to projections from the Food and Agriculture Organization (FAO), the irrigation water demand will increase by between 5-20% by 2080. On the other hand, the projected increase in household water demand and industrial water demand due to climate change is less than 5% by the 2050s in some parts of the world (Bates et al., 2008).

Climate change may also lead to increasing frequency and intensity of floods and deteriorating water quality (Brody et al., 2008). Climate change will result in decreased runoff in some parts of the world, leading to increased water resource stress, the number of people living in regions with severe water stress will increase from 2.3 billion in 1995, to 3.8-4.1 billion in the 2020s and to 5.2-6.8 billion in the 2050s (Menzel et al., 2007). Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilization which are expected to lead to decreased food security and increased vulnerability of poor rural farmers.

1.5 Statement of the Problems

Water resource and hydropower ranks highest impact sector among others (OECD, 2003) and is predicted to become one of the most pressing environmental problems with high impacts from climate change in hills and mountains of Nepal. Drying water sources, ground water depletion is likely due to long dry seasons, irregular rains, and high intensity rainfall leading to high run-off and less infiltration. Rural communities in hills and mountains of Nepal are experiencing the impact on water resource due to climate change. Improved understanding of the dynamics of climate change as it affects water supply and demand and the broader impacts on all water-using sectors in these areas will guide better water resources management in the area. Sound water management, which is a key to adaptation,

is weakest in Nepal, those with the greatest climate variability today, and those predicted to face the greatest negative impacts of climate change.

In most cases climate change problems have not been dealt with in water resource analysis, management and policy formulation' (Bates et al., 2008). This suggests a gap in the analysis required in understanding the full effects of climate change on human and natural systems and, moreover, how policy makers can and should improve future responses to climate change at country, regional and international levels.

Besides, NAPA to climate change report of Nepal reported Dhading as one of the high vulnerable districts of Nepal and further suggests carrying out vulnerability assessment in all the VDCs and villages of Nepal and identifying vulnerable areas and people accordingly. Hence, this study will be relevant to identify the actual impact of climate change in water resources and suggest the necessary adaptive measures to combat the subsequent impacts.

1.6 Objectives

1. To determine and evaluate impacts of climate change on water resources in Dhare Khola watershed of Dhading district.
2. To assess the vulnerability and effectiveness of coping strategies in poor and well off in terms of climate change impacts on water resources in the area.
3. To recommend the better coping mechanism for the future courses of action against climate change impacts on water resources for sustainable livelihood.

METHODOLOGY

2.1 Research Design

Participatory tools and methods along empirical field studies were used to collect data from the field. Both qualitative and quantitative research techniques were applied to gather the information related to objectives. The major elements of this methodology include the use of primary and secondary data, household questionnaire survey, focal group discussion (FGD), key informant interviews (KII), field observation.

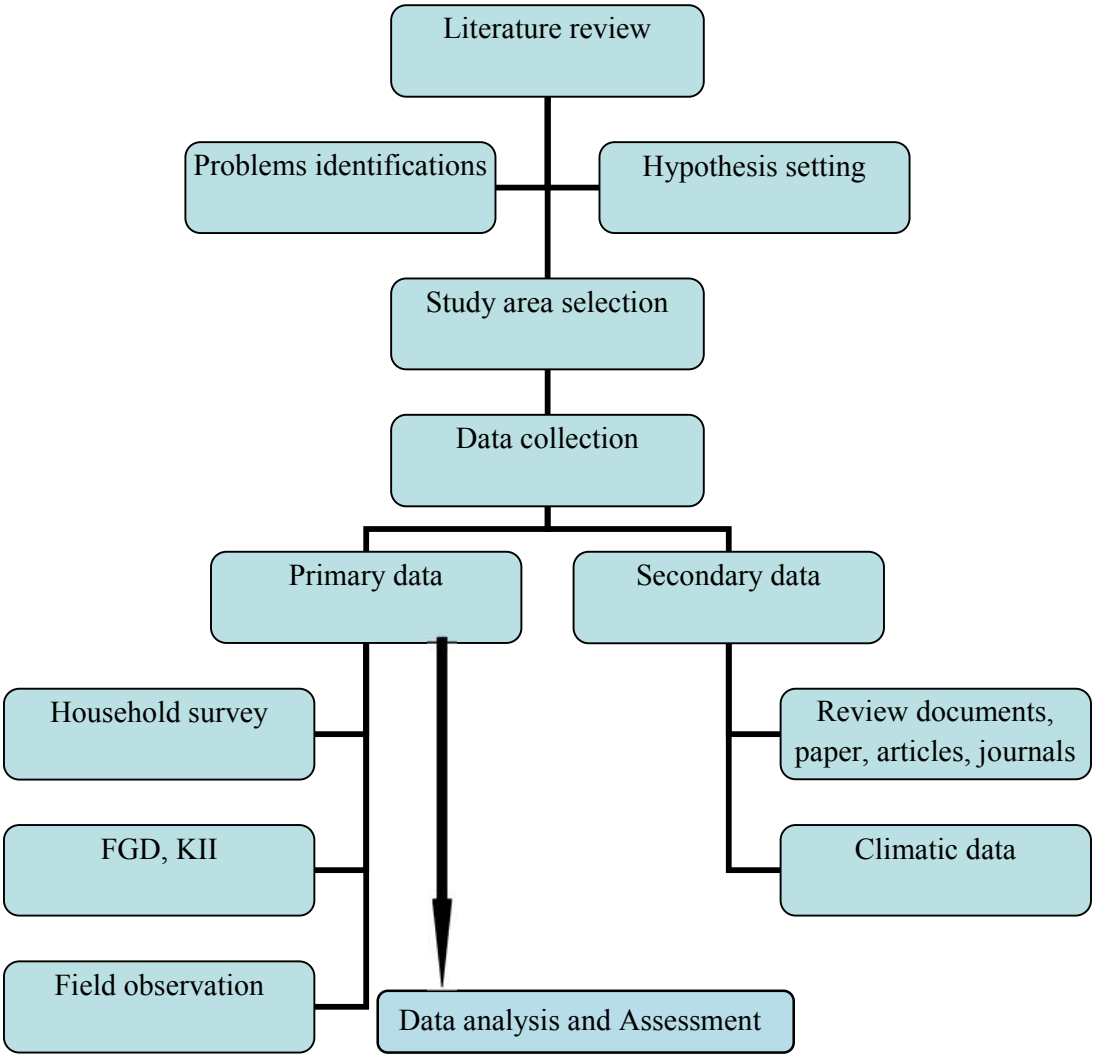


Figure 3: Research design

2.2 Assessing Climatic Scenarios

In this study, thirty year data (1979 to 2008) on temperature and rainfall of the nearest meteorological station from the study area (Dhunibesi, DHM index no. 1038, latitude $27^0$43' longitude $85^0$11', 1085masl) were collected from Department of Hydrology and Meteorology (DHM), Kathmandu.

The five year moving mean annual temperature and average monthly temperature for different time period of these thirty years were interpreted graphically. Similarly, five year moving mean annual rainfall and average monthly rainfall for different time period were also analyzed to indicate the climate variability. Besides, non-climatic indicators based on community perceptions of climate variability were also documented during FGD, KII and field observation and analyzed to support as indicators of climate changeability from 20-30 years of time.

2.3 Assessing Impacts, Vulnerability and Adaptation

Participatory tools and methods were used in the assessment process. The primary information was collected through in-depth interviews with key informants as well as focus group discussions with farmers and members of forest user groups, taking gender, social class into consideration. Participatory tools including FGD. KII, household survey and other group discussions were used to collect quantitative and qualitative data from the field.

Information received during FGD, KII and households survey were tabulated and analyzed using community based tool kit recommended by Regmi et al. (2010) was used for hazard ranking, and hazard mapping, assessing impact and vulnerability.

Table 4: List of study parameters and tools used

Assessment parameters	Tools used
Historical trend analysis: Changes, risk and impacts	FGD, KII
Climate Risks and Hazards	FGD
Vulnerability Assessment	FGD and group discussions
Comparative analysis of impacts across different groups	Household survey
Assessment of coping strategies and adaptation measures	FGD and household survey

2.4 Identifying Adaptation Needs

Adaptation options were recognized after analysis of the impact of water resource and its hazards, impacts on livelihoods, available coping and adaptation strategies that the community acquired, effectiveness of these strategies, preliminarily identified adaptation options, community resilience to cope with the hazards and risks and institutional arrangement and groups' dynamics and external support. The primary step of adaptation planning was to identify the hotspots of the vulnerability. It was then followed by identification and prioritizing of the most severe climatic risk and hazard sector.

2.5 Sampling Process and Techniques

2.5.1 Focal Group Discussion, Key informant interviews and Field Observation

Representatives from each small community (using different water sources in the watershed) and other focal persons from different class were invited during FGD to identify the facts on impacts of climate change on water resources; condition of water sources/bodies in the area in the last thirty years, water resources hazard mapping, and impact and vulnerability assessment and to develop long term adaptation strategies based on communities' indigenous knowledge and capacities to build resilience.

Besides, changes in climatic factors noticed by the community people were collected to support the indication of climate change in the area through FGD, KII having open and close ended formal and informal questions as well field observation. Some associated effects/ changes observed in agriculture, biodiversity, public health as well in other floral and faunal species within the last 30 years (non-climatic indicators of climate change) are also documented. Observation on the water sources conditions and other interrelating attributes around the peripheral zone as well photographs of the area were taken for the visual interpretation.

2.5.2 Class Differentiation

Participatory Well Being Ranking (PWBR) in users groups of Paharepani Community Forest, Batase Serapakha Community Forest and Pataal Community Forest stratified by Resources Identification and Management Society-Nepal (RIMS-Nepal) was used for the class differentiation (poor and well off). Furthermore, inquiries with key persons and information during household survey i.e, education status, major occupation, average monthly income, house type, physical assets, land and types of land owned, food sufficiency by self production and domestic animal owned were used as indicators of class differentiation and to verify it.

2.5.3 Household Survey

A total of 60 households were taken for the household survey. The well off and poor category of users as well as gender was considered during the sampling process. The household survey was intended to identify household level differences on degree of vulnerability on different social groups and coping and adaptation strategies they acquired.

2.6 Study Site

The study site, Dhare Khola Watershed lies in in latitude 27^0 44' 03'' N to 27^0 45' N and longitude $85^0$08'10" and 85^0 08' 19", having an area of 1.52 square kilometer in the border of Jiwanpur (ward no. 9) and Kebalpur (ward no 8 and 9) Village Development Committees (VDCs) in eastern Dhading district in Central Nepal. Altitude varies from 800 to 1100 masl. The study area is about 60kms from Kathmandu, the capital city towards Pokhara along Prithvi Highway. Naubise VDC lies in the south whereas Kumari VDC lies in north of the study area. Dhare khola watershed incorporates forest (20%), cultivated land (35%), settlement (15%) and bare land (15%). Within the study area, there are three community forests viz; Patal Community forest, Batase Community Forest and Paharepani Community Forest with more than 400 user's households amongst which more than 45% are Brahmins and Chhetris and were the dominant class in the area. Dalits and Janajatis were found marginalized and disadvantaged groups in the area.

2.6.1 Household information

Based on the information obtained from household survey, nuclear type of families were common in the study area having average family members 5. About 79% of the families

were nuclear type. Communities were found to be engaged in various on-farm and off-farm activities, including the sale of agricultural and livestock products. Agriculture was the major source of income for more than 69% of households in the study sites. More than 41 % have owned less than 0.25 ha (5 ropanies) of land per family. Most people depended on subsistence agriculture that contributed only partially to the household requirements needed to feed its members for a year. Only 33% of the families have food sufficiency round the year. In more than 41% of the families, food sufficiency was for below 6 months. Similarly, the education status was slightly more in comparison to national average in fact that 40% were found literate Household income level was relatively low in the study sites. Eighty- six percent of households revealed that monthly income do not exceeded NRs. 20,000. Due to the severe impact on agriculture, some of the community members had changed their occupation from agriculture to poultry farming and wage labor. Most of the houses (69%) in the study area were found made from mud and tin.

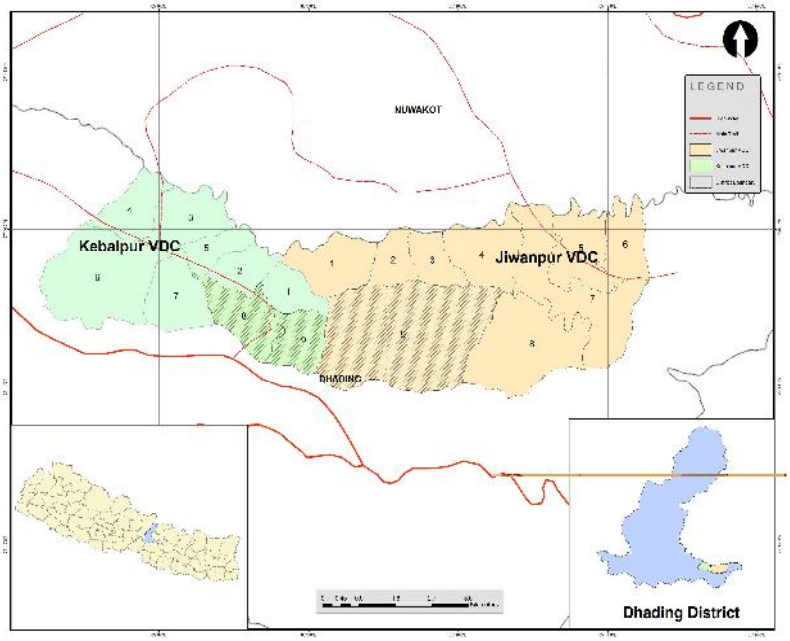


Figure 4: Study area map

2.7 Data analysis

The information collected from primary and secondary sources were tabulated and were analyzed. Quantitative information derived from the household survey was analyzed using Microsoft Excel 2007. The qualitative information collected through focus group discussions and key informant interview was analyzed using bar and chart graphs.

FINDINGS AND DISCUSSIONS

3. 1 Climatic scenario

3.1.1 Meteorological data

Among the many variables of climate, temperature is a direct way of measurement of climate warming, and most of the other variables are associated in some way to it. Rainfall and humidity are other important variables of climate, after temperature. The life zone in the world is influenced basically by these two variables: temperature and humidity. Thus, evidence of climate change can be observed by analyzing the instrumental measurements of temperature, atmospheric pressure, rainfall and humidity, etc (Lamichhane & Awasthi 2009).

3.1.1.1 Temperature analysis

Average yearly and five year moving mean yearly temperature of thirty years of the nearest meteorological station showed the increased trend of temperature (Figure 3). Temperature variation has been observed in comparing the two average five-year (1979-1983 and 2004-2008) monthly mean temperature (Fig 4) and showed the increased trend. In winter month (Dec-Feb) the monthly temperature increased by 0.23^{0}C to 1.35^{0}C. In pre monsson (March-May) the temperature has increased by 0.24^{0}C to 2.07^{0}C and in monsoon (June- Sept) by 0.23^{0}C to 1^{0}C. Similarly, this was increased by 0.18^{0}C in the months of post monsoon (Oct-Nov).

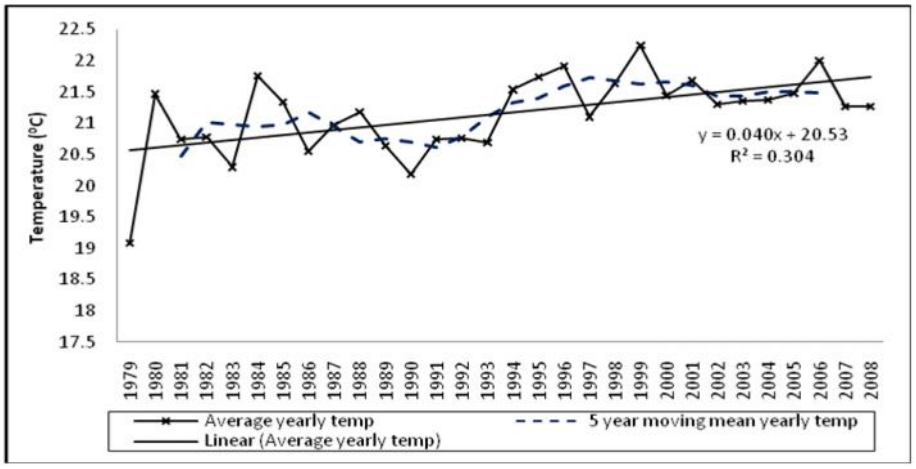


Figure 5: **Average yearly and five year moving mean yearly temperature (1979-2008)**

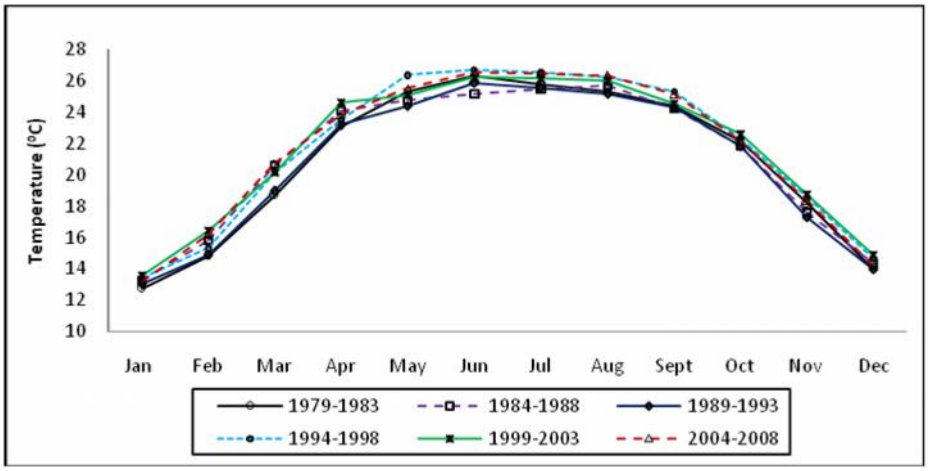


Figure 6: Average five year monthly temperature

3.1.1.2 Rainfall analysis

Average yearly and five year moving mean yearly rainfall of thirty years (1979-2008) showed the increased intensity trend of rainfall (Fig. 4). Comparing two average five-year (1979-1983 and 2004-2008) monthly rainfall pattern, it has been clearly oberseved that the winter rainfall has been reduced. Intensity of pre monsoon (March- May) was increased by 40 to 50%. Similarly, monsoon (June- Sept) declined till mid by 10- 15% and then increased from 3 to 5% till the end of post monsoon.

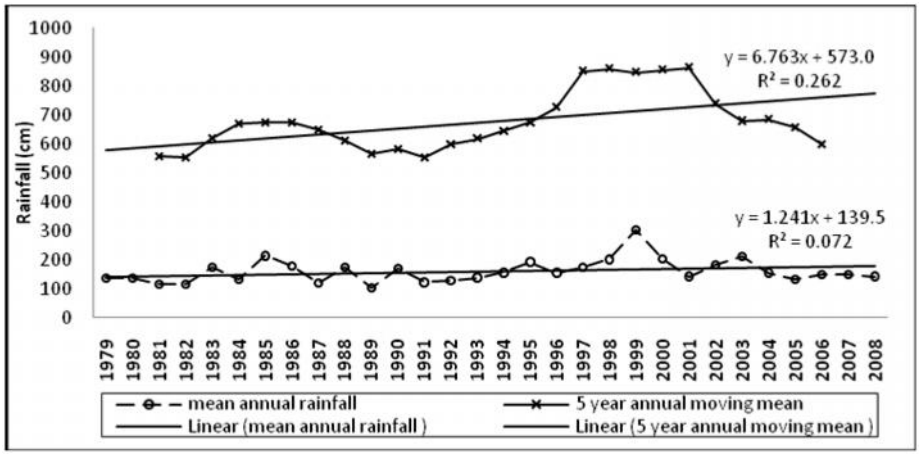


Figure 7: Average yearly and five year moving mean yearly rainfall (1979-2008)

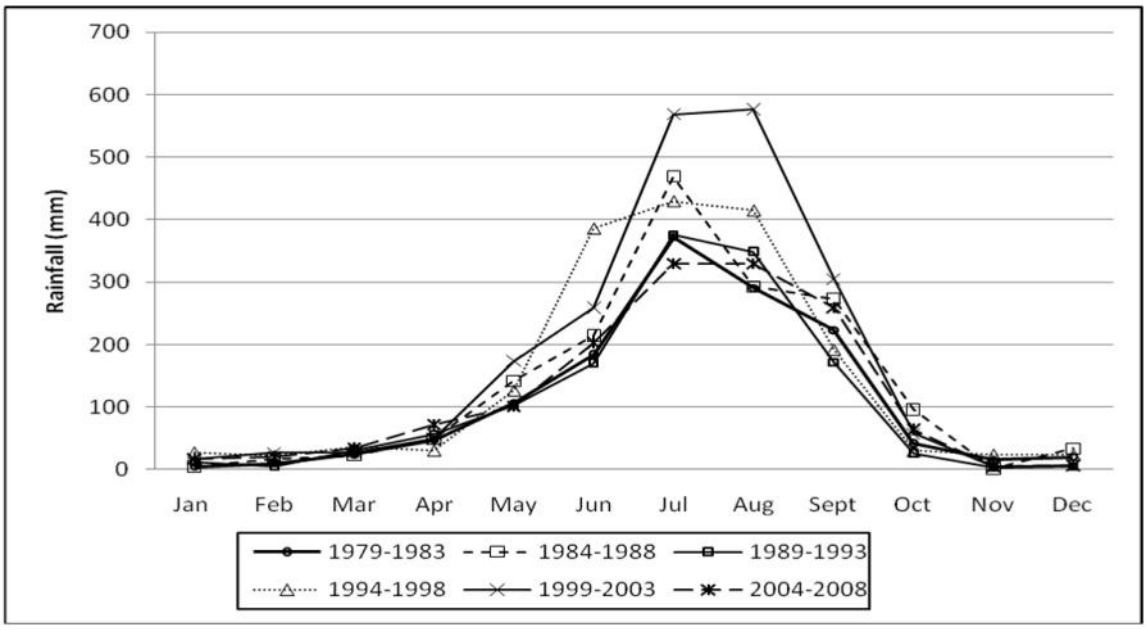


Figure 8: Average monthly rainfall in different time period

3.1.2 Community perceptions

The group discussion with communities and key informants indicated that communities experienced increased temperatures and changes in rainfall pattern in recent years. Almost all respondents during FGD revealed that local temperature has increased and rainfall frequency has decreased. However, they have perceived that intensity of the rainfall has increased compared to last 20-30 years back (Table 5). Community linked this situation to irregular monsoon and changes in rainfall patterns.

Table 5: Community's perception on variability in climatic parameters in the last 20-30 years

Perceptions	Temperature		Rainfall		
	Summer	Winter	Frequency	Intensity	Duration
Increased	✓			✓	
Decreased		✓	✓		✓

The local level indicators of temperature rise included the changes in plant phenology, occurrence of new diseases in human, in plants and in domesticated animals and outbreak of pest and diseases. Similarly, change in agricultural pattern, loss and emergence of plant species are also reported as indicators of climate change variability in local level.

3.1.2.1 Impact on Agriculture

Vegetable farming is the main source of livelihood in the area. Vegetable grown in the same field use to be sufficient to sell in market but at present it is only sufficient for household use in most of the houses. Less production of rice, less juicy fruits have also been observed in the area. Sowing and harvesting periods of the crops and fruits has changed in comparison to past years. The weather pattern is unpredictable so the yielding is unpredictable accordingly. Similarly, *Daduwa* in potato, G*abara* in banana, empty seeds in wheat, less *bala* in rice plants are some facts on the area. Unknown species of pests and insects are introduced and there has been increased in number of existing insects (*Khumre, White fly*) and drastic increase in rats' number.

3.1.2.2 Impact on forest and biodiversity

Significant change in availability grass fodder and non timber forest products (NTFPs) has not been seen in the area but the observation shows that some of the fruits such as *guava* and *papaya* which use to be available abundantly in the past have reduced. Similarly, *Nundhike, Chutro, Aank* and *Tuni* are some species of plants seems reducing in number. At the same time *Utis, Gandhe jhar* and *Banmara* has been increased in their number in comparison to past. Alien species of pest in bamboo seedlings (*taama*) and multi branches on it are also observed in recent days. *Leech, frog, fish, lizard, jackal* has been increased. The number of *udus* and *makura* has decreased while as decrease number has been observed in *whiteflies* in house. Less frequency in rainfall increased the number of caterpillar in comparison to past.

3.1.2.3 Occurrence of new diseases

The diseases seen in the recent days are also the indirect non climatic indicators of climate change. The incidence, range and seasonality of many existing health disorders have been observed in comparison to the past. The patients of diarrheal and respiratory disease have been increased in the area. Unlike diseases such as allergic diseases related to skin and eye diseases (conjunctivitis), jaundice patients number and some alien diseases in domestic animals increased.

3.1.1.4 Climatic hazards in the area

Based on community perception through FGD and KII, reduction in water sources in the area is the most climatic hazard seen in the area. The climatic stress assessment in the study areas suggests that landslides, drought, loss/reduction of natural springs, hailstones, wind storms, outbreaks of disease and forest fires are the major climatic risks and hazards. Communities have linked the observed trend of climatic risk and disasters with the ongoing sets of climatic variability. According to the communities, the temperature has increased and variability in intensity, magnitude and the duration of the rainfall in monsoon season has changed. Consequently, the frequency and impact of climate risks and hazards have increased (Table 6).

During the FGD and historical time line analysis, people expressed that they have experienced and observed increased climatic risks and hazards. According to their views, drying up water resources was the topmost hazard ranked in the area. This hazard is followed by flash flood, drought and in frequency of diseases outspread. Latest flood event was observed 17 yrs back (2050BS) and lost lives and property in the area and was the most dread able event in last few decades and also flash floods are occurring frequently in the area. Since the period, impact on water sources has been observed that leads on dry up sources and decrease in quantity. Long drought occurred 10 years before and was noticeable event and did great impact on agriculture and consequently on loss in economy. According to them, these events were getting more and more frequent and intense during the last 15-20 years.

Table 6: Climate hazards/risks cause and their ranking based on community's perceptions

Hazards	Causes			Ranking
	Temperature	Rainfall	Both	
Flood		✓		2
Landslide		✓		6
Drying up natural water sources			✓	1
Drought	✓			3
Forest fire	✓	✓		5
Out break of diseases			✓	4

3.2 Climate variability impacts on water resources

Drying up water resources was the major climatic hazard of the area and caused substantial decrease in water availability. Sixty percent of the sources[1] (24 out of 41) dried up and Dhare khola water volume decreased by almost fifty percent compare to past 15-20 years. More than 5 ponds[2] dried. Underground[3] water has also found reduced. Most of the water holes in the forest areas have been dried up, which posed adverse effects on biodiversity in the area.

From the rainfall data interpretation, increased trend of rainfall was observed. Examining the rainfall trend and community's perception on climatic scenario in the last 20-30 years, it is clear that the intensity of rainfall was increased whereas frequency and duration were decreased. So, this event results in increased flashflood, reduced in soil moisture and less water infiltration. This might be the reason of drying water sources and substantial decreased in water availability in the area.

Drying water sources in the areas has not only caused problems on accessible of drinking water source since agriculture, economic loss, threats to biodiversity, threats to human life were also the major impact sectors. Agriculture was found to be the most impact sectors followed by economic loss, threats to biodiversity and life threats. People revealed that the land irrigated by Dhare Khola water decreased almost by 30%. People have linked risk sectors with the ongoing sets of climatic variability. Approximately two-fifth of land was left barren or used as Bari (cultivating maize/millet instead of paddy cultivation). Forty-nine percent household have shifted to another water source and water insufficiency ratio has been increased compare to past. Household responsibilities combined with extensive involvement in productive

[1] Includes small *kuwa*, stone spouts and springs

[2] three seasonal ponds and remaining permanent

[3] Based on KII – According to Pramila Regmi (an activist, resident of Jivanpur- 9), there was sufficient water yielded from well but before 3 years 8 more ring were added in well, yet less water is harnessed in compare to past.

activities results an overwhelming workload in women and found to be more vulnerable than male since eighty percent of the household women in the area were found responsible for the hauling domestic water need.

Green area and forest density has found increased in the area in comparison to the past. Road has been constructed in the area. Other infrastructure was not found developed in the area. During the field observation, no any obstruction and linkage was identified between the road constructed and drying up water source and water bodies. Almost major people linked drying up water sources with ongoing climatic variability. Even though some linked this situation with the planted *Salla* tree as it was found one of the major tree species in some part of the forested area.

Table 7: Impact assessment on livelihoods

Agriculture	Economic loss	Biodiversity Loss	Threats to life	Domestic	Business
5	4	3	3	5	4

(Scaling: 5= Very High impact, 4=High impact, 3=Medium impact, 2=Low impact 1=No Impact)

3.2.2 Vulnerability assessment

The impact of climate change varies among the different regions, generations, ages, classes, income groups, occupations and genders. Vulnerability is defined as the degree to which a system is susceptible to or unable to cope with, adverse effects of climate change, including climate variability and extremes. Climate induced risks and disasters do not distinguish the poor and rich, young and old, men and women. However, the poor, women, the elderly and children are disproportionately affected by the hazards of climate change.

Table 8: Vulnerability on different social groups

Social groups		Impact sectors			
		water source (domestic need)	Irrigation source	Business	Work load
Gender differentiation	Male	3	3	3	2
	Female	4	2	3	4
Class differentiation	Poor	4	1	2	4
	Well off	3	3	3	3
Culture/ caste differentiation	Dalit	4	1	1	3
	Janajati	4	2	3	3
	Chhetri	3	3	3	3
	Brahmin	3	3	3	3

(Scaling: 5= Very High, 4=High, 3=Medium, 2=Low, 1=No Impact)

3.2.2.1 Impact on gender

It has long been noted in the gender and environment literature that women and girls generally assume primary responsibility for collecting water for drinking, cooking, washing, hygiene and raising small livestock, while men use water for irrigation or livestock farming and for industries (Fisher 2006; Khosla and Pearl 2003). These distinct roles mean that women and men often have different needs and priorities in terms of water use.

Women in the study area have limited access to resources like education, knowledge, skills and technology, land, credit facilities, social networks etc. These resources essential to maintaining one's livelihood would in fact help build the adaptive capabilities of women and poor households. However, due to limited resources women often suffer the most and are the least able to recover from the effects of hazards. As a result, this emphasizes gender inequalities that are already present and deeply rooted in rural Nepali societies. Living in a hilly area means daily dealing with life challenges in order to sustain one's livelihood. The steep slopes make the trouble of hauling water from the source.

In the study area, women are more vulnerable to climate change impact on natural water resources. Study showed that in 80% of the household the women are responsible for the hauling of water for domestic purpose. Almost 49 % of the household in the study area have changed the water source due to dry up the sources and similar percentage of the household has increased in the time and distance to carry water from the source. Water sufficiency for domestic purpose has decreased from 85% to 45% household in the last decade. So, all this trend of water source change and insufficiency is the addition of burden on women in the area. The decrease in water availability has made their livelihoods vulnerable and has increased their workloads. Only 3% of the women were in the position of community decisions and responsible in social activities (involving in community forest users group committee and mothers groups) in the area. Rest percentage totally has to devote on family and other income generating works all the time. Women's household responsibilities, combined with their extensive involvement in productive activities (vegetable farming and poultry farming) in well off families also results an overwhelming workload.

Besides, women in poor households are more vulnerable to climate change impact on water resources. The percentage of poor household shifting totally towards other water source

was 48% for collecting domestic water need. This also shows the real critical situation they are facing with climate change impact on water resources on the area. The frequent laboring of men in poor households and seasonal migration for earning due to lack of land of their owning also made the women more involved in managing household which usually an increased workload along with all of the added stress that it creates.

3.2.2.2 Impact on class

IPCC fourth assessment report mentioned that the poor are the most adversely affected by climate change due to their exposure and the impact of climate change on their livelihood assets. The study conducted in Dhare khola Basin of Dhading district validates this showing that climate risks and hazards have contributed in creating negative impacts on poor's livelihood. The impact on livelihood in deprived and well off due to impact on water resources to climate change showed that poor are more affected than the relatively affluent households (Figure 9 and 10).

More than 30% of the households are found under poverty of which majorities (80 %) from *Dalits (Mijar)* and *Janajatis (Rai, Shrestha, Bhujel)* that includes marginalized and disadvantaged group in the area. The average water demand for domestic purpose was 145 liters per day per household in poor families whereas 350 liters per day in well off family for this purpose. The reason behind this was that the average household number of family member in poor was 5 whereas in well off families it was found to be 7. Similarly, the average number of animal that are domesticated in poor families was 1, but in case of well off families it was found 4. These are the reasons behind demanding more water in well off families rather than in poor families.

Spring and *kuwa* are the main sources of water for household purposes in the area. 48% and 50% of the households in poor and well off families have changed their source of water for domestic use which results in increment in time and distance for hauling water from the source. In this regard, high percentage of poor family has shown the increment in time and distance to collect the water from the source for domestic purpose. The percentage of poor that have water insufficiency round the year for domestic purpose was 12% whereas in well off it was 9%. Also water insufficiency figure in poor family in dry season was 52% and in well off this was (36%). Based to the household response, higher percentage of the poor

were under high impact on access of drinking water and other domestic use purpose than the well off families. More than half percentage of the poor (Figure 9) are under high impact for these purposes.

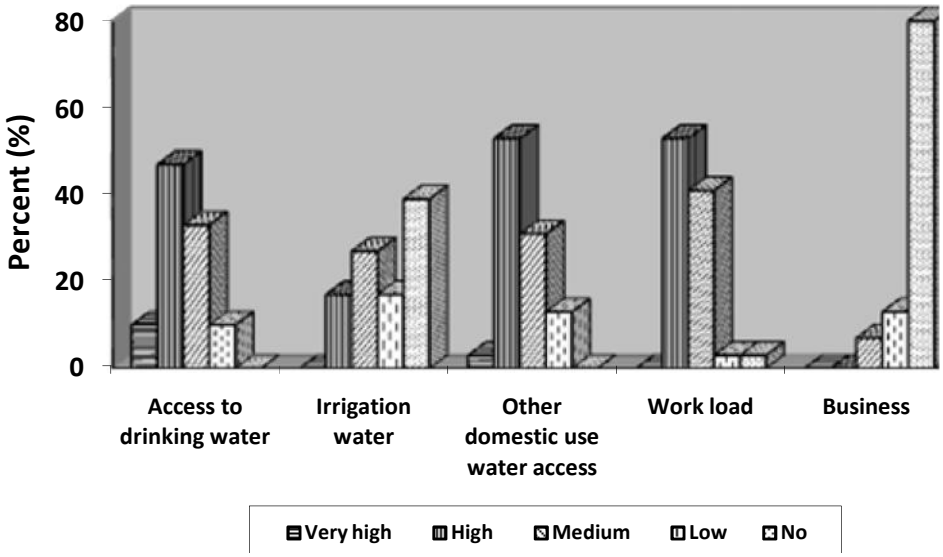


Figure 9: Impact of water hazard in poor (Source: Field Data, 2010)

Average land in per household in poor was 2 *ropani*, and was not arable. Very few families in poor have been found with irrigated land. Regarding this situation, almost cent percent of the poor household have to be dependent on labor works for fulfilling their daily needs and for their livelihood. The condition on water source change, water insufficiency and increment in time and distance to haul the water from sources has marked that the poor high vulnerable to climate change impact on water resource in that area. So, household responsibilities combined with their extensive involvement in most of the days in earning activities usually an increased work load in poor. More than 50% of poor responded there was high impact on their job that increased their daily workload.

Water demand for irrigation purpose in well off is high whereas this demand in poor seems negligible. Average irrigated land in well off was found to be 8 *ropanies*. The source of irrigation in almost in this land is Dhare khola. Community reflected that the volume of water in this water source reduced by 50% in the past 15 years. They also revealed that the land irrigated by this water source was more than 200 *ropanies* with and more than 21 stream canals (*kulo,* including small to big) used to flow from such stream for irrigation but

at recent time this number of *kulo* decreased to 9 irrigating just about 120 ropanies of land. Similarly, vegetable farming and poultry farming are the business operated by well off families in the area. These also added some stress on getting sufficient water for their business in well off class.

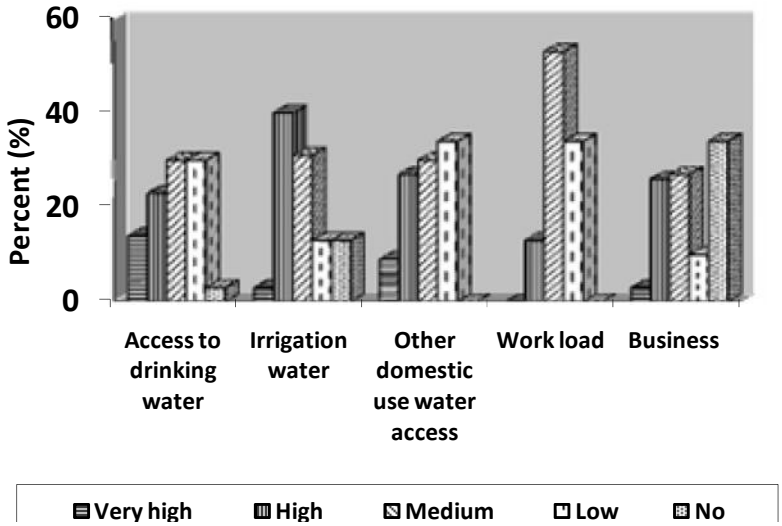


Figure 10: Impact of water hazard in well off (Source: Field Data, 2010)

The impacts of climate change have weakened the livelihood system of both poor and well off but have had comparatively higher impact on the poor's ability to respond as opposed to the well off due to factors like education, income, information and knowledge, access and options and opportunities and ability to cope with the situation.

Table 9: Household impact due to water hazard

Impact	Average no. of households	
	Poor	Well off
Very high	2.5%	6%
High	34%	26%
Medium	28%	34%
Low	11%	24%
No	24.5%	10%

(Source: Field Data, 2010)

3.3 Coping strategies adopted by the community

Coping and adaptation is an essential strategy for reducing the severity and the cost of climate change impacts. The study site was found to be highly vulnerable to impacts of climate change on water resources. Communities were found using some strategies at local

level to cope and adapt to the impacts of climate change on water resources. However, the coping and adaptation strategies to deal with the climate change related disasters were very poor and insufficient.

The concept of less water use is prevalent in the area. Less use of water in kitchen, washing utensils and other daily needs is common practices in most of the houses. Almost 70% of the households in the watershed area use this measure to cope with drying up water resource. Some of (5%) the households started lessening livestock in dry seasons (February to May) who are totally engaged in domesticating livestock all round year before.

The community's people (almost 10%) started going nearby river for bathing, washing clothes in the during dry season and also 9% of the households have been found starting to take livestock to the nearby stream daily and some 3% of the households temporarily started to take livestock making *goth* near the bank of the Maheshkhola so that it makes easy on feeding them with plenty of water.

Some of the community (Adhikari tol) also started covering the sources like *kuwa* with tin plates to protect from evaporation and slowly developing the water storage system (concrete reservoir) on nearby source and share out twice a day (morning and evening). Water management has been also done through pipeline system. Many households now have access to drinking water through this system. Most of the well off families have even used private pipeline for their supply. However, problems such as leakage of drinking water from the pipes, caused by the improper handling, and severe water shortage during the dry seasons have posed new challenges to the community. Lifting water from far spring source

(about 2 km) using electricity has been done in Kharka (Acharya Pokhari) by some well off families and reserve in tanks for the distribution in their community. Some well off families started rearing of poultry and goat, as they require less water and easy handling than the livestock. But in some poor families, the trend of collection of water from nearby source of next village and digging small *jaruwa* (temporary *kuwa*) in the marshy locations in the side of *kholsa* (small stream) nearby to their residential area are also common coping strategies during dry season. Rain water harvesting is also another coping strategy in the area in 15% well off families, collecting rain water during rainy season and collecting in water storage system for the use in dry season.

Farmers have started to change their cropping pattern. People have shifted from paddy cultivation to maize and millet due to delay in monsoon and lack of water on the Dhare khola. The focus of the communities has shifted to subsistence vegetable farming instead of cultivating cereal crops and intensive farming. Communities were found slowly shifting from three season irrigated production to seasonal production and irrigated land (*khet*) as unirrigated land (*bari*) for maize and millet cultivation.

Communities were slowly developing the water storage system. They have constructed water tanks for storing water and collecting from small pipe in the night time and dripping technique is used for irrigation purpose in vegetable farming. About 40% of in well off families who are engaged in intensive vegetable farming have developed this strategy. Similarly, collecting kitchen waste water and urine of livestock have also been developed in few poor and well off families for vegetable farming for their own use.

Communities are developing pipe as a means of transporting water for irrigation instead of direct open *kulo* from the irrigation source to resist from evaporation and other leakage problems. Rain water harvesting during summer season and reserved in plastic tank or in cemented tank have also been developed in few households to use in dry season for vegetable farming. Sharing water on time basis where there is same irrigation source has also been developed to fulfill some needs of water for irrigation.

3.4 Effectiveness of coping strategies

The coping strategies gained by the community are effective if only the strategies help to reduce the severity and the cost of climate change impacts in the local level. The

effectiveness of coping strategies may vary on the degree of impact on different areas/sectors, its vulnerability and the way of adopting the strategies in the sense of changing patterns of climate and significant deviations from historical adjustment, their effectiveness may be significantly reduced.

The level of coping strategies among poor and well off also differentiate the level of effectiveness on two social categories. Based on the household survey, FGD and KII information effectiveness of the coping strategies in the study area was assessed. The study found that the coping strategies adopted by the well off were much more effective than in poor.

Majority of the poor revealed that the effectiveness of the coping strategies they owned for domestic water use (access to drinking and for other household water use) was found medium effective (Figure 11). Least figure, only six percent and three percent poor acquired very high effectiveness of coping strategies for the access of the water for access of drinking water and other domestic purpose. In well off household, only four percent of the families responded the low effectiveness of the adaptation approach they applied for the access of drinking water. Similarly, some more percent of this class supposed the low effectiveness of coping strategies in access to other domestic use. Higher percentage of well off responded the strategies were not applicable in comparison to poor, since these figure of the household got the same source of the water for drinking and other domestic use from 20 years of time.

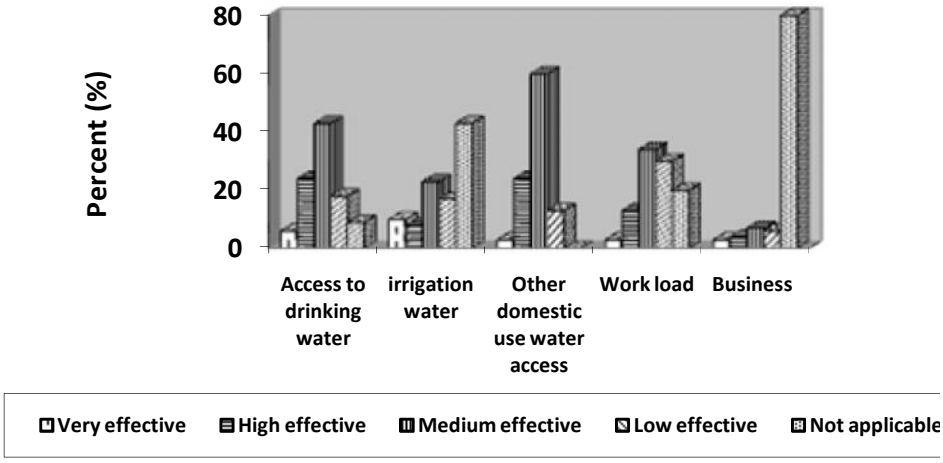


Figure 11: Effectiveness of coping strategies in poor (Source: Field Data, 2010)

Conversely, higher percentages of poor were found not acquiring the coping strategies applied for the access of water for irrigation and for business (Figure 12). The average household irrigated land in poor was very low in comparison to well off and also very few percentages of the poor were engaged in business (poultry farming and intensive vegetable farming). Higher percentage of the poor responded the coping strategies were not applicable for these purposes since the demand of water for this class was very low in comparison to well off for irrigation and business purpose.

The strategies owned by the poor households in the area for collecting domestic water somehow fulfill the water demand for domestic use but this increased the work load on these communities. The majority of the well off families have even used private pipeline for their supply. However, problems such as leakage of drinking water from the pipes, caused by the improper handling, and severe water shortage during the dry seasons have posed new challenges to the community. Less use of water for domestic purpose and lessening the number of livestock is not the better solution for the better livelihood. Despite the fact that lifting water by the electricity from long distance sources in some community is effective, it is not economical in long term in the context of rural poor people to pay the high electricity charge.

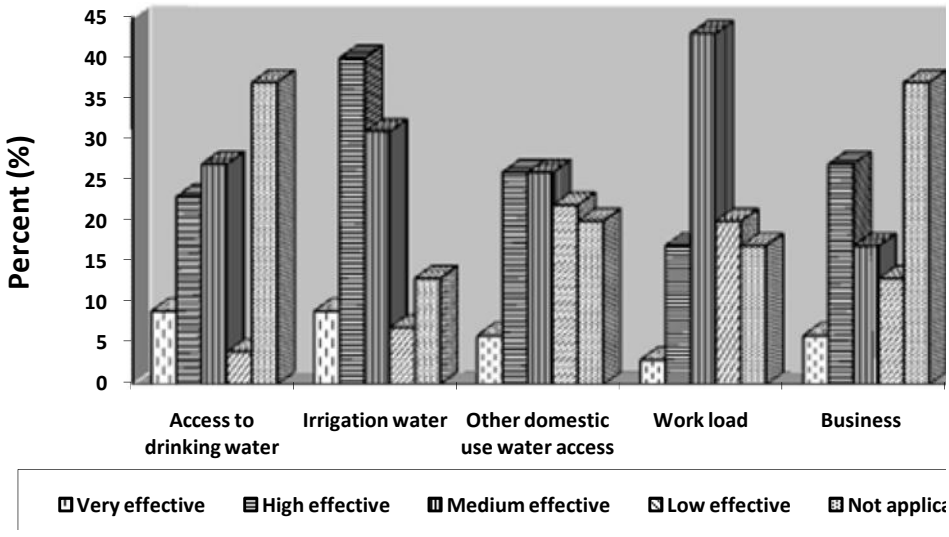


Figure 12: Effectiveness of coping strategies in well off (Source: Field Data 2010)

Because of lack of high volume reservoir and other technological oblivious even in some well off households of the area, the concept of rain water harvesting was found low

effectiveness. Similarly, changing the cultivation pattern with variation of the climate in the area is excellent method of coping but lack of agricultural knowledge made them to cultivate haphazardly on their own way. Dividing water from the source for irrigation even in the summer season is the indication of critical situation and the situation is worsening year by year. According to the community people, this coping strategy was the best way to solve the water insufficiency for the irrigation but was found it as the cause of conflict in the community. Comparatively, the effectiveness scenario on adopting coping strategies in well off was found more effective than in poor.

Table 10: Effectiveness of coping strategies on average households

Effectiveness	Average no. of households	
	Poor	Well off
Very high effective	5%	7%
High effective	15%	27%
Medium effective	32%	29%
Low effective	17%	13%
Not applicable	31%	25%

(Source: Field Data, 2010)

3.5 Institutional arrangement and group dynamic

Institutional arrangement and group dynamics play an important role in identifying options and opportunities for building resilience of communities. Previous study showed that the stronger the group, the more effective the initiatives and activities in terms communities resilience and their livelihoods. The study area had no separate formal institutional arrangement at community level to deal with water hazard. But community forest users groups, *Aama samuhas and* Farmers Cooperatives were involving for the community development through plantation and other trainings related to farming which are directly of directly associated in uplifting economic status and capacity of the farmers that directly relates with community resilience to cope with the climatic hazards.

3.6 External Support

External support and interventions also determined the degree of vulnerability of communities. These are further linked to exposure and access to information, knowledge, technology and resources to cope with climate risks and disasters. Very fewer organizations were working in the study area, in the sector forestry, agriculture, disaster management, health, and infrastructure. Communities revealed that they were receiving nominal support

(financial and technical) from the governmental organizations such as the District Development Committee, District Soil Conservation Office, District Agriculture Office for the development of community work. Other some non-governmental organizations (NGOs) were also working in the area.

Community Development Program for the economic upliftment of community and other training/ awareness program related to under Local Adaptation plan of Action: Scoping and piloting program were carried out in the area by various NGOs with the support from other national International organizations. Programs like farmers' training/awareness programs concerning Integrated Pest Management, climate change adaptation and mitigations programs were run under these programs. Communities revealed that the support provided by these organizations is effective for the communities that these types of community development and training/awareness program increased the people ability to cope with the climate change impact on the area.

3.7 Adaptation Planning

Bottom up processes are significant to come to a common understanding with the community on what are the most major climate risk and hazards, which among them are urgent and of urgent precedence, and what could be done at local level given the rich local knowledge and perceptions. This planning process seeks to establish a vertical link between top down, the national-scale assessments of current climate risks and future climate risks, with bottom-up assessments from community members themselves – informed by local knowledge and geographical specificity.

In the study, adaptation options were recognized after analysis of the impact of water resource and its hazards, impacts on livelihoods, available coping and adaptation strategies that the community acquired, effectiveness of these strategies, preliminarily identified adaptation options, community resilience to cope with the hazards and risks and institutional arrangement and groups' dynamics and external support. The primary step of adaptation planning was to identify the hotspots of the vulnerability. It was then followed by identification and prioritizing of the most severe climatic risk and hazard sector.

3.7.1 Identification of hotspots of vulnerability

Communities recognized the hotspots of vulnerability based on the water resource hazard/risk sectors and its impacts on their livelihoods. Based on the accessibility of water for domestic, irrigation, business and its impact on workload were the major sectors to identify the vulnerability of water hazards in the area in different social groups. Other water related hazard has not been documented in the area. Based on the FGD, KII, household survey and field observations it has been clear that Kebalpur VDC ward no 9 is much more vulnerable in terms of drying up water resources as climatic hazard than other wards. Community of this most vulnerable area was inhabitant of *Dalits, Janajatis* who were poor and marginalized groups in the area. Lack of knowledge and financial capacity to anticipate and respond to climate change direct and indirect effects, poor were more vulnerable in the area and have less resilience capacity to climate change.

3.7.2 Prioritization of the climatic risk and hazard sector

This step was to prioritize what the communities felt the climatic risks and hazards impact on different sectors. Drying up of water resource and its associated concern were the main climatic hazards and risks of the area. Based on the degree of adverse effects of climate change in water resources and considering the degree of impacts on natural eco-systems, production system, and the human system as well consequent impacts on these systems were also considered in the watershed area. It was done based on the discussion on the existing as well as the probable prospect of risks in different these sectors. Based on the community perceptions and field observations, the high hazard and risk was felt in human system. Access to domestic water and agriculture is the main hazard sectors in human system from existing climatic hazard.

3.7.3 Identifying most immediate and urgent needs

The necessity and immediacy of adaptation needs were identified based on the prioritization, frequency and intensity of water hazard and risk in the area assuming that the delay to start adaptation measures could increase vulnerability.

The study revealed that communities had a number of coping and adaptation strategies developed to overcome the drying up water sources. Over the period, some government and non government organizations have initiated some activities to reduce the adverse

impact from existing climatic hazard in the area but they were less effective. Following adaptation strategies (intervention and facilitating adaptations) are recommended in the study area to address the adverse impacts of climate change on water resource based on both acquiring coping mechanisms and practices, and community perceptions and expectations gained during FGD and KII.

3.7.4 Short term measures

3.7.4.1 Awareness and sensitizations

Awareness campaign relating to climate change, its impact and risks and adaptation measures at local levels for vulnerable groups and class in the society should be done. The existing local mother groups, youth clubs, eco clubs, schools and government offices working in the areas can be integrated in common forum in managing the risks and hazards of climate change and its vulnerability. Different training and seminars related to climate change, its mitigation and adaptation should be conducted to aware and sensitize different community people, groups and institutions.

3.7.4.2 Sustainable water resource management

Water is a primary medium through which climate change will have an impact on people, ecosystems and economies. Improved understanding of the dynamics of climate change as it affects water supply and demand and the broader impacts on all water-using sectors will guide better water resources management. This will in turn develop resilience to existing variability in climate, at the same time as builds additional capacity to adapt to future climate change. So, better water resource management is a cost effective strategy; bringing instant benefits to fight against vulnerability of all groups and classes.

For this reason, it is recommended on sustainable use of water resources in the community. Development and introduction of technologies that increase water efficiency, improve the drainage system, improve water usage, conserve the natural water sources, promote rainwater harvesting, kitchen waste water and other waste water collection are some measures to promote water management sustainably from household and community level. Community preference was also found in promotion of rain water in the area could be used to collect water in monsoon season and preserve for dry periods. Though some households were found using this technology but in less efficient way and was found less effective. This

collected water could be use both for domestic use and even for irrigation purpose for vegetable farming during water shortages periods. Besides, different new technologies like supplemental water system, dual-purpose system, and combined system should be identified that is fitted to this area. Similarly, water in Dhare Khola stream can be collected making large reservoirs leaving overflow and timely distribution for irrigation in dry seasons is also another strategy.

3.7.4.3 Strengthening agriculture system

Promotion of local climate resistant hybrid crop varieties and drought tolerant varieties suitable for the particular area should be recognized. Awareness programs on minimum tillage practices and crop diversification program should be encouraged. Installing Agro-meteorological station could be another way to strengthening agriculture system in the area. Agricultural insurance programs can be set up for the encouragement of the community. Promotion of underutilized species like yam, taro, millet, buckwheat is some species that can be grown well in adverse and marginal conditions. Consequently, capitalizing these species will enhance better opportunity for farmers mainly in poor household who have less and non irrigated land owning. Trainings for farmers like Integrated Pest Management, Organic Farming and other technical and scientific consultation dealing with different coping strategies and promoting green house farming technologies mainly on tomatoes and other creeping vegetable farming could also be done to cope with drought.

3.7.4.4 Support the local groups and institution

Capacity building training for the different groups, institutions like mothers groups, youth clubs, eco clubs working for the development and economic upliftment of community people of the area as well for local organizations working in different sectors such as climate change, water and its cross cutting issues like agriculture, forest and land management of the area can be done to increase the resilience of the community. Eco clubs can be established in the schools for the better and easy support to strengthen the students' capacity. It is also necessary to form different groups and committees with well equipped with information, knowledge, skills and resources and make strong coordination to strengthen their capacity that can immediately respond.

3.7.5 Long term measures

3.7.5.1 Research and development

Potential drying up of water resources and its cross cutting impacts in near future should be identified and mapping and assessing of risks and vulnerability is necessary. In addition, carrying out participatory research on identifying alternative technologies endow with domestic water, agriculture and business that can minimize climatic impacts.

3.7.5.2 Technology transfer and financing

Introduction of technologies that can cope with drought in agriculture and reduce the impact of drying of water resource in the area is greatly required. Furthermore, establishing relief fund to help that could be used to farmers in case of crop damage and dead of livestock through the concept of farmers' cooperatives.

3.7.5.3 Stakeholder mapping

Stakeholder mapping was done with the purpose of providing basis for developing outline of multi stakeholder on climate change action and identifying key stakeholders for implementing adaptation actions; their condition of providing strategies and collaborate for obtaining their common interest and agenda on climate change issues and planning adaptation strategies. This is the most significant part of adaptation planning. The stakeholders were identified based on their activities and their field of interest. Following are some stakeholders identified in the study area and their working areas are recapitulated below.

Table 11: Stakeholder mapping

SN	Institutions/ organizations	Sectors
1.	District Development Committee, Village Development Committees, District Agriculture Office, Red Cross	Infrastructure Development and Training
2.	Ministry of Environment, Ministry of Water, Ministry of Forest and Soil Conservation, Ministry of Agriculture and Cooperatives	Research
3.	Schools	Education
4.	National Planning Commission	Planning Activities
6.	World Wildlife Fund for Nature, Local Mothers Groups, Forest Users Committees, Navajyoti Farmers Cooperatives and Eco clubs	Awareness and capacity building

CONCLUSIONS

About sixty percent of the sources have been found dried up and substantial decrease in the volume of *Dhare khola*. More than 5 small ponds and most of the water holes in the forest areas have been dried up. Human and production systems were found to be the most impact sectors. Poor were found to be more vulnerable in terms of domestic water accessibility whereas well off were more vulnerable with respect to availability of irrigation water and business purpose. More than 35% poor have found high impact due to drying up water sources in the area whereas only thirty two percent in well off were facing high impact.

The concept of less water use, lessening livestock in dry seasons, covering the water sources with tin plates, developing the water storage system, electricity lifting water from far spring source, rain water harvesting, rearing of poultry and goat instead of vegetable farming that needs less water are frequent in well off whereas, collection of water from next source, digging temporary *kuwa* on marshy areas in stream side is common in poor for adaptation during insufficiency and dry periods. Shifting cropping pattern, rain water harvesting and developing the water storage system in well off and collecting kitchen waste water and urine of livestock have also been developed in few poor and well off families to overcome in accessibility of irrigation water. Coping strategies was found to be more effective in case of well off rather than that of poor. Higher percentage of water insufficiency round the year and in dry season, higher percentage of household compulsions to shift to next water source, water insufficiency and increment in time and distance to haul the water from sources, less resilience capacity to deal with the hazard made poor more vulnerable to climate change in the area.

Kebalpur VDC 9, inhabitant of Dalits, Janajatis (poor and marginalized groups in the area) was found more vulnerable site. Lack of effective external support and formal institutional arrangement, lack of knowledge and financial capacity to respond to its direct and indirect effects, community possessed low resilience capacity to deal with hazard/risks.

Both the intervention and facilitating adaptations measures are required to be developed considering, bottom up and top down approach simultaneously. Awareness and sensitizations in groups and institutions, providing technical and financial support for the vulnerable groups, shifting towards sustainable water resource management, strengthening agriculture system are some recommended measures as short term adaptation strategies while research and development, technology transfer & financing and stakeholders mapping are some long term adaptation measures.

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Glossary

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Adaptive capacity: The ability of a community to adapt to climate change or other environmental disturbances.

Climate change: A change in the world's climate, persisting for an extended period of time (typically decades or longer which occurs as a result of natural conditions or anthropogenic sources changing the composition of the atmosphere or the land use type.

Coping strategy: Approaches to increase ability of socioeconomic, institutional and cultural systems to adjust to climate change, natural disasters or degradation in the water resource base.

Greenhouse gas: Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydro chlorofluorocarbons (HCFCs), ozone (O_3), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Poor: In a low comfortable position in a community, having little or no wealth and few or no possessions.

Technology transfer: A broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change among different stakeholders

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Well off: In a comfortable or favorable position by some standards; easy living, a prosperous family, financially strong, well-to-do members of the community, literate.

Resilience: The ability to absorb disturbances, to be changed and then to re-organize and still have the same identity (retain the same basic structure and ways of functioning).