(Faculty of Applied Ecology, Agriculture Science and Biotechnology)

Nabin Baniya

Master thesis

Impact and Adaptation to Climate Change in Nepalese Agriculture

- A case study of Jumla, Mustang and Chitwan districts

Effekter av og tilpasning til klimaendringer i landbruket i Nepal – en caseundersøkelse fra Jumla, Mustang og Chitwan

Master of Sustainable Agriculture

2018

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Acronyms

ADP	Agriculture Development Bank
APP	Agriculture Perspective Plan
CC	Climate Change
DADO	District Agriculture Development Office
DF	Degree of Freedom
FAO	Food and Agriculture Organization
FGD	Focal Group Discussion
GDP	Gross Domestic Product
GHGs	Green House Gases
GLOF	Glacial Lake Outburst Floods
HFCs	Hydrofluorocarbons
HH	Households
INGOs	International Non-Governmental Organizations
IPCC	Intergovernmental panel on climate change
Masl	Mean above sea level
MoAD	Ministry of Agriculture Development
NARC	Nepal Agriculture Research Council
NGOs	Non-Governmental Organizations
PACEST	Presidential Advisory Council on Education, Science and Technology
PFCs	Perfluorocarbons
RAP 3	Rural Access Program 3
SD	Standard Deviation
UN	United Nation
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Research Institute

English summary (abstract)

Climate change refers to the variation of earth's global or regional climate over a long period due to natural variability or because of human induced activities. Agriculture is the backbone of the Nepalese economy and climate change significantly affect agriculture productivity. This study attempted to map impact of climate change and farmers adaptation to the situation in three different districts of Nepal. The study sample comprised of 120 households, 40 randomly sampled from each of the districts of Jumla, Mustang and Chitwan, respectively. The results indicated that most of the respondents were aware of climate change and the majority of them totally agreed on important indicators of climate change like climate change cause erratic rainfall pattern and climate change cause decrease in agriculture production. Most of the respondent reported a situation with increased problems with crop pests, diseases and weeds. They also have experienced increased production costs and reduced yield. The respondents highlighted three types of adaptation technologies: crop rotation, irrigation and integration of livestock with plant production. Knowledge on climate change was influenced by education level and in general, farmers used few adaptation practices to cope with climate change. The results are discussed based on literature and recommendations are drawn based on this. It will be beneficial for the farmers to adopt most of the adaptation technologies that are on farmer’s level, this to minimize the negative effects of ongoing climate change.

Key words: adaptation to climate change, agriculture, awareness of climate change, climate change, impact of climate change, Nepal

Norwegian summary

Klimaendringer refererer til langtidsendringer i globalt eller regionalt klima som følge av naturlig variasjon eller på grunn av menneskeskapte aktiviteter. Landbruk er grunnlaget for økonomien i Nepal og klimaendringer har tydelig påvirkning på landbruksproduksjonen. Denne oppgaven forsøker å kartlegge effektene av klimaendringer og hvordan bønder tilpasser seg til de endringer som skjer med utgangspunkt i tre områder i Nepal. Oppgaven bygger på innsamlet materiale fra 120 gårder som ble valgt ut tilfeldig, 40 fra hvert av områdene Jumla, Mustang og Chitwan. Resultatene viste at de fleste som ble spurt var klar over klimaendringer og de fleste var også helt enige i viktige indikatorer som at klimaendringer forårsaker uforutsigbarhet i nedbørsmønstre og nedgang i landbruksproduksjonen. De fleste av de som ble spurt rapporterte om en økning i problemene med insekter, sykdommer og ugras i dyrkingen. De har også erfart økte produksjonskostnader og reduserte avlinger. De som ble spurt løftet fram tre typer av teknikker for å tilpasse seg klimaendringene. Disse var vekstskifte, vanning og integrering av husdyr i planteproduksjonen. Kunnskap om klimaendringer var påvirket av utdanningsnivå, men i store trekk tok ikke bøndene i bruk så mange teknologier for å tilpasse seg. Resultatene ble drøftet og anbefalinger ble gitt. En anbefaling var at bøndene burde ta i bruk flere av de teknikker som finnes for å redusere de negative effektene av pågående klimaendringer i Nepal.

Nøkkelord: effekter av klimaendring, kjennskap til klimaendring, klimaendring, landbruk, Nepal, tilpasning til klimaendring

1. INTRODUCTION

1.1 Background

Climate change is real, imperative and genuinely a global problem that refers to "the variation of earth's global or regional climate over a long period of time, whether due to natural variability as normal changes or it is the result of human induced activities (IPCC, 2007). The UN Intergovernmental Panel on Climate Change (IPCC, 2007) presented substantial scientific evidence in its fourth report on climate change, which became clearly accepted worldwide. People became aware of the fact that global warming cannot be obviated due to continued increase in greenhouse gases (GHGs) emissions and changes in the climate system (Chang, 2014). IPCC (2007) stated that if mankind continues consumption of fossil fuels in its present level, the average temperature of earth will rise by 6.4°C and sea level will rise by 59 cm by the end of the 21st century. Change in average temperature and precipitation are not the only results of global warming but also floods, droughts, heat waves, typhoons and hurricanes with change in temperature and precipitation patterns are the results of global warming. Various effects of climate change, such as rise of sea level, decrease in glaciers, northward movement of plant habitats (on the northern hemisphere), changes in animal habitats, rise of ocean temperature, shortened winter and early arrival of spring are also shown as the impacts of climate change throughout the world (Chang, 2014). Climate change is a real threat to many organisms in the world as it affects the all environments, including freshwater habitat, oceans, forests and other vegetation. Climate change affects water resources and agriculture, and geological processes such as landslides, floods, desertification, and in long-term food security and human health (Malla, 2007).

Theoretically, climate change can be understood by changes in one or more components of the climate system (such as atmosphere, hydrosphere, biosphere, lithosphere and cryosphere), or by the interactions among those components (Chang, 2014). There are natural and artificial causes which brought climate change. The change in solar activity, volcanic eruption, sea water temperature, ice cap distribution, westerly waves and atmospheric waves are the natural causes of climate change. Carbon dioxide and other GHGs emission from industries and agricultural activity, deforestation and destruction of the ozone layers, soil organic matter reservoirs and other ecosystems are the artificial cause (PACEST, 2007). Another term frequently used is "global warming". The average increase of the earth's temperature due to greenhouse effect caused by carbon dioxide (CO_2), methane (NH_4), nitrous oxide (N_2O), hydro fluorocarbon (HFCs), perfluorocarbon (PFCs) and sulfur hexafluoride (SF_6) refers to global warming (Kim Chang-Gil et al, 2009). Estimation of future climate change and global warming vary greatly from scenario to scenario. IPCC (2007) estimated that in continuous development scenario where economic development and environmental conservation are compatible to each other, average temperature is estimated to increase with about 1.8°C, while the increase of temperature will be expected to be around 4°C in case of a rapid economic growth scenario based on fossil intensive energy sources. However, the temperature will rise at the rate of 0.2°C for every 10 years in all scenario until 2030, this due to processes that are already initiated (Figure 2).

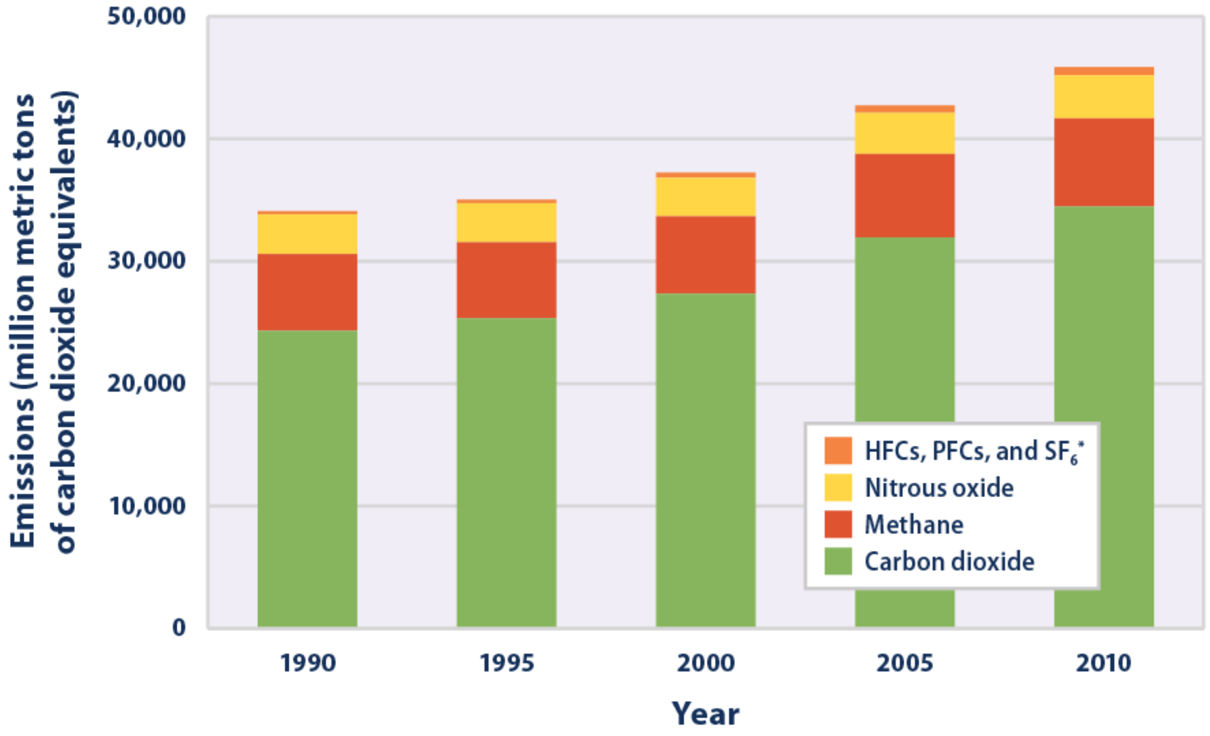

Figure 1. Global greenhouse gas emission by gas 1990- 2010 (WRI, 2014)

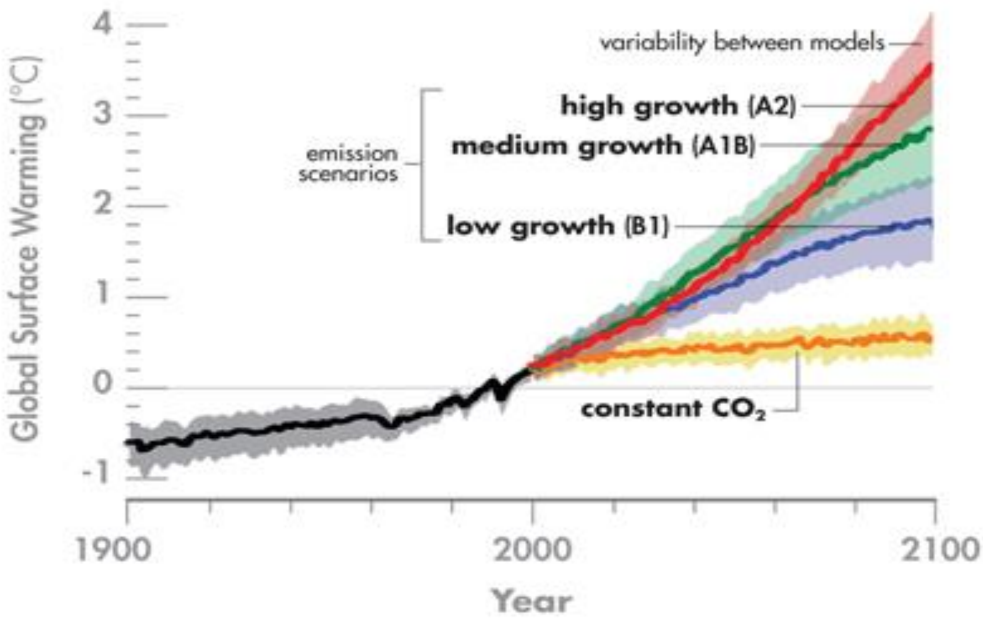

Figure 2. Predicted temperature increases for various emission scenarios (IPCC, 2007)

The overall food production of the world may not be threatened but those developing countries who are already suffering from the chronic food problems will likely bear additional adverse impacts of climate change (WRI, 2005). About 25-42 % of species habitats in Africa could be lost, affecting both food and non-food crops, and some of which are already underway in some regions, leading to species range shift, change in the plant diversity, which includes indigenous foods and plant-based medicines (McClean et al, 2005). There could be a total reduction of around 11% in the arable land in developing countries due the effect of climate change, which may cause a reduction in cereal production in up to 65 countries and 16% agricultural gross domestic product in developing countries (FAO, 2005). In mid to high latitudes, it is projected a slight increase in crop productivity due to a local mean temperature increase by 1-3^{o}C (IPCC,2004).

1.2 Climate change in Nepal

Nepal is a small land lock country situated between two giant countries China in north and India in east, west and south. The country is vulnerable to natural disasters like river flood, erosion, landslides, glacial lake outburst floods (GLOF), drought etc. Records have shown that Nepal's average temperature has increased by 1.8 $^{\circ}$C over the last 32 years, which gives an annual increase of 0.06 $^{\circ}$C but with large regional differences, as +0.04 $^{\circ}$C per year in the Terai region and +0.08 ˚C per year in the Himalayas, respectively (Gautam and Pokhrel, 2010) (Figure 2). The trend in average rainfall shows a more erratic pattern with large fluctuations from year to year both in average rainfall and the distribution within a year (Malla, G, 2007) (Figure 3). Over the period 1971-2006, low average precipitation levels were recorded in 1972, 1977, 1992 and 2005, while high levels were recorded in 1975, 1985 and 1998, respectively (Baidya and Karmacharya, 2007). Erratic rainfall events, not necessarily with difference in the total amount, have been experienced. Overall, there will be increases in climatic extremes like irregular monsoon pattern, drought and floods (Malla, 2007). As an example: In Nepal, there were rain deficits in the eastern parts of Terai and the western region of Nepal, while normal rainfall came in the far-western region, but heavy rainfall came in the mid-western region creating flood, landslide and inundation in this region (Malla, 2007).

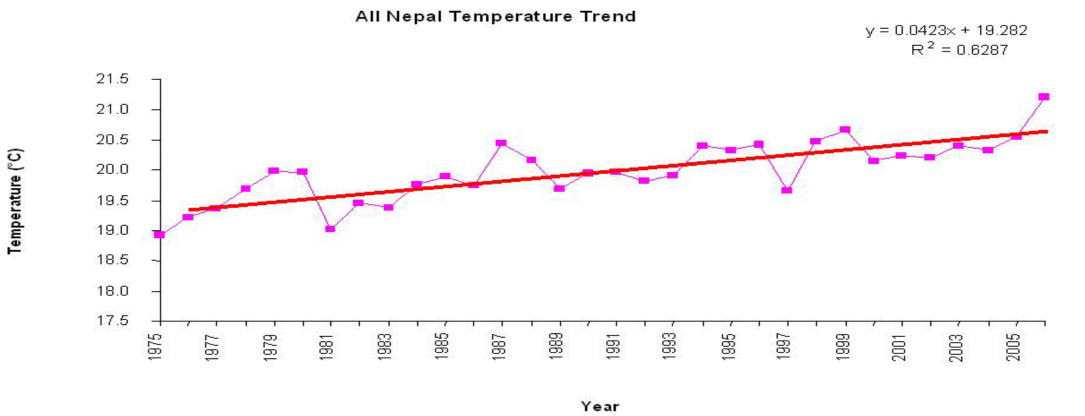

Figure 3. Trend of average annual max. temperature of Nepal (1975-2006) (Baidya and Karmacharya, 2007)

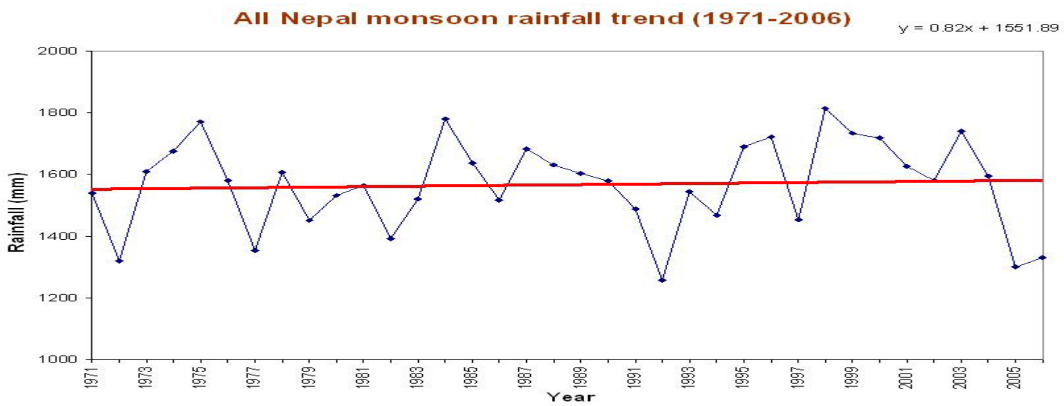

Figure 4. Trend of total precipitation (Baidya and Karmacharya, 2007)

Human activities have been identified as the major factor for the alteration of the earth's climate, resulting in challenges for many living organisms, man included. Continuing such activities becomes a threat to the entire living world through different climate related disaster. United Nation Frameworks Convention on Climate Change (2001) stated that the quicker warming of the earth enhanced by greenhouse gases (global warming) has ultimately brought unavoidable consequences as climate change**.** Due to the limited capacity to cope with hazard or disaster associated with climate change, developing country like Nepal is more susceptible than more developed countries like Norway (Kates, 2000). Thus, Nepal is experiencing the negative effects of global warming although the country is responsible for only 0.025 % of the total emission of greenhouse gases of the world (Karki, 2007. Nepal has good reasons to be concerned on climate change as over two million of population largely dependent on climate sensitive activities like agriculture and forestry for their livelihood (Garg, Shukla and Kapshe, 2007). Nepal is vulnerable also because such productions to a great extend is carried out in the young and fragile mountains (Dhakal, 2003).

1.3 Climate change and agriculture

As the agriculture on one hand is very much dependent on the climate but on the other hand influence the climate by its different agricultural activities, climate change and agriculture are interrelated process which take places on global scale. As demonstrated global warming is predicted to have significant impact on conditions like temperature and precipitation but also on glacial run off and irrigation possibilities, which ultimately affect agriculture as such conditions very much determine the capacity for food and feed production. To foresee and adapt farming to the new climate, and at the same time have an efficient agricultural production, it is necessary to assess the effects of climate change on agriculture on various places around the world. With a predicted reduction in crop yields in most of the tropical and subtropical regions, due to the decreasing water availability and incident of new and damaging insect pest population, the poorest countries will be the hardest-hit due to climate change (IPCC, 2001).

Crop and livestock production are not only affected by change in temperature and precipitation but also influenced by human investment like irrigation system, transportation, animal shelters etc. There are uncertainties about climate change and how farmers respond to it. Most people are still uncertain or unaware about the effects of climate change on agricultural production, consumption and human well-being, which is making difficulties to move forward on policies to combat with the effects of climate change (Gerald, 2009). Rapid changes in climate are bringing risks to life of living beings by changing the food chain where water sources are receding or disappearing, medicine and other sources are harder to obtain as the plant they are derived may be reducing or disappearing (Shah, 2012). High temperature could favor the agriculture by increasing the amount of arable land in high latitude by reducing the amount of frozen land (Sasson, 2012). On the other side, high temperature and humidity could favor the spread of fungal and bacterial diseases as well as insect pests and probably also weeds (Cline, 2007).

In general, it is predicted to have more positive effects of future climate on agriculture in northern areas of Europe through introduction of new crop, increase of crop yield and expansion of worthy areas for production however, it may cause negative effects such as lower yield, increase yield variability and reduction of suitable production area through increased water shortage and extreme weather variability in Southern Europe (Olsen and Bindi, 2002). In a northern country like Norway, many potential impacts of climate change are assumed to have positive effects or less inauspicious than for example in southern Europe or sub-Saharan Africa (McCarthy et al, 2001; Yohe and Tol, 2002). It is predicted a 25-30% increase in the yield of potato with large increase in northern Norway (Torvanger et al., 2014). Gaasland (2002) calculated a 14% increase in yield of wheat in most productive southeastern area of Norway using the same climate scenario conjugated to crop yield model of Norwegian agriculture.

Although most of the Nepalese population very much depends on agriculture for their subsistence, still about 63 % of the agricultural land lack modern irrigation facilities (FAO, 2004). This means that most of the land is rain-fed and the crops' water requirement is fully dependent on the rainfall. Thus, alteration in precipitation patterns could make severe difficulties for the farming. This may result in poor yields and could result in food insecurity for the growing population dependent on the rain-fed farming system. However, in an irrigated farm also, there may be problems in future like not having enough irrigation water for the cultivation season, but also having problems like floods, landslides and erosion to the cultivated land. The changing climate is adding serious risks to the entire agricultural sector (ADB, 2003).

1.4 Impact of climate change in Nepalese agriculture

The impact of climate change is complex as it affects differently around the world. In some regions, the changes might be somewhat positive and could increase the crop productivity, while it causes serious negative impacts and decreasing productivity in other region (Pathak et al, 2003). Overall, there will be high impacts on the Nepalese agriculture as most cultivable land is rain-fed, where productivity totally depend on distribution and timing of precipitation. When agriculture is affected, most of the people will be affected (Dahal et al, 2010). Increase or decrease in amount of rainfall is not the only factor of importance but a potential shift in the timing of the rain will have significant effects on the Nepalese agriculture. In future scenarios, current irrigation facilities and reservoirs may not have enough water during the dry season (APP, 1995). The monsoon rainfall (summer rainfall) is crucial to the Nepalese agriculture as it accounts for almost 80% of the annual rainfall. The rainfall pattern is characterized by monsoon rainfall during June-July and more low intensity rainfall during January-February (Shrestha, 2007). It could be critical if there is a shift in the precipitation pattern, as this would ultimately influence the cropping calendar. Increasing temperature with insufficient rainfall has detrimental effect on plants and livestock by causing drought. Intense rainfall over a short period of time also could cause negative effects as it would reduce ground water recharge by causing more surface runoff and less infiltration compared to a more low-intensity rainfall. In addition, intense rainfall ultimately results in flooding and by such the risks of damaging agricultural lands and living areas.

Climate change conditions such as rising temperature, delayed monsoon, increased annual rainfall and increased occurrence of intense rainfall has already affected many rain-fed farmers in Nepal (Regmi and Adhikari, 2007). The conditions are expected to be even worse as ongoing climate change will create even more damage in agricultural production in the coming decades (UNFCCC, 2000; IPCC, 2001). Climate induced risks, such as disappearance of certain forests, invasion of exotic species, new disease outbreak, sharp decline in food security and threats to biodiversity often have wide ranges of unpreceded effects on environments, including effects on agriculture and food security (World Food Program, 2009).

As an example, the Eastern Terai region of Nepal faced rain deficits during the 2005-2006 growing season. The early monsoon was delayed, and crop production was reduced by 12.5% on national basis. Nearly 10% of the agricultural land was left fallow due to rain deficit, but mid-western Terai faced heavy rain with floods that reduced the production by 30% (Regmi, 2007). Early maturation of the crops due to high temperature may help to have more crops in the same crop cycle. A cold wave in 1997-98 had serious negative impact on agricultural productivity. A 30% yield reduction was reported in crops like potato (*Solanum tuberosum)*, toria *(Brassica napus),* rayo *(Brassica juncea)*, lentil *(Lens culinaris)* and chickpea *(Cicer arietinum)* (NARC annual reports from 1987/88 to 1997/98).

1.5 Statement of the problem

Nepal has different types of agricultural zones such as plains, mid-hills, high-hills and mountains. These different zones have different cropping patterns. Therefore, changes in climate may change the ecological distribution of agricultural crops in the country. Traditional rainfall pattern of June/July has shifted to July/August in the whole country, which has been affecting the paddy rice production in plains and mid-hill regions. Farmers of hill and mountain regions are also affected by climate change, but they are still unaware why their production pattern is changing. In this context, a study on impact of climate change on agricultural production will help local farmer to know more about climate change and how to cope with the problem. Thus, it is very important to know the impact of climate change and its possible implications. About 29% of total disaster deaths and 43% of the property losses in disasters in Nepal are related to water induced disasters like floods, landslides and avalanches (Khanal, 2006). Therefore, it is very important to identify problems but also adaptation options or ideas, so that we could minimize the potential damages of climate change, prepare farmers and still be able to produce food and secure livelihood locally as well as at a regional or national scale.

1.6 Objective of the study

A survey was conducted to learn more about the accurate situation in Nepal. The objectives of the study were:

- To map the current perceptions of how climate change (CC) influence farming of concerned districts in Nepal.
- To overview farmers adopted practices against climate change in these districts
- To highlight certain climate smart practices that can be further adopted by the farmers.

The main research questions were:

I. How does the socio-economic profiles of the farmer in Jumla, Mustang and Chitwan districts of Nepal look like?
II. To what degree are the farmers in these districts aware of climate change - and how do they judge their knowledge on the topic?
III. What are the impacts of climate change on agricultural production in the targeted regions of Nepal?
IV. How are farmers in the target regions practicing adaptation technologies against climate change?
V. How does the farmers judge a set of recognized adaptation technologies to meet climate change?

2. MATERIALS AND METHODS

2.1 Methodology

The study is primarily designed to capture the perception of climate change and climate change adaptation among farmers and agricultural experts in Nepal. These are the primary data of the study. In addition, secondary data like climatic data recorded over time from various districts and published scientific articles and internet sources are analyzed. The main design was a survey research design and interviews. Selected questionnaires and key informant interviews (expert interviews) were conducted to collect primary data. Rainfall and temperature data were retrieved from Department of Hydrology and Metrology.

2.1.1 Site selection

To study the impact of climate change and its adaptation, three districts in Nepal; Jumla, Chitwan and Mustang were selected, which are indicated on the map below (Figure 5). Two villages from each district were selected for the survey.

Figure 5. Map of Nepal indicating Jumla, Mustang and Chitwan district

(Source: google map)

Jumla district is situated in Province 6, which is within the Mid-Western region of Nepal. The total area of Jumla is 2531 square kilometer and Jumla is surrounded by Dolpa in the east, Kalikot in the west, Mugu in the north and Jajarkot in the south. Jumla is situated at around 81º to 82º E longitude and 29º N latitude. The elevation of Jumla ranges from 915 m a.s.l. to peaks as high as 4679 m a.s.l. The average temperature varies from 18º C to 30º C in summer and -14º C to 8º C in winter, and the annual average rainfall is around 1300 mm. The major rivers in Jumla are Hima, Tila and Jawa, which are used for irrigation and brings water from the mountains/glaciers. The major economic activity of the district is agriculture, where more than 85% of Jumla's population is depending on agriculture for livelihood (RAP 3, 2016). The major cereal crops growing in the district are paddy rice (*Oryza sativa*), maize (*Zea mays*), millet (*Eleusine coracana*), wheat (*Ttiticum aestivum*), barley (*Hordeum vulgare*), while apple (*Malus pumila*), potato (*Solanum tuberosum*), common bean (*Phaseolus vulgaris*), as well as various oil seed crops and herbal plants are cultivated as cash crops. Due to a general lack of rural infrastructures (roads, market centers, electrification and communication), the living standard of rural people has not improved over the last decades despite a top priority given to the agriculture sector by the government (RAP 3, 2016).

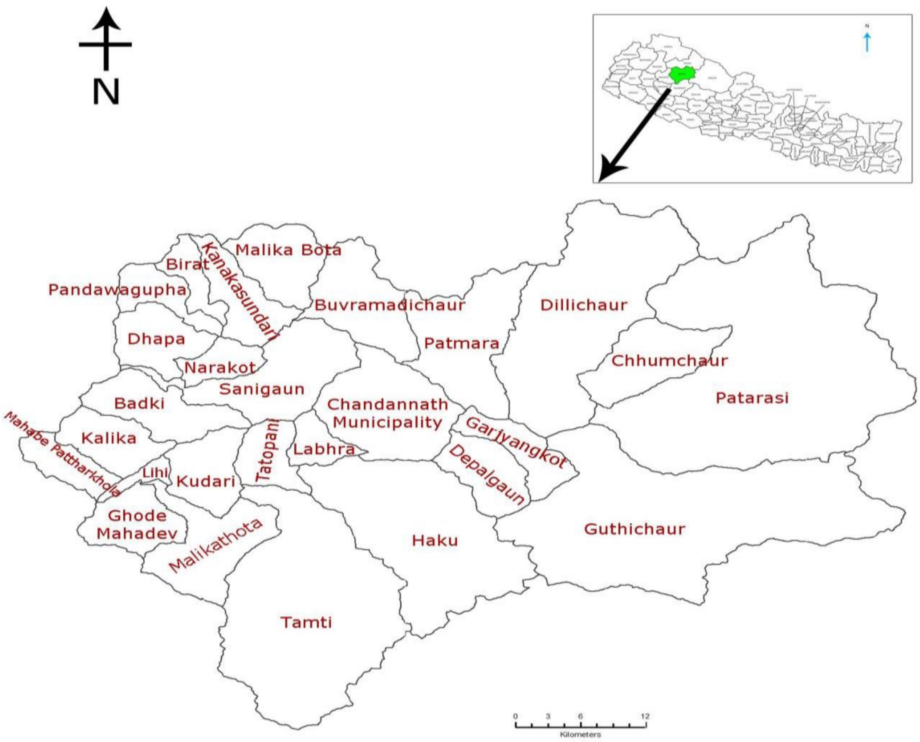

Figure 6. Map of Jumla District (source: MoAD, n.d.)

Mustang district is situated in Province 4 at around 29° N latitude and 84°E longitude (Mustang Latitude and Longitude, 2018). The total area of the Mustang district is 3573 square kilometers with a population of 13,452 (National Census, 2011). The elevation ranges from 1,372 to the very high peaks at 8,167 m a.s.l. (Mt. Dhaulagiri, the 8th highest mountain in the world). The district is dominated by a vast and arid valley with eroded canyons, rock formation and high-altitude deserts. There is less than 260 mm average annual rainfall in the lower Mustang area, where spring and autumn are generally very dry, and some precipitation comes by the summer monsoon. The mean monthly minimum temperature falls to -2.7°C in winter, while mean monthly maximum temperature reaches 23.1°C in summer. Only about 1 % of the total land area of Mustang is cultivated but about 40 % is pasture land used for grazing. Agriculture is the dominant economic activity in the district where people are engaged traditional forms of an agro-pastoralist economy common to the mountain regions of Nepal. Many people in the Mustang district depends on sheep and mountain goat rearing for their livelihood as well as yak-cow hybrids (called jhopa) and horses that are reared for transport. Apple is the major agricultural cash crop grown in the district and barley, wheat and buckwheat are cultivated mainly in terraced fields.

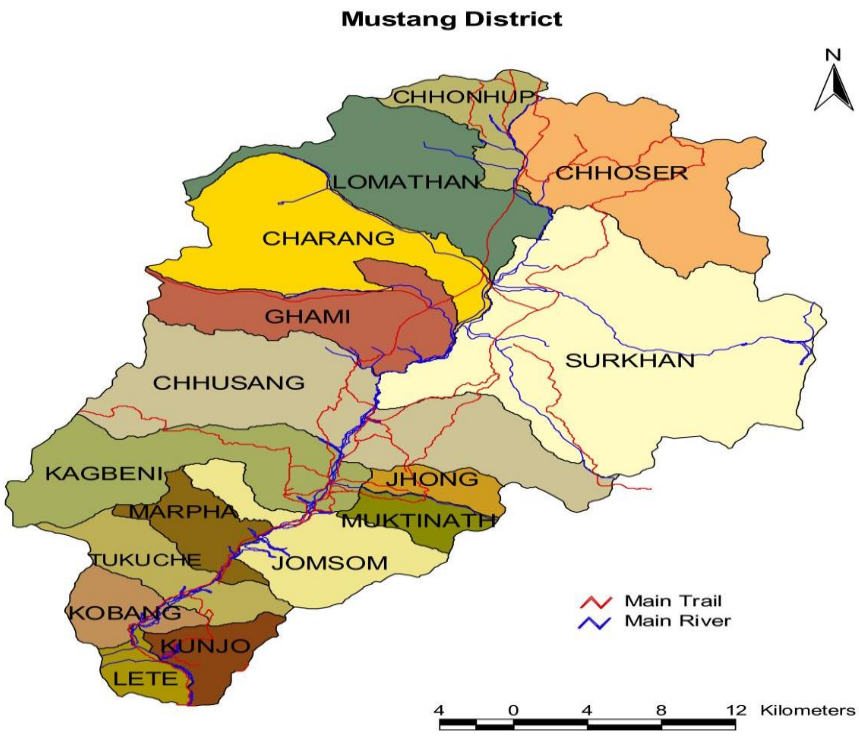

Figure 7. Map of Mustang district (Bhattarai et al, 2010)

Chitwan district is situated in Province 3, in the central region of Nepal. The total area of Chitwan is 2,238.39 square kilometer, with a total population of 579,984 (National Census, 2011). Chitwan is located at around 27-28° N and 84° E and elevation ranges from 200 to 1100 m a.s.l. (Rasel, 2013). Most of the people are farmers who mainly cultivate rice, maize, wheat, beans, lentil, mustard and vegetables. The poultry production of the district is important also on a national level. There are different climatic zones in the district such as lower tropical zone, upper tropical zone and subtropical zone. The average temperature varies from 7°C in winter to maximum 37.9°C in the summer, and average rainfall varies from a few mm in winter to around 302 mm in summer.

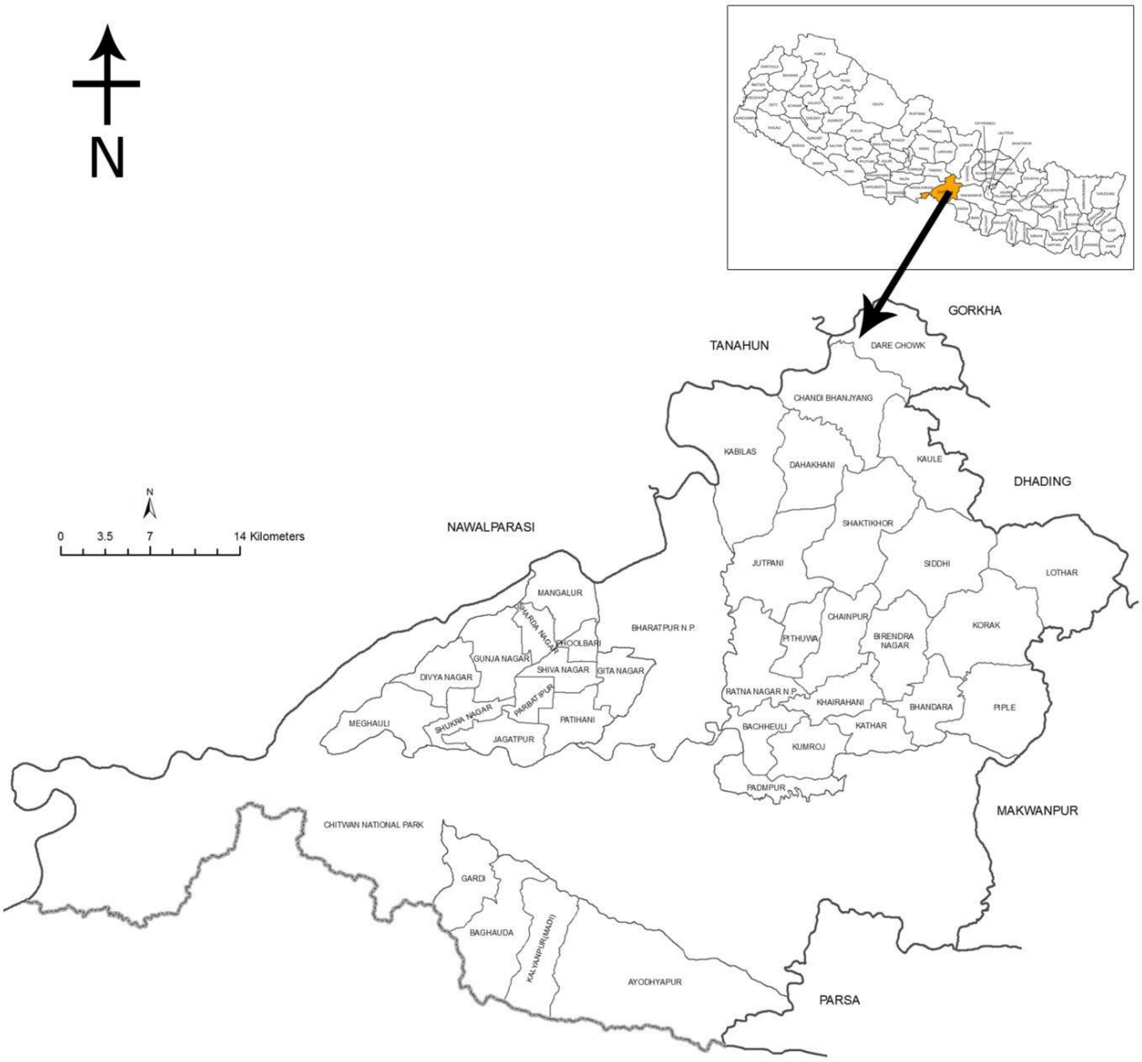

Figure 8. Map of Chitwan district (source: MoAD, n.d.)

2.1.2 Data sampling and analysis

In total 120 household/farmer and six experts were asked for their perception/opinion regarding climate change. In each district (Jumla, Mustang and Chitwan), 40 households/farmers (HH) were randomly selected for a survey. Semi-structured questionnaires were used to gather such data. In addition, selected experts from different institution were interviewed. The institution involved were Nepal Agriculture Research Council (NARC), District Agriculture Development Offices (DADO) and Department of Hydrology and Metrology.

The semi-structured questionnaire was formulated to capture knowledge on agriculture and climate change. Two different questionnaires were prepared, one for the HH survey and one for the expert interviews, the latter with more open-ending questions (see Appendix). After having completed the survey in a district, a focus group discussion (FGD) was conducted. This was done both to verify the data from the survey but also to supplement the data. For the FGD, different ethnic group, different age group, different education level group and different gender group were invited. The FGD was organized with discussions on awareness and knowledge of climate change, impact of climate change to agriculture, adaptation of climate change to the local level.

Secondary data for the study were collected from the different research articles and other publications. Furthermore, additional information’s and data were collected from the Department of hydrology and metrology, and from DADO and NARC.

The questionnaire consisted of four sections; (1) basic profile of the farmer, (2) awareness of climate change to the farmer, (3) impact of climate change in agriculture, and (4) adaptation technology to climate change at a farm level (use or practice of technology and judgement of technology). To find the awareness and knowledge on climate change, farmer’s responses to different evidence of climate change were tested consisting of five response options (Very good, Good, Medium, Low and Very low). Impact of climate change to agriculture production was mapped through three response options (Yes, Not sure and No) to six different effect of climate change. To find the use of adaptation technologies at farm level, three different response options (Yes often, Sometimes and Never) to ten different adaptation technologies. Judgement of the adaptation technology were mapped through the three different response options (Useful, Limited value and Will not help).

The collected survey data were first coded according to category and then entered into Excel spreadsheets. Frequency and percentage were calculated for the socioeconomic data (basic profile of the respondents). To analyze the farmers' level of knowledge on climate change, an instrument was developed, which was a structured questionnaire on 5-point rating scale of very good knowledge (VG), good knowledge (G), medium (M), low (L) and very low knowledge (VL). Value assigned to them were: VG=1, G=2, M=3, L=4 and VL=5. A neutral mean of these values was used for comparison, which is (1+2+3+4+5)/5= 3. To analyze data of impact of climate change, another instrument was developed on a 3-point rating scale: yes (1), not sure (2) and no (3). To analyze the data on use of adaptation technology and judgement of technology different instruments were developed on the same way. The questionnaire was divided into five sections based on the objective of the study.

Chi-square tests were conducted to test the significance of categorical descriptors. Chi-square tests were conducted on 95% level of significance, where the chi-square value in each test was compared with critical value (taken from a chi-square distribution table at the given number of degrees of freedom and at the given significance level). Chi-square tests were performed to examine the relationship between the following descriptors: experience of farmer and use of mulching technology; experience of farmer and awareness of climate change to the farmer; education level of farmer and grade of knowledge on climate change to the farmer; and awareness of climate change to the farmer and use of crop rotation technology. The study areas Jumla, Mustang and Chitwan are represented by code 1, 2 and 3 respectively. The result is presented in different topics below accordance with objective of the study. The result portrayed all three different regions of Nepal but the contrast result from particular region is also mentioned.

3. Results

3.1 Basic profile of the farmers

To overview the data, the basic profile of the farmers is given below (Table 1).

Table 1. Basic profile of the farmer with frequency and percentage

Basic profiles	Frequency	Percentage
Gender		
Male	75	62.5
Female	45	37.5
Education level		
No formal education	60	50
Up to SLC	51	42.5
Higher secondary	7	5.8
University level	2	1.7
Farming experience		
0-3 years	0	0
4-10 years	20	16.6
11-20 years	47	39.2
More than 20 years	53	44.2
Farm size		
<1 ha	66	55
1–3 ha	45	37.5
>3 ha	9	7.5
Soil type		
Clay	11	9.2
Silt	1	0.8
Sand	6	5
Mixture	102	85
Slope		
Flat land	40	33.3
Some slope	80	66.7
Very steep	0	0
Source of income		
Personal	76	63.3
Family support	44	36.7
Cooperative or bank	0	0

Out of the total number of 120 farmers, 62.5% were men and 37.5% women. Half of the farmers do not have any formal education and another 42% have only few years in school. We can say that majority of the farmers are experienced as more than 80% have been doing farming for more than 11 years and many of them for more than 20 years. Furthermore, the majority (55%) have less than one hectare of land, which means that they are involved in farming only on a subsistence level. Most of the respondents (63.3%) also say that they operate their farming activity by themselves (as source of income) while family support was also common (36.7%). The majority (85%) have a mixture of soil types, as fields with some slope (66.7%).

3.2 Awareness and knowledge of climate change to the farmer

We were interested to find out more of farmers' perception of climate change in form of awareness and knowledge, where they could grade their knowledge/awareness on a numeric 1-5 scale. The results showed that the respondents are very much aware of climate change with mean score 1.02 ± 0.18 (Table 2). Most of the respondents also have good knowledge of climate change (2.06 ± 0.73). All the related, detailed questions on climate change are agreed by respondents with mean rating between 1.27 to 2.01 on the 1-5 scale, which were below a neutral mean of 3. Respondents were totally agreed on that climate change cause rise in temperature and cc decrease the agriculture production with mean rating of 1.28±0.53 and 1.27±0.51 (Table 2).

Table 2. Awareness and grade of knowledge on climate change to the farmers, mean value with standard deviation (SD) on a 1-5 scale where 1 is very good knowledge and 5 is very low knowledge

Awareness and knowledge on climate change	Mean	SD
I am aware about the climate change	1.02	0.18
I have knowledge on climate change	2.06	0.73
Climate change cause erratic rainfall pattern	1.52	0.6
Climate change cause drought	1.52	0.7
Climate change cause rise in temperature	1.28	0.53
Climate change cause decrease in agriculture production	1.27	0.51
Climate change cause high rate of pest and disease to the crop	1.86	0.7
Climate change cause high weed infestation to the crop field	2.01	0.72
Climate change causes flooding, erosion and landslide to the farmland	1.58	0.81

3.3 Impact of the climate change to the agricultural production

Table 3. Impact of climate change to the agriculture production, mean value and standard deviation (SD) on a scale rating from 1-3 where; 1= Yes, 2= Not sure and 3= No

Impact of climate change to farmer	Mean	SD	Remarks
Change in agricultural pattern	1.7	0.82	Not sure
Increase in crop pest and disease infestation	1.33	0.58	Yes
Increase in crop weed	1.49	0.69	Yes
Increase in cost of production in agriculture	1.2	0.46	Yes
Delay in planting date for major crops	1.83	0.8	Not sure
Reduction in crop yield	1.1	0.34	Yes

Table 4. Impact of climate change to the agriculture production of different districts (scale rating from 1-3 where; 1= Yes, 2= Not sure and 3= No)

Impact of climate change to farmer	Mean Jumla	Mean Mustang	Mean Chitwan
Change in agricultural pattern	2.76	1.37	1.29
Increase in crop pest and disease infestation	1.56	1.23	1.22
Increase in crop weed	1.86	1.49	1.20
Increase in cost of production	1.20	1.20	1.20
Delay in planting dates of major crops	2.68	1.86	1.23
Reduction in yield	1.00	1.20	1.10

Farmers’ views on the impact of climate change on the agricultural production is summarized in Table 3. Respondents very much agreed that a reduction in crop yield (score 1.1 ± 0.34) and increased costs of the production (score 1.2 ± 0.46) are important impacts of climate change on their agricultural production. They were less sure whether climate change requires a change in the agriculture pattern or a delay in planting dates for the major crops (mean rating of 1.7

and 1.83, respectively, with a neutral mean at 2.0). There were some differences between the regions. In region 3, farmers saw a delay in planting date as an important impact of climate change with mean score of 1.23±0.45 (in contrast to region 1 and region 2).

3.4 Adaptation technology at farm level

3.4.1 Practice or use of technology

We were interested to map how farmers adapt to climate change by using various technologies. They were given the options to answer on a 1-3 scale how often a given technology is practiced where 1 is often used, 2 is sometime used, and 3 is never used. The result showed that three types of adaptation technologies are often practiced. These are irrigation, integration of livestock, and crop rotation, with mean scores of 1.04, 1.10 and 1.17, respectively. Practices like use of native variety of crop, use of drought tolerant variety of crop, use of fast maturing variety of crop, delay or early planting of crop, mulching and minimum or zero tillage are sometime practiced while rain harvest is not practiced.

Table 5. Use of adaptation technology against climate change by the farmer (rating from 1-3 where; 1= Yes often, 2= Sometime and 3= Never)

Technology	Mean	SD	Remarks
Crop rotation	1.17	0.42	Yes often
Native variety of crop	1.96	0.77	Sometime
Drought tolerant variety of crop	2.16	0.83	Sometime
Fast maturing variety of crop	2.26	0.8	Sometime
Delay or early planting of crop	1.97	0.76	Sometime
Irrigation	1.04	0.24	Yes often
Rain harvest	3	3	Never
Mulching	2.1	0.69	Sometime
Minimum or zero tillage	2.24	0.67	Sometime
Integration of livestock	1.10	0.3	Yes often

The result also showed that use of drought tolerant variety of crop, fast maturing variety of crop, delay or early planting of crop and mulching were often practiced in region 3 with mean scores of 1.23±0.45, 1.31±0.48, 1.34±0.49 and 1.46±0.49. On the contrast, use of drought tolerant variety and fast maturing variety of crop were never practiced in region 2.

Table 6. Use of adaptation technology against climate change by the farmer of different district (rating from 1-3 where; 1= Yes often, 2= Sometime and 3= Never)

Use of technology	Mean Jumla	Mean Mustang	Mean Chitwan
Crop rotation	1.27	1.14	1.09
Use of native variety	2.30	1.48	2.20
Drought tolerant variety of crop	2.73	3	1.23
Fast maturing variety of crop	2.93	3	1.31
Delay or early planting of crops	2.82	2.02	1.34
Irrigation	1.12	1	1.01
Rain harvest	3	3	3
Mulching	2.73	2.32	1.46
Minimum or zero tillage	3	1.82	2.05
Integration of livestock	1.07	1.03	1.20

3.4.2 Judgement of adaptation technology by farmers

We were interested to find the farmers' judgements of the different adaptation technologies and they were given the opportunity to grade each technology on a 1-3 scale where 1 is useful, 2 is of limited value, and 3 will not help (Table 5). Results revealed that the irrigation, the use of fast maturing varieties, and the use of drought tolerant varieties were highest ranked (mean score 1.10, 1.12 and 1.20, respectively, followed by crop rotation and delay or early planting (mean score 1.20 and 1.25). The use of native varieties and minimum or zero tillage was regarded as limited value with mean score of 1.71 and 1.52, respectively.

Table 7. Judgement of adaptation technology against climate change by the farmer (rating from 1-3 where; 1= useful, 2= limited value and 3= will not help)

Technology	Mean	SD	Remarks
Crop rotation	1.21	0.40	Useful
Native variety of crop	1.71	0.41	Limited value
Drought tolerant variety of crop	1.20	0.44	Useful
Fast maturing variety of crop	1.12	0.37	Useful
Delay or early planting of crop	1.25	0.46	Useful
Irrigation	1.10	0.34	Useful
Rain harvest	-	-	-
Mulching	1.39	0.5	Useful
Minimum or zero tillage	1.52	0.48	Limited value
Integration of livestock	1.31	0.52	Useful

3.5 Relation between experience of farmer and use of mulching technology

Table 8. Overview of the relationship between farmers' years of experience (three categories) and how many of them (in actual numbers) that are using mulching technology often, sometimes or never, respectively.

Mulching	Experience			Sum
	4- 10 year	11- 20 year	>20 year	
yes often	4	5	9	18
Sometime	12	24	20	56
Never	4	18	24	46
Sum	20	47	53	120

The chi square test showed that the use of mulching technology was independent of the years of experience of the farmers. The null hypothesis (mulching practice is independent of farmers' years of experience) could not be rejected at a 95% significance level (X^2=1.63, DF=4, P=0.80).

3.6 Relation between experience of farmer and awareness of climate change

The chi-square test showed that awareness of climate change to the farmer was independent of farmer's year of experience. The null hypothesis (awareness of climate change will not increase with experience) could not be rejected at 95% significance level **(**X^2= 2.28, DF= 2 and P= 0.51).

Table 9. Overview of the relationship between farmer's years of experience (three categories) and how many of them (actual number) are aware of climate change (two categories)

Awareness of cc	Experience			sum
	4- 10 year	11- 20 year	> 20 year	
yes	20	47	49	116
No	0	0	4	4
sum	20	47	53	120

3.7 Relation between education level of farmer and knowledge of climate change

Table 10. Overview of the relationship between the farmer's education level (four categories) and their grade of knowledge to the climate change (four categories)

	Education level				sum
Grade of knowledge	informal	slc	Hsec	Uni	
Very good	6	7	5	1	19
Good	31	29	2	0	62
Medium	21	13	0	1	35
Low	2	2	0	0	4
Sum	60	51	7	2	120

The chi-square test showed that farmer's grade of knowledge on climate is dependent on the education level of the farmer. The null hypothesis (grade of knowledge on cc is not influenced by the education level) was rejected at 95% significance level (X^2= 18.01, DF= 9 and P= 0.03).

3.8 Relation between awareness of climate change and use of crop rotation technology

The chi-square test showed that use of crop rotation practice by the farmer is independent of the awareness of climate change to the farmer. The null hypothesis (crop rotation not increased with awareness of climate change) could not be rejected at 95% significance level (X^2= 1.95, DF= 1 and P= 0.16).

Table 11. Overview of the relationship between farmer's awareness to the climate change (two categories) and how many of them (actual number) are using the crop rotation technology (two categories)

	Awareness of cc		Sum
Crop rotation	Yes	Sometime	
Yes	92	1	93
Sometime	24	3	27
Sum	116	4	120

4. Discussion

The result showed that most of the respondents from the three examined regions in Nepal do not have formal education, or they have education at a low level (Table 1). This means that many farmers are illiterate people with respect to formal education. Many rural people are illiterate, and they could not get the proper job in public or private sector because they are illiterate. Instead they started farming on their own land and for subsistence of their livelihood. There are reports that show that a higher education level of the people helps them to establish good agricultural systems addressing the different problem like the effects of climate change (Alam et al, 2009). Our study showed that most of the respondents have less than 1 ha of land, which may be due to the fragmentation of land from generation to generation, as they need a piece of land to survive, and this has caused a division of farms into smaller farms (Niroula and Thapa, 2007). Most respondents said that they operate the farms on their own creating their own income, but family support was also common.

Most of the respondents had been doing farming for many years. Furthermore, people involved in the agriculture sector generally had good knowledge on climate change, according to their own grading, and despite a generally low formal education level. They were also aware of the problems related to climate change (Table 2). Due to experience, they may have seen the impacts of climate change in their long journey of farming. If the farmers are more experienced, they may notice the climate change events such as variation in temperature and precipitation and their impact on agricultural production as stated by Moyo et al (2012) in their research in Zimbabwe. In addition to experience, our result in Nepal can be explained by awareness programs of climate change in different media carried out by government bodies and non-governmental organizations (INGOs\NGOs) (Arlt, Hoppe and Wolling, 2011). The result is consonance with the finding of Raghuvanshi, Ansari and Amardeep (2017) who reported in their study that all farmers in north-Himalayan region of India were aware of climate change.

Based on the survey results, we can say that most of the respondents could identify the major indicators of climate change, such as erratic rainfall pattern, increase in temperature, increase in drought period, increase in pest and disease to crops, calamities like flood, landslide, and erosion. This may be so since these changes are observable and can be seen by experienced farmers, even if they are illiterate. The study is supported by the finding of Kemausuor et al (2011) who reported 93% of farmers believed irregular and unpredictable pattern of rainfall.

The result of the study is also at par with the finding of Baul et al (2013) who reported that 84% of the farmers in middle-hills of Nepal believed that temperature has increased, and with and Legesse et al (2013) who reported that 95% of the respondents in Ethiopia perceived increased frequency of drought.

In Nepal, our study showed that the respondents were experiencing the impact of climate change (Table 3). Four indicators were highlighted and included increased crop pests and diseases, increased crop weeds, increased production costs, and reduced yield of agricultural crops. Theses impacts was seen in their production system. In contrast to Region 1 and Region 2, delay of planting time of major crops was also found in Region 3 as an impact of climate change(Table 4). The increase of the population of insects and fungus, but also weeds, may be due to conditions like warmer temperature, wetter climate and increased carbon dioxide level, where they will thrive more effectively (United States Environmental Protection Agency, 2016). Such impact may also explain increased costs of agricultural production in addition, intercultural practice due to drought and erosion is most likely adding up costs. Increased production costs are well elaborated by Hatfield et al (2014) that calculated that US farmers must spend more than $11 billion per year to fight weed. Perhaps a reduction in yield is the major impact of extreme temperature and precipitation. Malla (2008) showed that yields of maize will decline by 10-30% in terai and hill areas of Nepal with a 4^{o}C rise in temperature. Our study shows that farmers' perceptions of the impacts of climate change supports such trends. Another effect of climate change will be a shift in crops. One of the officers from DADO, Region 1 told that:

"Lower region of the district will become suitable for citrus cultivation, and climate change will help to shift to other crops in higher region. This may be one of the positive impacts of climate change".

To underline this, one of the officers from NARC, Region 3 told that:

"Climate change has resulted in yield loss of *Brassica campestris* in Region 3. This is mainly a result of a higher emergence of insects and diseases".

Our study revealed that respondents often used three of the ten different adaptation technologies often suggested as useful against the effects of climate change. The three technologies most often mentioned by the farmers were crop rotation, irrigation and integration of livestock in the farming system (Table 5). Respondent sometime used other technologies (such as use of native varieties, use of fast maturing varieties, use of drought tolerant variety, delay or early planting of crops, mulching and minimum tillage). Results also revealed that the adaptation technologies such as use of drought tolerant variety, use of fast maturing variety and mulching was practiced often in Region 3 but the respondents from Region 2 never practiced such technologies (Table 6). None of the respondents used water-harvesting technology. One reason to the latter could be they lack knowledge and facilities to do so. Farmers use crop rotation technologies in accordance with their indigenous traditional knowledge of soil conservation (Rajasekaran, Warren and Babu, 1991), which automatically become an adaptation technology to climate change. However, they did not start this technique to cope with the effect of climate change. Farmers have started to use irrigation and have increased the frequency of irrigation to cope with dry period resulted from high temperature and little precipitation, which was mentioned by the local farmers in this study, especially in the Region 1. Integration of livestock is also a commonly used adaptation technology which farmers have used a long time as part of a common agriculture practice. Other technologies, such as the use of climate smart varieties, are not frequently used. This may be due to insufficient knowledge on the technologies but most importantly it could be explained by lack of access of the varieties in remote area like Region 1 and Region 2.

The study also revealed that most of the adaptation technologies such as crop rotation, use of fast maturing varieties, use of drought tolerant variety, delay or early planting of crops, irrigation mulching and integration of livestock was found useful to cope with the effect of climate change (Table 7). While other technologies like use of native varieties and minimum tillage practice was judged by the respondents to have limited value to cope with the effect of climate change. Crop rotation practice may help the farmer through conservation of the soil and by compensating a potential failure of one crop by production of another crop, as the farmer do not need to depend on one crop only in the cropping system. The value of mixed cropping is supported by FAO (2009), which showed that in forage legume/grass mixtures, up to 30% of the nitrogen fixed by legumes is transferred to grasses. Irrigation will help to cope up with the negative effects of drought if there are available water resources to fulfill the crop's water requirement. Integration of livestock may help in two way, firstly by increasing the organic matter content of the soil (with the help of manure) and secondly by compensating crop failure with animal products. Use of drought tolerant varieties may help the farmer in their production even during prolonged drought period. Here, the use of early planting, or delayed planting, in accordance with expected temperature and rainfall are efficient ways of escaping from the climate hazard so that the production system is not impeded.

The result revealed that there is no significant relation between respondent's experience of farming and use of mulching practice (Table 8). Most of the respondents were engaged in farming for more than 11 years though they never thought about mulching practice seriously which can be efficient adaptation technology to cope with climate change. This may be due to lack of knowledge to respondents of Region 1 and Region 2 on advantages of mulching practice for soil conservation and for safeguard in extreme conditions of high precipitation and prolonged high temperature while this technology was common to the respondents of region 3. Nyong, Adesina and Elasha (2007) stated in their study that, natural mulches moderate temperature extremes of the soil, suppress harmful disease and pests and conserve the moisture of soil. When asked about the mulching, most of the local farmers of Region 1 and Region 2 answered they are not aware of this technology and its advantages to cope with climate change. One of the officers from DADO Region 2 reported that the awareness program of mulching and other soil conservation technologies is of primary importance to them, and such a program will be conducted within a one-year period.

The study showed that there is no significant relation between experience of the farmers and their awareness of climate change (Table 9). As mentioned, a more experienced farmer may notice the climate change events such as variation in temperature and precipitation and their impact on agricultural production (Moyo et al, 2012), however, climate change is the hot topic of the world so both experienced and inexperienced farmer got the knowledge of climate change from different climate change related program from media and government or non-government bodies. When asked the question about how you are aware of climate change, one old farmer from Region 1 replied:

"From radio programs - and some people told me, or I heard it from the discussion with people".

The survey furthermore revealed that there is significant relation between education level of farmer and their grade of knowledge on climate change (Table 10). The result is consonance with the finding of Raghuvanshi, Ansari and Amardeep (2017). Education may help people to know the situation of global warming and the different scenarios related to climate change.

Educated farmers have more knowledge on climate change and are aware on adaption technologies against climate change (Maddison, 2007).

There was no significant relation between awareness of climate change and the use of crop rotation practice (Table 11). As most of the respondents are aware of climate change and most of the people use crop rotation, we cannot find the significant relationship between the two factors. According to the respondents in three different districts, they are all familiar to the use of crop rotation practice for the conservation of soil as well as for some extra income. In contrast to our finding, the result of Raghuvanshi, Ansari and Amardeep (2017) revealed that there is a significant relation between farmer's awareness of climate change and the use of soil conservation practices like crop rotation.

5. Conclusion

The study provided expressed perspectives on the impact and adaptation to climate change from farmers in three districts in Nepal. We revealed that most of the respondents are aware of climate change, though their knowledge on how to adapt to climate change is not at the same high level. The study showed that climate change already has a great impact on agricultural production in Nepal according to farmers' own perceptions. Though the farmers know the impact of climate change in their production system, they are not using many adaptation technologies. This can be explained in different ways. They may lack knowledge on different technologies or they lack access to the technologies, or both. Some common adaptation technologies such as crop rotation, irrigation and integration of livestock in the production system are commonly used in all three districts. Other technologies such as the use of drought tolerant crop varieties, fast maturing varieties, shifts in planting time, and mulching is commonly practiced in Chitwan district only. This can be explained by better access to the technologies due to better infrastructure. Furthermore, farmer's grade of knowledge on climate change is dependent on education level of the farmer, which again could explain their use or not-use of different adaptation technologies against climate change.

We recommend that it should be initiated an effective training on adaptation technology of climate change, especially in remote districts like in Jumla and Mustang. Governmental bodies, which are essentially for agriculture development in the country, should facilitate farmers with such knowledge. Furthermore, it is important that farmers have access to a set of different adaptation technologies to meet the grand challenges of ongoing climate change.

6. References

ADB, DFID, EC, BMZ, OECD, UNDP, UNEP and the World Bank, (2003). Poverty and Climate change: reducing the vulnerability of the poor through adaptation [Sperling. F. (ed)]

Agriculture Perspective Plan, (1996-2015). Agriculture Perspective Plan. Agricultural Project Service Centre, Kathmandu, Nepal.

Alam, G. M., Hoque, K. E., Khalifa, M. T. B., Siraj, S. B., & Ghani, M. F. B. A. (2009). The role of agriculture education and training on agriculture economics and national development of Bangladesh. *African Journal of Agricultural Research*, *4*(12), 1334-1350.

Arlt, D., Hoppe, I., & Wolling, J. (2011). Climate change and media usage: Effects on problem awareness and behavioural intentions. *International Communication Gazette*, *73*(1-2), 45-63.

Baidya, S.K., and J. Karmacharya (2007), Observed and Future Climate Change in Nepal, proceeding report on National Workshop on Climate Change and Human Health: Potential Impact, Vulnerability and Adaptation in Nepal, organized by Nepal Health Research Council on December 19-21

Baul, T. K., Ullah, K. M., Tiwari, K. R., & McDonald, M. A. (2013). People's local knowledge of climate change in the Middle-Hills of Nepal.

Bhattarai, S., Chaudhary, R. P., Quave, C. L., & Taylor, R. S. (2010). The use of medicinal plants in the trans-himalayan arid zone of Mustang district, Nepal. *Journal of Ethnobiology and Ethnomedicine*, 6(1), 14.

Cline, W. R. (2008). Global warming and agriculture. *Finance and Development*, *45*(1), 23.

Dahal, N. (2008). Understanding climate change adaptation issues in Nepal. *The Initiation*, *2*(1), 138-144.

Dhakal, S. (2003). *One World South Asia, Kathmandu.* Nepal.http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/title_page.html)

Enate, I. C. (2014). Impacts of climate change on agricultural production in Enugu State, Nigeria. *Journal of Earth Science and Climate*, 5(9): 1-3.

FAO (2004c). Food insecurity and vulnerability in Nepal; Profile of seven vulnerable groups. ESA Working Paper No. 04-10. Food and agriculture organization of United Nations (www.fao.es/esa), Rome, pp32

FAO (2005)."Impact of Climate Change, Pests and Diseases on Food Security and Poverty Reduction." Special event background document for the 31st Session of the Committee on World Food Security. Rome. 23-26 May 2005.

FAO, F. (2009). Global agriculture towards 2050.

Gaasland, I. (2004). Can a warmer climate save northern agriculture?

Garg, A., Shukla, P. R., & Kapshe, M. (2007, May). From climate change impacts to adaptation: A development perspective for India. In *Natural Resources Forum* (Vol. 31, No. 2, pp. 132-141). Oxford, UK: Blackwell Publishing Ltd.

Hatfield, J., G. Takle, R. Grotjahn, P. Holden, R. C. Izaurralde, T. Mader, E. Marshall, and D. Liverman, 2014: Ch. 6: Agriculture. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 150-174. doi:10.7930/J02Z13FR.

International Institute for Sustainable Development (2000). Agriculture and Climate Change. Institute for environmental studies: University of Torornto.

IPCC (2001b). Climate Change 2001: Impacts, Adaptation, and Vulnerability, synthesis report. Contribution of Working Group I, II, III to the Third Assessment Report of the Intergovernmental Panel on Climate Change [McCarthy, M.C., O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White (eds.)] Edited by R.T. Watson and the Core. Writing Team. Cambridge University Press, pp.1031

IPCC (2003). Climate Change 2001: Impacts, Adaptation and Vulnerability, GRID- Arendal. 98 pp.

IPCC (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.). IPCC, Geneva, Switzerland. pp 104

IPCC, 2013. Climate Change 2013. The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Karki, M. B. (2007). Nepal's experience in climate change issues. In *Fourteenth Asia Pacific Seminar on Climate Change, Sydney, Australia*.

Kates, R.W. (2000). Cautionary Tales: adaptation and the global poor, climate change, pp. 5-17.

Keane, J., Page, S., Kergna, A., & Kennan, J. (2009). Climate change and developing country agriculture: An overview of expected impacts, adaptation and mitigation challenges, and funding requirements. *Issue Brief*, 2.

Kemausuor, F., Dwamena, E., Bart-Plange, A., & Kyei-Baffour, N. (2011). Farmers' perception of climate change in the Ejura-Sekyedumase District of Ghana. *ARPN Journal of Agricultural and Biological Science*, 6(19), 26-37.

Khanal, C. R. (2005). Climate Change and Organic Agriculture. *Journal of Agriculture and Environment*. Review Paper. 10: 102-104.

Ladan, S. I. (2014). An appraisal of climate change and agriculture in Nigeria. *Journal of Geography and regional planning*, 7(9), 176-184.

Legesse, B., Ayele, Y., & Bewket, W. (2013). Smallholder farmers' perceptions and adaptation to climate variability and climate change in Doba district, west Hararghe, Ethiopia. *Asian Journal of Empirical Research*, 3(3), 251-265.

Maddison, D. (2007). *The perception of and adaptation to climate change in Africa*. The World Bank.

Malla, G. (2008). Climate change and its impact on Nepalese agriculture. *Journal of agriculture and environment*, 9, 62-71.

McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., & White, K. S. (Eds.). (2001). Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change (Vol. 2). Cambridge University Press.

McClean, C. J., Lovett, J. C., Küper, W., Hannah, L., Sommer, J. H., Barthlott, W., ... & Taplin, J. R. (2005). African plant diversity and climate change. *Annals of the Missouri Botanical Garden*, 139-152.

MoAD. (n.d.). District Profile. Retrieved from http://namis.gov.np/publication/district-profile?fbclid=IwAR3zFhXO1_rNVgLF9MLPbAlSDCa2GJNxlf1DVfFuWLrZU5RkjsuhUrl-z5g

Moyo, M., Mvumi, B. M., Kunzekweguta, M., Mazvimavi, K., Craufurd, P., & Dorward, P. (2012). Farmer perceptions on climate change and variability in semi-arid Zimbabwe in relation to climatology evidence. *African Crop Science Journal*, 20(2), 317-335.

NARC (1998). National Agriculture Research Council. Annual Report (1987/88 and 1997/98). Agriculture Environment Unit Nepal, Agricultural Research Council, Lalitpur.

Niroula, G. S., & Thapa, G. B. (2007). Impacts of land fragmentation on input use, crop yield and production efficiency in the mountains of Nepal. Land degradation & development, 18(3), 237-248.

Nyong, A., Adesina, F., & Elasha, B. O. (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitigation and Adaptation strategies for global Change, 12(5), 787-797.

Pathak, et al., (2003). Climate Potential and On-farm Yield Trends of Rice and Wheat in the Indo Gangatic Plains Field Crops. *Journal of Climate Research*. 80:223-234.

Presidential Advisory Council on Education, Science and Technology (PACEST). 2007. Current Status and Prospects for Climate Change. Presidential Committee on Green Growth. 2010. Road to Our Future: Green Growth.

Raghuvanshi, R., & Ansari, M. A. (2017). A Study of Farmers' Awareness About Climate Change and Adaptation Practices in India. Young (Less than 45), 45, 40-90.

Rajasekaran, B., Warren, D. M., & Babu, S. C. (1991). Indigenous natural-resource management systems for sustainable agricultural development—a global perspective. *Journal of International Development*, 3(3), 387-401.

RAP 3. "District Profile." District Profile |Rural Access Program, 2016, rapnepal.com/district/district-profile-12.

Rasel, S. M. M. (2013). Effect of elevation and above ground biomass (AGB) on soil organic carbon (SOC): a remote sensing-based approach in Chitwan district, Nepal. *International Journal Scientific & Engineering Research*, 1546-1553

Regmi, H. R. (2007). Effect of unusual weather on cereal crops production and household food security. *The Journal of Agriculture and Environment*, pp20-29.

Rosegrant, M. W., Ewing, M., Yohe, G., Burton, I. Huq, S. & Valmonte-Santos, R. (2008). Climate change and Agriculture. Escborn Germany: Deutsche Gessellschaft für Technische Zusammnarbeit (GTZ) GmbH.

Sasson, A. (2012). Food security for Africa: an urgent global challenge. *Agriculture & Food Security*, *1*(1), 2.

Saul, E. (2015). Impact of climate change on agriculture and food security in Nigeria: Challenges and adaptation. *Global advanced research Journal of Medicinal plant*, 3(1): 001-009.

Shah, A. (2012). Climate Change Affects Biodiversity. Global Issues: Social, Political, Economic and Environmental Issues That Affect Us All.

Torvanger, A., Twena, M., & Romstad, B. (2014). Climate change impacts on agricultural productivity in Norway. *Climate Change Effect on Crop Productivity*, 459.

Tsojon, J. D. Impact of Climate Change on Agricultural Production by Farmers in Taraba State, Nigeria.

UNFCCC (2001). United Nations Framework Convention on Climate Change. Retrieved September 13, 2008, from http://unfccc.int/resource/docs/cop7/13a02.pdf.

United States Environmental Protection Agency, "Climate Impacts on Agriculture and Food Supply." EPA, Environmental Protection Agency, 6 Oct. 2016, 19 january 2017 snapshot.epa.gov/climate-impacts/climate-impacts-agriculture-and-food-supply_.html.

WFP (2009). The Cost of Coping. A collision of crises and the impact of Sustained Food Security Deterioration in Nepal. United Nations World Food Programme. Nepal Food Security and Monitoring System

World Resources Institute (2005). The Wealth of the Poor—Managing Ecosystems to Fight Poverty collaboration with United Nations Development Programme, United Nations Environment Programme Washington, DC: WRI

WRI (World Resources Institute). 2014. Climate Analysis Indicators Tool (CAIT) 2.0: WRI's climate data explorer. Accessed May 2014.http://cait.wri.org.

Yohe, G. and Tol, R.S.J. 2002. Indicators for social and economic coping capacity- moving toward a working definition of adaptive capacity. *Global Environmental Change* 12, 25-40.

Appendixes

Appendix 1: Results of Chi-square tests

a) Relation between experience of farmer and mulching technology

H0= mulching practice will not increase with increase in experience of farmer

H1= mulching practice will increase with increase of experience of farmer

df= (3-1) (3-1) = 4

α= 0.05

p value = 0.80260768

X^2 value= 1.634338

Since x^2 value is lower than critical value of 9.488 at 0.05 level of probability and 4 DF, we failed to reject null hypothesis. Result showed that there will not be increase of mulching practice with the increase of experience of farmer.

b) Relation between experience of farmer and awareness of climate change

H0= awareness of climate change will not increase with experiences

H1= awareness of climate change will increase with experience

df= (2-1) (4-1) = 3

α=0.05

p value = 0.515405711

X^2 value= 2.284973422

Since X^2 value is less than critical value at 3 DF and 0.05 level of significance, we failed to reject null hypothesis. Thus, experience of farmer is not related to awareness of climate change to the farmer

c) Relation between education level of farmer and knowledge of climate change

H0= grade of knowledge on cc is not influenced by education level

H1= grade of knowledge on cc is influenced by education level

df= (4-1) (4-1) = 9

α=0.05

P value= 0.035095821

X^2 value= 18.00670574

Since X^2 value is higher than critical value at 9 DF and 0.05 level of significance, null hypothesis is rejected. Thus, grade of knowledge on climate change is influenced by the education level of farmer.

d) Relation between awareness of climate change and use of crop rotation technology

H0= crop rotation not increased with awareness of cc

H1= crop rotation increased with awareness of cc

df= (2-1) (2-1) = 1

α= 0.05

p value= 0.162250122

X^2 value = 1.9531

Since X^2 value is lower than critical value at 1DF and 0.05 level of significance, we failed to reject null hypothesis. Thus, there is no significant relation between awareness of climate change to the farmer and use of crop rotation practice.

Appendix 2: Questionnaire involved in the study (for farmers)

Farmers Survey

Respondent number:
Date: ………

A. Basic profile of the respondent:

1. Region:
2. Village:

3. Gender …. Male …..Female
4. Age:

5. Education level:
…..No formal education …..Up to SLC …..Higher secondary ….University level

6. Farming experience:
….0-3 years …..4-10 years …..11-20 years …..more than 20 years

7a. Farm size ..... < 1 ha ......1-3 ha ....>3 ha
7b. Soil type ..... clay .....silt ....sand ....mixture
7c. Slope ...... flat land ..... some slopes ......very steep

8. Source of income (how they operate agriculture)
…„Personal ……Family support ……Cooperative or bank

9. Income per annum from agricultural production: ……………

B. Awareness and Knowledge of climate change to the Farmer:

1. Are you aware of climate change? ……Yes ..…No

2. How do you grade your knowledge on climate change?
…..Very good …..Good ….Medium ….Low …..Very low

3. How do farmers agree to the awareness and knowledge on the different evidences of climate change? Reply the different claims below on the given scale.
i. Climate change cause erratic rainfall pattern
.....Totally agree …..Agree …..Not sure ….Disagree …..Totally disagree

ii. Climate change cause drought
.....Totally agree …..Agree …..Not sure ….Disagree …..Totally disagree

iii. Climate change causes rise in temperature
.....Totally agree …..Agree …..Not sure ….Disagree …..Totally disagree

iv. Climate change causes the decrease in agricultural production
.....Totally agree …..Agree …..Not sure ….Disagree …..Totally disagree

v. Climate change causes high rate of pest and disease to the crop
.....Totally agree …..Agree …..Not sure ….Disagree …..Totally disagree

vi. Climate change causes high weed infestation to the crop field
.....Totally agree …..Agree …..Not sure ….Disagree …..Totally disagree

vii. Climate change causes flooding, erosion or landslides of the farmland
.....Totally agree …..Agree …..Not sure ….Disagree …..Totally disagree

C. Impact of the climate change to the agricultural production:

1. Do you experience change in agricultural pattern due to climate change?
….Yes …..Not sure …..No
2. If yes, then what was before and what is now?

3. Is there any increase in crop pest or disease infestation due to climate change?
….Yes …..Not sure …..No
4. If yes, then which pest is increased or emerged than before and which crop is more infested than before?

5. Do you find any increase in weed due to change in climate?
….Yes …..Not sure …..No
6. If yes, what are the major weeds that suppress crop growth that have increased or emerged because of climate change?

7. Is there any increase in cost of production due to climate change?
….Yes …..Not sure …..No
8. If yes, which activities cost higher than before?

9. Is there any delay of planting date of your major crop than before?
….Yes …..Not sure …..No
10. If yes, what is the reason behind this? And can you please mention the date of planting of these major crops before and now?

11. Do you experience a reduction in yield due to climate change?
….Yes …..Not sure …..No
12. If yes, can you please mention the yield of your major crop before and now?

D. Adaptation technology at farm level

1A. Do you practice or use any of these technologies today?

a. Crop rotation ….Yes often …..Sometimes ….No
b. Native varieties of crop ….Yes often …..Sometimes ….No
c. Drought tolerant varieties of crop ….Yes often …..Sometimes ….No
d. Fast maturing varieties ….Yes often …..Sometimes ….No
e. Delay or early planting of crops ….Yes often …..Sometimes ….No
f. Irrigation ….Yes often …..Sometimes ….No
g. Rain harvest ….Yes often …..Sometimes ….No
h. Mulching ….Yes often …..Sometimes ….No
i. Minimum or zero tillage ….Yes often …..Sometimes ….No
j. Integration of livestock ….Yes often …..Sometimes ….No

1B. How do you judge these technologies as useful for climate change adaptation?

a. Crop rotation ….Useful ….Limited value ….Will not help
b. Native varieties of crop ….Useful ….Limited value ….Will not help
c. Drought tolerant varieties of crop ….Useful ….Limited value ….Will not help
d. Fast maturing varieties ….Useful ….Limited value ….Will not help
e. Delay or early planting of crops ….Useful ….Limited value ….Will not help
f. Irrigation ….Useful ….Limited value ….Will not help
g. Rain harvest ….Useful ….Limited value ….Will not help
h. Mulching ….Useful ….Limited value ….Will not help
i. Minimum or zero tillage ….Useful ….Limited value ….Will not help
j. Integration of livestock ….Useful ….Limited value ….Will not help

<u>(Question 2-8 are only for the used adaptation technology)</u>

2. Can you please mention the drought tolerant varieties of your major crops?

3. Why do you use fast maturing crop varieties and for which crops? How many days does it matures faster than normal varieties?

4. Which crops are planted earlier or later than normal time and why?

5. For which crop do you use irrigation and what is the number of irrigation for your major crops?

6. How do you know about rain harvest? Is there any problem making such arrangement for the rain harvest?

7. For which crop do you use minimum or zero tillage? What is the major purpose of this?

8. Which materials are used as mulch? For which period do you use mulch and for which crops?

Appendix 3: Questionnaire involved in the study (for experts)

Experts Survey

Date:

Region:

Office:

Name:

Gender: ………...Male ……………Female

1) a. Is there any evidences of climate change since past 10 years on this region? If yes, please elaborate it briefly with major evidences.

1) b. How does these climate change effects on agriculture? Please mention these effects with some evidences.

2. What are the major adaptation practices used by farmer against climate change?

3. Is there any use of modern resistant varieties of major crop to cope the effect of climate change? If yes, can you mention these varieties used by farmer in this region.

4. Does farmer use delay planting and fast maturing varieties to minimize the effect of climate change? If yes, how the major crops delayed than normal time? And for which crops fast maturing varieties are used and please mention these varieties of major crops in this region.

Appendix 4: Some glimpse of study area

Surveying with farmer of Jumla district

A view of Jumla district

A view of Thini village of Mustang

Surveying with a farmer of Mustang district