# Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices. Reg Environ Change

**ARTICLE** *in* REGIONAL ENVIRONMENTAL CHANGE · JUNE 2010

Impact Factor: 2.26 · DOI: 10.1007/s10113-010-0137-1



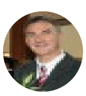
**4 AUTHORS:**

Sujata Manandhar
Tohoku University



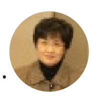
Dietrich Schmidt-Vogt
Chinese Academy of Sciences





Sylvain Roger Perret
Cirad - La recherche agronomique pour le d…





Futaba Kazama
University of Yamanashi

Reg Environ Change (2011) 11:335–348
DOI 10.1007/s10113-010-0137-1

ORIGINAL ARTICLE

# Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices

**Sujata Manandhar · Dietrich Schmidt Vogt · Sylvain R. Perret · Futaba Kazama**

Received: 17 February 2010 / Accepted: 3 July 2010 / Published online: 23 July 2010


**Abstract** Climate change is a global challenge that has a particularly strong effect on developing countries such as Nepal, where adaptive capacity is low and where agriculture, which is highly dependent on climatic factors, is the main source of income for the majority of people. The nature and extent of the effects of climate change on rural livelihoods varies across Nepal in accordance with its highly diverse environmental conditions. In order to capture some of this variability, a comparative study was performed in two different ecological regions: Terai (lowland) and Mountain (upland) in the western development region of Nepal. The study focuses on perceptions of, and on adaptations to climate change by farmers. Information was collected from both primary and secondary data sources. Climate data were analyzed through trend analysis. Results show that most farmers perceive climate change acutely and respond to it, based on their own indigenous knowledge and experiences, through both agricultural and non-agricultural adaptations at an individual level. The study also shows that there is a need to go beyond the individual level, and to plan and provide support for appropriate technologies and strategies in order to cope with the expected increasing impacts of climate change.

S. Manandhar (✉)
Department of Eco-Social System Engineering,
University of Yamanashi, 4-3-11, Takeda,
Yamanashi, Kofu 400-8511, Japan
e-mail: sujatamanandhar@gmail.com

D. S. Vogt
Centre for Mountain Ecosystem Studies,
Kunming Institute of Botany, Chinese Academy of Sciences,
650204 Heilongtan, Kunming, China

S. R. Perret
UMR G-Eau, Cirad, Asian Institute of Technology,
PoBox 4, Klong Luang Pathumthani 12120, Thailand

F. Kazama
International Research Center for River Basin Environment,
University of Yamanashi, 4-3-11, Takeda, Yamanashi,
Kofu 400-8511, Japan

**Keywords** Climate change · Ecological regions · Indigenous knowledge · Adaptation · Nepal

## Introduction

Climate change is considered the most critical global challenge of the century. It is predicted that global temperatures will increase further by between 1.4 and 5.8°C by 2100. Sea level rise, polar ice melting, glacier melting, extreme weather events such as storms, floods, droughts and heat waves, changes in morphology, physiology, phenology, reproduction, species distribution, community structure, ecosystem and species evolutionary processes in marine, freshwater and terrestrial biological systems, change in crop production patterns, spread of infectious diseases and pests are some of the incidences likely to happen as a result of climate change (IPCC 2007). Least developed countries such as Nepal, while not contributing significantly to global warming, are more sensitive to the effects of climate change because of their weak coping capacity (Huq et al. 2003).

Nepal is a small landlocked country with a diversity of eco-climatological conditions that is mainly due to its enormous altitudinal gradient, its location at the interface of the Tibetan Plateau and the plains of Northern India, and its highly dissected mountain terrain. Ecologically, Nepal is divided into three regions: Terai (lowland), Hill (mid

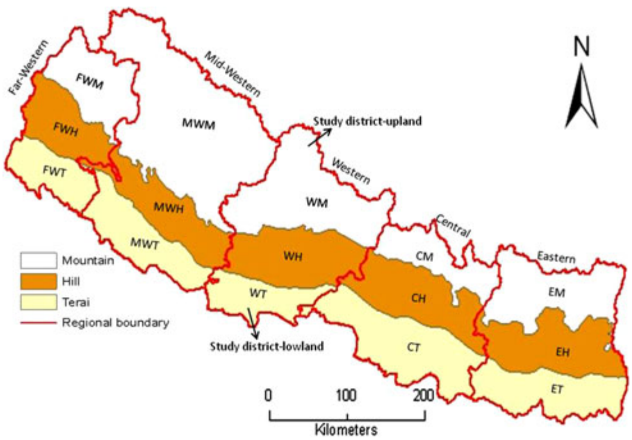



**Fig. 1** Map of regional divisions of Nepal. *FWM* far western mountain, *FWH* far western hill, *FWT* far western tarai, *MWM* mid western mountain, *MWH* mid western hill, *MWT* mid western tarai, *WM* western mountain, *WH* western hill, *WT* western tarai, *KV* Kathmandu Valley, *CM* central mountain, *CH* central hill, *CT* central tarai, *EM* eastern mountain, *EH* eastern hill, *ET* eastern tarai. *Source* NGIIP (2010)

hill) and Mountain (upland) regions, which are arranged in latitudinal belts running from northwest to southeast (see Fig. 1).

The Mountain region (upland) covers the northern part of the country, ranging in altitude from 4,877 to 8,848 m above sea level. This region constitutes 35% of the total area of Nepal but is very sparsely populated (Statistical Year Book of Nepal 2007).

The Hill region lies between the Mountain and the Terai regions and ranges from 610 to 4,877 m above sea level. It comprises 42%, of the total land area and has been the historical core of Nepal.

The Terai region (lowland) is located in the southern part of the country. It is the northern extension of the Ganges Plain, a fertile region with level terrain, which covers 23% of the total area. Due to good opportunities for farming, proximity to India, and internal as well as external migration, it has become the most densely populated part of Nepal.

The three regions differ from each other with respect to ecological and climatic conditions but also with respect to climate change scenarios. Diversity of climatic and ecological conditions is reflected in diversity of local agro-ecosystems and livelihood options. Agriculture is the major income source of nearly 80% of the population in Nepal and accounts for 40% of the GDP (Ministry of Population and Environment 2004). Since agriculture depends strongly on weather and climatic conditions, an important part of the economy of the country is sensitive to climate change (Alam and Regmi 2004). Unusual changes in climate such as rising temperatures, irregular monsoon, and changes in intensity and pattern of rainfall have become increasingly noticeable in Nepal. Chaulagain (2006) has pointed out that climate in the Nepal Himalaya is changing faster than the global average. This applies especially to temperature rise, which at higher altitudes is more pronounced than at lower altitudes (Baidya et al. 2008). Changing temperatures and erratic rainfall pattern are affecting crop production in Nepal (Malla 2008). Other changes in agriculture, such as loss of local land races of both crops and domestic animals, changes in cropping sequences, scarcity of water due to drying up of wells, and increasing incidences of disease and pest have also been noticed (Regmi et al. 2008). Climate change is not always the main reason behind these changes but may have acted in many cases as a catalyst. Climate change is expected to increasingly affect the livelihoods of farmers, especially those who are economically more vulnerable.

This paper aims first to assess the magnitude and trends of climate change, second to analyze the mode and accuracy of farmers' perceptions of climate change phenomena, and third to investigate their adaptation measures. Research for this study has been carried out in the form of two case studies.

## Methodology

### Selection and presentation of case study areas

In order to study the climate change patterns and effects in two fundamentally different ecological regions, two districts in the western development region of Nepal were selected as study areas: Rupandehi district in the Terai region (lowland) and Mustang district in the Mountain region (upland).

Rupandehi district borders on India and ranges in altitude from 100 to 1,219 m above sea level (see Fig. 2). It has a hot and humid climate and receives 1,391 mm annual average precipitation.

Mustang district ranges in altitude from 2,000 m to the top of the world's 7th and 10th highest mountains: Dhaulagiri and Annapurna—8,137 and 8,168 m above sea level (see Fig. 3). It covers an area of 3,573 square kilometers. Mustang is located in the rain shadow of the Himalayan range and receives on average less than 200 mm rain annually. The southern part of the district receives, however, comparatively more rain than other areas. A defining feature of Mustang is the deeply incised valley of the Kali Gandaki River with its arid valley bottom and characteristic diurnal wind system.

Following the selection of districts, research sites were selected from each district in consultation with the agricultural organizations working there (National Wheat Research Programme [NWRP] and Nepal Agricultural

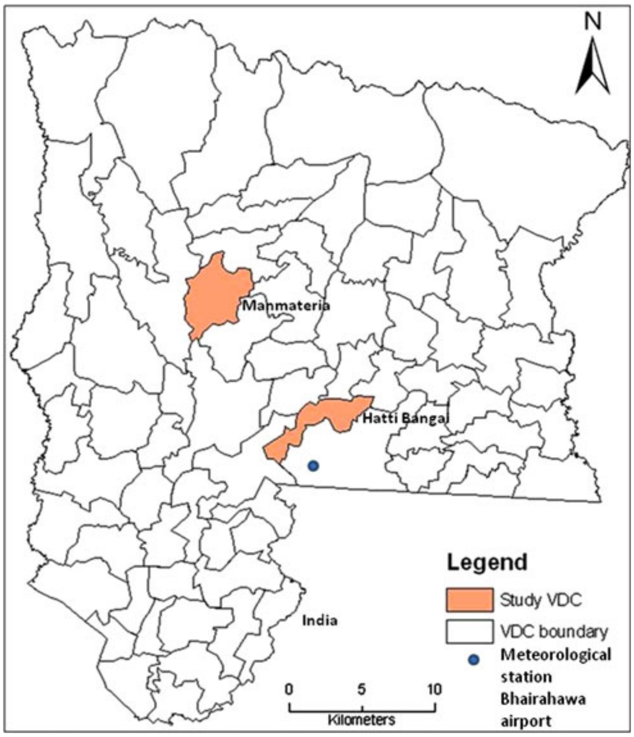



Fig. 2 Map of Rupandehi district and VDC's. *Source* NGIIP (2010)

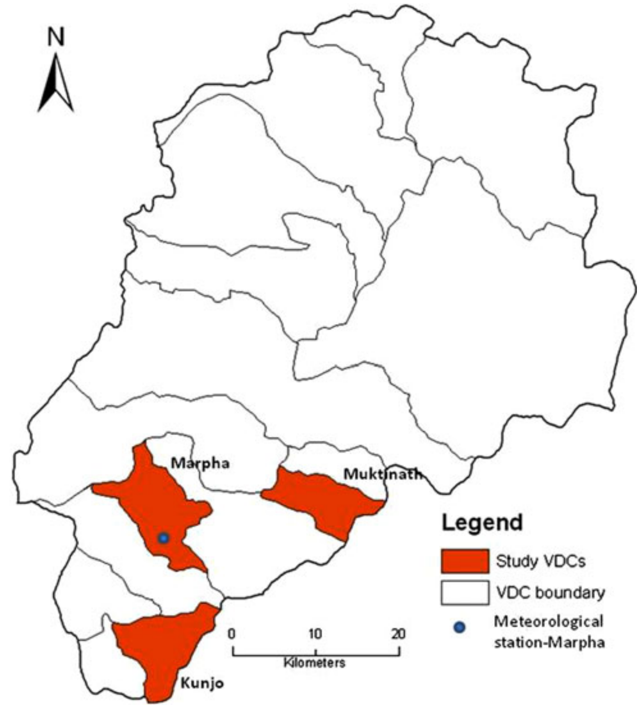



Fig. 3 Map of Mustang district and VDC's. *Source* NGIIP (2010)

Research Council [NARC] in Rupandehi district, and District Agriculture Development Office [DADO]—Mustang in Mustang district). An important selection criterion was the availability of long-term (30 years) climate data.

In Rupandehi district, Gargatti village of Hatti Bangai VDC and Bhaglapur village of Manmateria VDC were selected. VDCs or Village Development Committees are fourth level units of altogether six units in the administrative hierarchy in Nepal. Residents of these villages rely on agriculture as a major source of livelihood. The two villages differ from each other in terms of their natural environment: Gargatti is located in a dry upland area (113 m), whereas Bhaglapur is located in a low-lying wetland area (102 m) with high water table.

Gargatti village (ward no.8) is situated 10 km southwest of the district headquarters, Bhairahawa. Out of a total of 74 households, more than 50% are small-scale farmers with only one hectare or less of land, 34% are medium-scale farmers with one to three hectares of land, and only 15% have more than 3 hectares of land and can thus be regarded as large-scale farmers. Seventy-six percent of the farmers derive most of their income from planting rice, 20% from planting wheat, 4% from planting vegetables, and 1% from planting pulses. Farmers in Gargatti village practice different cropping sequences: rice–wheat–fallow, rice–wheat–vegetables, rice–mustard–vegetables, and rice–lentil–fallow.

Bhaglapur village (ward no.1) is situated 21 km northwest of the district headquarters. The total arable land area of the village is about 167 ha; 67% are located in lower-elevation wet land, 30% in mid-elevation wet land, and 3% in upper elevation dry land. Out of a total of 102 1 households, 66% are small-scale farmers, 34% are medium-scale farmers, and only one or two farmers belong into the category of large-scale farmers. All of the farmers grow rice in the rainy season, and paddy land comprises 98% of the cultivated land. In the dry season, when rice cannot be cultivated due to lack of irrigation facilities, 80% of the farmers grow wheat on 31% of their land. Most of the remaining land lies fallow during the dry season, and only a few farmers grow mustard, lentil, linseed, khesari (*Lathyrus* sp.), and other minor crops. Farmers in Bhaglapur follow the same cropping sequences as in Gargatti village, but some of them have started fish farming.

Mustang district is divided into upper Mustang (above 3,800 m) and lower Mustang (below 3,800 m), the two divisions differing from each other with respect to prevailing climatic conditions. Three VDCs from lower Mustang—Kunjo, Marpha, and Muktinath—were selected for this study on the basis of climatic conditions, accessibility, and availability of climate data. Since villages are scattered in Mustang, and farm households' small in size, VDCs rather than villages were chosen as sampling units.

Kunjo VDC is located in the southern area of lower Mustang at an altitude of 2,420 m and includes more than 200 households. This area receives more rain than the central and northern areas of Mustang (Nepal Trust for

Nature Conservation (NTNC) 2008). Most of the villagers are involved in agriculture except for a few, who are working outside the region or who are involved in tourism. The major crops in this area are buckwheat, corn, potato, and barley.

Marpha VDC is located in the central part of lower Mustang at an altitude of 2,700 m and contains 302 households. This area lies in the rain shadow of the Himalayan range and is thus significantly drier than Kunjo VDC. Despite the dry conditions, farmers grow two crops per year due to good irrigation facilities (Nepal Trust for Nature Conservation (NTNC) 2008). Besides growing cereal crops, apple farming and tourism have become major additional sources of income for farmers in Marpha.

Muktinath VDC is also situated in the central part of lower Mustang and in the rain shadow of the Himalayan range. It is located at an altitude of 3,664 m and contains 189 households (Agriculture Diary 2008). Muktinath is a famous attraction for pilgrims and tourists. Besides tourism, agriculture is the major source of income. Farmers grow buckwheat, corn, potato, barley, and naked barley.

## Data collection

Primary data were collected from September to October 2008 through a reconnaissance survey, a household questionnaire survey, and through the application of different RRA (Rapid Rural Appraisal) tools such as focal group discussion, key informants interview, transect walk, time line, crop calendar and direct field observation. Focal group discussions and key informant interviews were used to crosscheck and generate information on farmers' experiences of climate change, problems in farming practices, their indigenous knowledge systems and the different adaptation measures adopted. Discussions were also held with elderly farmers to tap into their long-term memory of climate events and experience in farming. However, in most cases, it was not easy to get answers from these old people due to their faded memories of past climatic events. They were able to recall and put a date to major climatic events of the past in most cases only with reference to important political or other events that had occurred at the same time.

Household surveys were conducted with structured questionnaires to gather detailed information on farmers' perception of climate change and on their adaptation measures. Both open- and close-ended questions were included in the questionnaire. Households were selected through simple random sampling technique covering more than fifty percent of the farmers in the two study sites in Rupandehi district. A total of 35 farmers were selected from Gargatti village and 39 farmers from Bhaglapur village. Altogether 74 samples were collected from the lowland study site. Because of the low and scattered population in lower Mustang district, altogether 48 samples were randomly selected from different villages in Kunjo, Marpha, and Muktinath VDCs, i.e. about 7% of all households in each VDC. In both study sites, climate change was studied using climate data from 30 years back.

Secondary data were collected from different sources including 30 years climate data (daily temperature and rainfall data) from Bhairahawa airport in Rupandehi district, and from Marpha in Mustang district, as well as district level population and agricultural data. In Rupandehi district, data were collected on crop varieties, especially on newly adopted varieties. Since agricultural production data were not available on a local scale, it was difficult to quantify the impact of climate change on agriculture.

## Household data analysis

Primary data were analyzed quantitatively using descriptive statistics. Contingency tables and Chi square tests were performed to investigate the correlation between farmers' perception of climate change and climatic factors. Thirty-five and 39 samples from Gargatti and Bhagalapur villages in Hatti Bangai and Manmateria VDCs in the Terai region, and 48 samples from different villages in Kunjo, Marpha, and Muktinath VDCs in the Mountain region were used to perform chi-square tests. Alongside with quantitative descriptive statistics, qualitative information in the form of narrative experiences and observations are provided in textboxes, bearing witness to the changing climate and increasing climatic variability in the study areas.

## Climate data analysis

Descriptive statistics such as sum, mean, relative frequency, and standard deviation as well as analytical tests such as student t-test and Mann–Kendall test were used in studying the trend of rainfall, temperature change, and number of days of cold waves. Trend analysis of long-term climate data was done to ascertain the changes in climate pattern and to analyze the match between farmers' perceptions and climatic facts. The stability of trend in rainfall and temperature changes was checked by performing t-test between different datasets with equal variances. The test, however, did not perform well due to the fact that the study did not cover more than 30 years of climate data. A total of 360 datasets for mean monthly maximum and minimum temperature trend stability analysis over 30 years were used for the Terai region and 324 datasets over 27 years for the Mountain region. A lower number of years were considered for the Mountain region than for the Terai region to avoid prevalence of error due to missing data sets in some years. A total of 360 datasets were used for 30 years mean monthly rainfall trend stability analysis for the Terai and Mountain region. The trend of occurrence of number of days of cold waves was tested by the Mann–Kendall test. This is a non-parametric test that tests trends in time series data. Thirteen years (1991/92–2005/06) monthly cold wave data in terms of number of days were used in the Mann–Kendall test. Only data from 1991 to 2006 was considered. This timeframe is determined by the fact that cold waves have increased markedly since 1991, and that data from the Department of Hydrology and Meteorology was available only until 2006.

## Results and discussion

### Farmers' perception of climate change

#### *Lowland Nepal*

More than two-thirds of the farmers interviewed in Gargatti and Bhaglapur village in the lowland study area have personally experienced and perceived changing climate. In addition to that, some farmers have heard about increasing global temperatures and erratic rainfall from mass media or through conversations with other farmers.

Farmers from both villages reported that since many years they have not experienced Loo (a very hot and dry wind occurring in the hot pre-monsoon season that may push temperatures above 45°C and cause fatal sunstrokes) and big storms. Moreover, they have noted that the western wind which used to blow throughout the month of February, bringing cool air and rain, does no longer blow so frequently. Farmers in both villages have experienced an increasing trend of untimely and erratic rainfall, and a decrease in the level of water in the nearby Sukahali and Tinau rivers. Farmers in Gargatti village can still remember the severe drought that occurred in the year 1992 as well as in the years 2002–2006, which caused a big loss in rice production. After 15 years, 2007, however, has been the first year of normal rain. Farmers in Bhaglapur village remember the severe floods that occurred in the years 1981, 1984, 1989 and 1998. They reported also that there used to be more than ten artesian wells in the past, but that due to persisting drought most of them have dried up and only three to four still exist (Box 1).

#### *Climate data analysis*

Analysis of 30 years climate data shows that there is evidence for climate change in the lowland study site. Figure 4 shows the monsoon precipitation anomaly generated from 30 years monthly rainfall data from the nearest meteorological station (Bhairahawa airport) and highlights the decreasing trend of precipitation in the area. It also demonstrates a positive monsoon precipitation anomaly for 14 years randomly, and a negative anomaly for the remaining 16 years as well as the highly erratic character of rainfall. It confirms farmers' perception of a changing rainfall pattern and shows the droughts over many years before the years 1995 and 2007 reported by farmers. The year 1992 (with high negatively normalized value) was found to be the driest year in the last 30 years. The precipitation fluctuation in Nepal, according to Shrestha et al. (2000), is strongly correlated with the El Niño-Southern Oscillation (ENSO). That the dry year of 1992 coincides with the elongated El Niño of 1992–1993 could, therefore, be an indication of cyclical variability rather than of linear change. The years 1981, 1984, 1989 and 1998, for which farmers reported floods, are shown to have the highest rainfall records. The analysis of 30 years of temperature data shows a slight increase in minimum temperatures while maximum temperatures have remained the same (see Figs. 5, 6). Moreover, it was found that temperature is increasing at a higher rate in upland than in lowland Nepal, and that erratic rainfall is characteristic of both regions. Chaulagain (2006) also found temperature change to be more pronounced at higher altitudes than at lower altitudes. However, the analysis of the stability of mean monthly rainfall, and monthly maximum and minimum temperatures employing t-test does not show any significant trend.

Fifty-six out of 74 farmers reported that the number of days of cold waves has been increasing in the last 14 years and that this trend seems to proceed at an alarming pace. A cold wave is a sudden drop in temperature within 24 hours and is often accompanied by thick fog over many days. The cold wave combined with dense fog has an adverse impact on agriculture as well as on the quality of life of people. Low temperatures over a long time shorten the vegetation period, and thus inhibit the productivity of many tropical or sub-tropical horticultural and agricultural plants (Salinger et al. 2000).

Farmers' perception that the length of cold waves has increased over the last 14 years has been supported by climate data which shows an increasing trend in the number of days of cold waves from 1992 to 2004, but a sharp drop to zero in 2005 (see Fig. 7). The longest-lasting cold waves were recorded in 1998 (21 days) and 2003 (27 days). The Mann–Kendall test showed a significant result at 95% level of confidence, and thus confirms the increasing trend in the number of days of cold waves (see Table 1).

The chi-square test performed to check farmers' perception of climate change showed significant results for most tests except for the temperature increase in Bhaglapur village (see Table 2). However, the strong match between

**Box 1** An experience of drought in Gargatti village (source: author's interview)

Omkar Yadav is a smallholder farmer from Gargatti village in HattiBangai VDC. Agriculture is his only source of income and he grows rice every year. He says that rainfall is an important factor to determine rice production and food availability in his homestead. He cannot afford irrigating rice when there is no rain. He still remembers the hard times when there was a long drought in the years 2002–2006. At that time, there was rain once at the time of rice transplanting in July but no more rain later. As a result, the entire rice crop dried up and spoiled. He could not do anything and had no options except waiting for the rain to come. Eventually, he lost hope and left his cattle to graze in the rice field

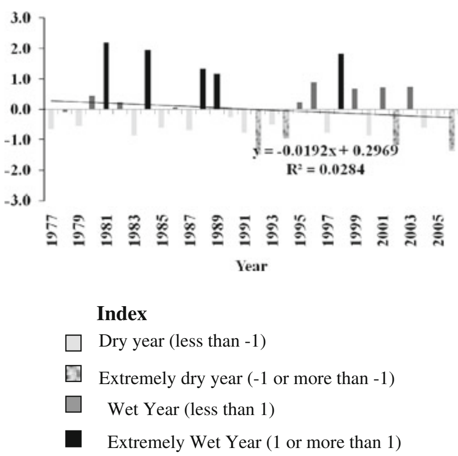



**Fig. 4** Standardized time series of monsoon precipitation observed in Bhairahawa in last 30 years

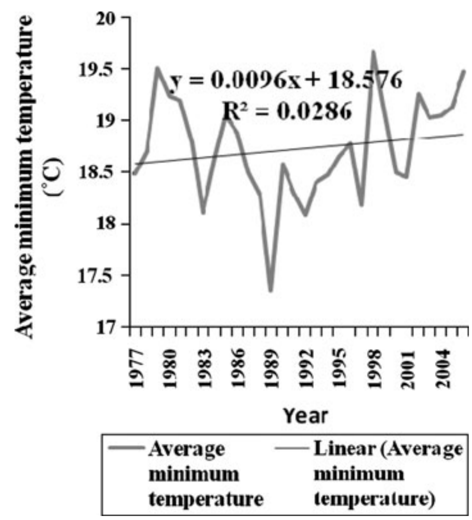



**Fig. 6** Average variation of minimum temperature in Bhairahawa in last 30 years

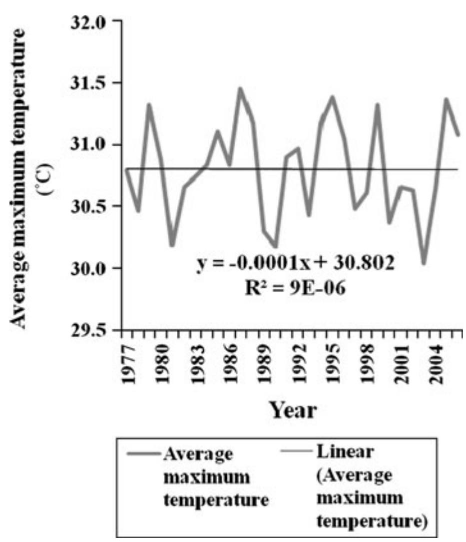



**Fig. 5** Average variation of maximum temperature in Bhairahawa in last 30 years

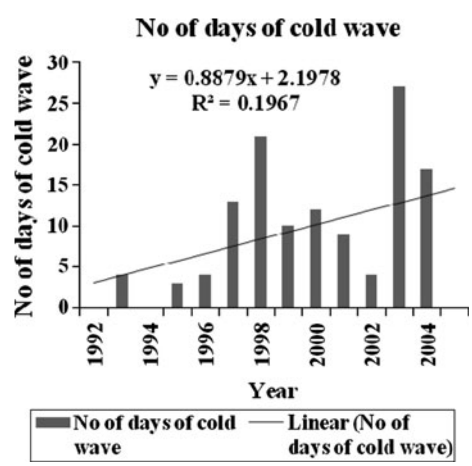



**Fig. 7** Variation in number of days of cold waves in Bhairahawa in last 14 years

farmers' perceptions and climate data shows clearly that farmers in the lowland study area have perceived climate change.

*Upland Nepal*

Farmers in lower Mustang have also experienced changes in climate. They have perceived changes in intensity and timing of rainfall, and an unusual rise in both summer and winter temperatures. They observed that there were no mosquitoes in the past but that increasing temperatures have been favorable for mosquitoes and many other insects, and have also led to an increase in crop diseases. Most of the farmers interviewed in the three VDCs are unanimous about a decrease in the volume and a change in the timing of snowfall. Decreasing snowfall has been experienced along

**Table 1** Statistical details of Mann–Kendall test performed for no. of days of cold waves from 1992–2005 in Bhairahawa

| Number of data points (years) | Mann–Kendall statistic (*S*) | Computed *Z* value | $Z_{\alpha/2}$ | Trend at 95% level of significance |
|---|---|---|---|---|
| 14 | 29 | 1.550 | 0.4394 | Increasing trend |

**Table 2** Correlation between farmers' perception of climate change and climate change in the Terai region

| Study area | Farmers' perception of climate change | Correlation with climate data | Chi Square test statistics | |
|---|---|---|---|---|
| Terai | Gargatti village | Changes in temperature | Positive | Significant |
| | | Changes in rainfall | Positive | Significant |
| | Bhaglapur village | Changes in temperature | Positive | Non-significant |
| | | Changes in rainfall | Positive | Significant |
| | Both villages | Increasing number of days of cold waves | Positive | Significant |

Chi square hypotheses were tested against $P > 0.05$ error

**Box 2** An experience of decreasing snowfall in Kunjo VDC-5, Kunjo village (source: author's interview)

Hom Bahadur Serchan, 68-year-old resident from Kunjo VDC-5, Kunjo village, still has a hazy memory of the winter of the year 1953. When he was a 12-year-old boy, snow cover in Kunjo was one storey high. Due to heavy snowfall, people were not able to move around for sometimes up to an entire week. Everyone was confined to the house, eating stored food, drinking melted ice water and also using it for cooking purposes. He said that in the past snow used to be thick on the mountains till the month of May but that nowadays it melts earlier, exposing the black surface and giving a dirty appearance to the mountain slopes. He appeared to be very concerned about the changes that have been taking place

with increasing winter rain, and less snow cover has been noticed in the Dhaulagiri and Annapurna ranges.

Besides temperature, rainfall, and snowfall changes, a distinct change has been noticed in the occurrence and timing of frost. Farmers in Muktinath VDC reported that frost, which used to occur from the 2nd week of September onwards in past years, has now been delayed by 2 weeks and occurs only from October onwards. Farmers in Marpha and Kunjo VDCs have also complained about increasing rain and fog in their areas. Before, there used to be 2–3 days of fog; now fog may last for 15–20 days (Box 2).

*Climate data analysis*

The graphs of seasonal rainfall patterns in Figs. 8 and 9 show an increasing trend in the last 30 years. Ichiyanagi et al. (2007) found, too, that winter rainfall over western Nepal has increased. The graph of total rainfall shows a small increase in the last 30 years (see Fig. 10). Dey and Kumar (1983) found an inverse relationship (negative correlation) between Indian Summer Monsoon (ISM) rainfall and the extent of snow cover in the Himalayas, which suggests that there might be a link between increasing rainfall and decreasing snowfall in the Mustang region. Arnell (1999) explained that a rise in temperature can lead to a general reduction in the proportion of precipitation falling as snow, and a consequent reduction in many areas in the duration of snow cover.

Average annual maximum temperature data over a 30-year period have revealed a significant rise in temperature in Marpha (see Fig. 11), which supports both Arnell's statement concerning a link between rising temperatures and decreasing snowfall, and farmers' perception of increasing temperatures in Mustang. Shrestha et al. (1999) stated that the analysis of maximum temperatures from 1971 to 1994 showed an increasing trend after 1977, ranging from 0.06 to 0.12°C $year^{-1}$ in the Middle Mountain and Himalayan regions, while the Siwalik (hills bordering the Gangetic plain with little potential for agricultural production) and Terai regions show a comparatively lower increase in temperature. The chi-square test showed a significant match between actual changes in temperature and farmers' perception of temperature changes; the test for changes in rainfall, however, is not significant (see Table 3). Similarly, the t-test showed an insignificant result for change in mean monthly maximum and minimum temperatures as well as mean monthly rainfall.

The comparison of farmers' perceptions and the climatic records has revealed a close match between both, and provided evidence for the ability of farmers to accurately observe and recall climatic events. This proves that farmers in both study areas are aware of climate change. This ability combined with farming experience provides the basis for their various endeavors to adapt their land use to the increasing impacts of climate change.

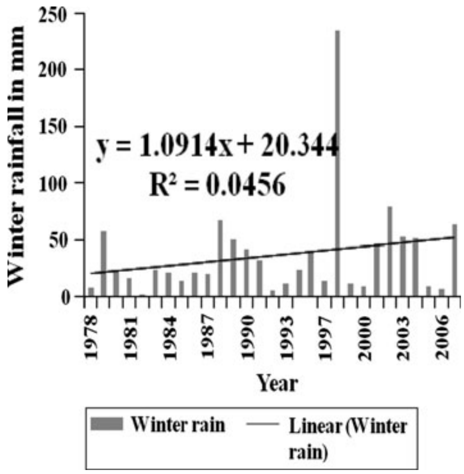



**Fig. 8** Variation of winter rainfall in Marpha in last 30 years

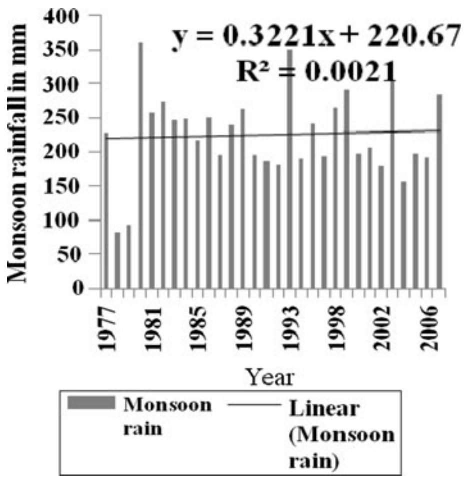



**Fig. 9** Variation of monsoon rainfall in Marpha in last 30 years

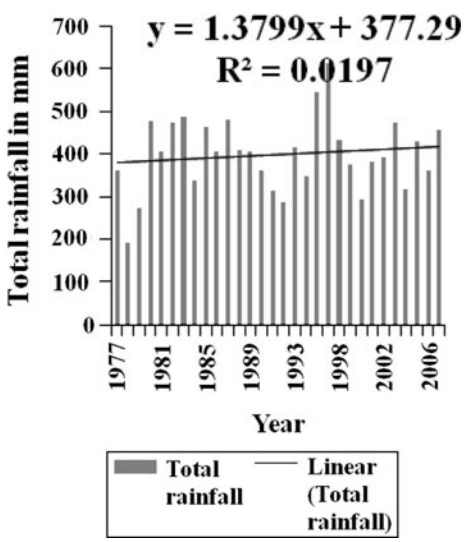



**Fig. 10** Variation of total rainfall in Marpha in last 30 years

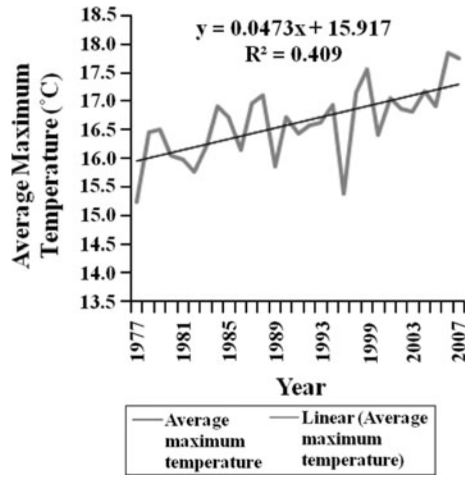



**Fig. 11** Average variation of maximum temperature in Marpha in last 30 years

## Adaptation measures undertaken by farmers

### *Lowland Nepal*

Indigenous knowledge systems provide the basis for local adaptations to climate change. An important component of such indigenous knowledge systems is the use of indicators for weather forecasting (see Box 3). Farmers in Gargatti and Bhaglapur villages, for instance, have a rich indigenous knowledge of rainfall forecasting from their long experience in rain-fed agriculture. They still make rainfall predictions for the near future and schedule farming operations accordingly. Accurate forecasts of climate 3–6 months ahead of time would allow farmers to make decisions that could more effectively reduce unfavorable impacts or that would allow them take advantage of expected favorable climate conditions (Jones et al. 2000).

Rice-based cropping systems predominate in both study areas of the Terai region, and make farmers dependent on a sufficient and reliable water supply. Untimely and decreasing rainfall is the biggest threat to rice growers. Water is more of a limitation in Gargatti village than in Bhaglapur village because in Gargatti village only 2–4% financially well-off farmers have irrigation facilities, which make them somewhat independent of the vagaries of rainfall. The other farmers practice rain-fed rice cultivation. Farmers feel that with government help to establish and manage irrigation systems, they could grow rice even in the dry period. But since the lack of irrigation facilities is further exacerbated by lacking water-conserving practices and water-harvesting technologies, fields are largely left fallow during dry seasons and dry years.

While Gargatti village is plagued by drought problems only, Bhaglapur village is facing flood problems in addition

**Table 3** Correlation between Farmers' perception of climate change and climate change in the high hill region

| Study area | Farmers' perception of climate change | Correlation with climate data | Chi square test statistics |
|---|---|---|---|
| High Hill (Muktinath, Marpha and Kunjo VDC) | Changes in temperature | Positive | Significant |
| | Changes in rainfall | Negative | Non-significant |

Chi square hypotheses were tested against $P > 0.05$ error

**Box 3** Indigenous knowledge of rainfall forecasting (source: author's interview)

Farmers in Gargatti and Bhaglapur village still believe that rain will come when the house sparrows play in the dust on the ground and when black ants come out from the hole carrying eggs and seeking high places. Similarly, when a large number of fire-flies revolve around a tree at night there will be a possibility of raining. Farmers say that when in the month of August the eastern wind stops and a western wind starts to blow, this wind will carry rain. When frogs croak, rain will follow. If there is an eastern wind in the month of November/December, clouds may form but there will be no rain. Rain may fall when in the evening the sky appears red in the east. They also share that a distant smoky halo around the sun will bring early rain and vice versa. They have also noticed that buffaloes will be happy and run here and there when it is about to rain. An elephant-trunk-shaped cloud below the rainbow also foretells heavy rain in near future

to drought due to its location in a low-lying area with high water table. Farmers report that rice production is affected by late and insufficient rainfall in some years and by flood in other years. There is no provision of crop and livestock insurance, and farmers have to endure big losses every year. To adjust to the climatic hazards of drought, flood and late rainfall, most farmers have slowly shifted from local to modern hybrid varieties: to early maturing and less water-requiring varieties in Gargatti village, and to flood tolerant varieties in Bhaglapur village. They have also changed cropping calendar, cropping sequences, and planting methods. Changes of rice varieties and of cultivation practices, however, have been carried out not only in response to a changing environment but also in response to the demands of a growing population as well as to the availability of new technology. Pest and weed infestation has increased with rising temperatures and greater incidence of drought. In order to meet this threat, farmers in both villages have increased the frequency of manual weeding and adopted chemical pest and weed control. The repeated application of agrochemicals has, however, gradually enhanced the resistance of insect pests, thus further increasing the demand for chemical use. Farmers from both villages have adopted soil conservation technologies such as zero tillage and surface seeding. Despite these measures, agricultural production is still insufficient to support the expanding families, so that farmers have started off-farm activities such as driving rickshaws, working as porters, and seeking employment either locally, e.g. in brick factories or as migrant workers in other countries. Bhaglapur village has experienced not only out-migration but also some incidences of in-migration. Migrant farmers, attracted by the abundant supply of water, have started off-season vegetable production and fish-farming activities.

Fish farming, which gives a higher return in a shorter period than rice farming, has also been adopted by resident farmers of Bhaglapur village as a response to the repeated problems of floods washing away the rice crop and of declining yields. As a result of this development, farmers' income has increased due to fish farming but at the cost of a decreasing rice plantation area. Adoption of fish farming is influenced by various factors that are presented in Table 4. Another chronically flood-prone village—Majgaon of Assam, India—has developed subsistence fishing into a viable alternative livelihood through the establishment of cooperatives, and the setting-up of production and marketing channels (ICIMOD 2009).

During periods of normal rainfall, farmers in both villages used to follow the rice–wheat or rice–mustard or rice–lentil cropping sequences. To cope with the problems of increasing drought and late rainfall as well as increasing number of days of cold waves, farmers have made changes in their cropping calendar and cropping sequences (see Tables 5 and 6). In order to cope with the effect of late rainfall, they changed the cropping sequence from rice–wheat/mustard/lentil to rice–wheat. Cold waves, on the other hand, affect the winter crops. Most farmers have, therefore, stopped planting mustard and lentil, and only a few of them still grow these crops on a limited scale.

Several modern varieties of rice have been introduced in Nepal to increase productivity, to fulfill the demand of an increasing population, and to adjust to a changing environment. Besides considering yield, farmers also consider characteristics such as drought tolerance, suitability of grains for specific purposes, and insect/pest resistance when adopting modern varieties (Joshi and Pandey 2006). In both Gargatti and Bhaglapur VDCs, farmers plant only a few local varieties. They have adopted many improved

**Table 4** Comparative advantages of rice and fish farming

| S. no | Rice farming | Fish farming |
|---|---|---|
| 1 | High labor cost and investment throughout the cropping period | Low labor cost. Initial investment is high, but in the long run profitable |
| 2 | Too much or too little rain affects rice production and causes loss | Insufficient rain will cause slow growth of fish but not a big loss |
| 3 | Heavy rain takes away paddy | Fish farming is not much affected by heavy rain |
| 4 | In rice farming, price fixing is not under farmer's control | In fish farming farmers' will fix the price themselves |
| 5 | Farmers' have to wait for long time to get payment as rice is sold on credit | Fish is sold against immediate payment and is more profitable than rice |

*Source* Field survey conducted in 2008

**Table 5** Cropping calendar in Gargatti and Bhaglapur village during normal rainfall

| Months/Crops | May → | Jun → | Oct → | Mar | Apr ► |
|---|---|---|---|---|---|
| 1.Rice | | 1$^{st}$ wk June(SS), 3$^{rd}$ wk June (T) → | 2$^{nd}$ wk Oct(H) | | |
| 2.Wheat → | 2nd wk(H) | | 3$^{rd}$-4$^{th}$ wk Oct (SS) → | → | → |
| 3.Lentil | | | 3$^{rd}$-4$^{th}$ wk Oct (SS) → | 1$^{st}$/2$^{nd}$ wk Mar (H) | |
| 4. Pea | | | 3$^{rd}$-4$^{th}$ wk Oct (SS) → | 1$^{st}$/2$^{nd}$ wk Mar (H) | |

*SS* seed sowing, *T* transplanting, *H* harvesting (*Source* Field survey conducted in 2008)

**Table 6** New cropping calendar in Gargatti and Bhaglapur village during late rainfall

| Months/Crops | May → | Jun → | Aug → | Nov → | Jan → | Apr ► |
|---|---|---|---|---|---|---|
| 1.Rice | | 1$^{st}$ wk June(SS) → | 2nd wk Aug(T) → | 2nd -3$^{rd}$ wk Nov(H) | | |
| 2.Wheat (Zero tillage) → | 2nd wk(H) | | | | 1st-2nd wk Jan(SS) → | → |

*SS* seed sowing, *T* transplanting, *H* harvesting (*Source* Field survey conducted in 2008)

Old Cropping Sequences: Rice–wheat—fallow; Rice—lentil—fallow; Rice—pea—fallow

New Cropping Sequence: Rice–wheat

varieties from India as well as some released and registered varieties from Nepal. The characteristics of local and improved varieties with respect to drought and flood tolerance, and preference for early or late rainfall are listed in Tables 7, 8 and 9.

*Upland Nepal*

Compared to Rupandehi district, Mustang district in upland Nepal displays a wider climatic variation within a smaller area. Climate change in upland Nepal, which manifests itself mainly through increasing rainfall and temperatures, seems to be more beneficial to farmers in the rain shadow and cold upland areas of upper Mustang than to farmers in lower Mustang. To cope with climate change and variability, farmers have adopted changes in agriculture or branched out into tourism.

As shown in Box 4, farmers in some villages of Mustang follow the advice of local Lamas and believe that their harvest will be good only if they do so. In some villages, however, the Lama had passed away and there is no one to fill the position. Farmers reported that as they were no longer getting information on weather forecasts and advice on their agricultural operations, harvests were getting worse year after year. They express that the traditional knowledge of Lamas should be conserved as it is of great importance for their agriculture-based livelihoods. Nyong et al. (2007) explained that farmers in the African Sahel implemented adaptation strategies based on their indigenous knowledge systems which have enabled them reduce their vulnerability to severe and frequent droughts. Although the importance of indigenous knowledge systems for adapting to the challenges of living in mountainous areas has been recognized, the potential of indigenous knowledge for adaptation to

**Table 7** Existing local rice varieties grown in Hatti Bangai and Bhaglapur VDCs

| S. no | Varieties name | Degree of drought tolerance | Degree of flood tolerance | Early/medium/late variety |
|---|---|---|---|---|
| 1 | Padheni | High | | Early |
| 2 | Anadi | Medium | Medium | Late |
| 3 | Mansara | Medium | Medium | Late |

*Source* Field survey conducted in 2008

**Table 8** Improved varieties imported from India and adopted by farmers' in Hatti Bangai and Bhaglapur VDCs

| S. no | Varieties name | Degree of drought tolerance | Degree of flood tolerance | Early/medium/late variety |
|---|---|---|---|---|
| 1 | Ram dhan | Moderate | | Early |
| 2 | Gorakhnath Gold | Moderate | Moderate | |
| 3 | Mayur | Moderate | | |
| 4 | Sarjubaun | High | | |
| 5 | Sarju-49 | Moderate | | |
| 6 | Bajigar | Moderate | Moderate | Middle |
| 7 | Motisava | Moderate | Moderate | |
| 8 | Panta-10 | Moderate | | |
| 9 | Golden mansuli | Moderate | Moderate | |
| 10 | Sundar Sabha | Moderate | Moderate | |
| 11 | Gauri | Moderate | | Late |
| 12 | Sava Mansuli | Moderate | | |
| 13 | Saba | Moderate | | |

*Source* Field survey conducted in 2008

**Table 9** Released and registered rice varieties adopted by farmers' in Hatti Bangai and Bhaglapur VDCs

| S. no | Varieties name | Degree of drought tolerance | Early/medium/late variety |
|---|---|---|---|
| 1 | Makwanpur-1 | Low | Late |
| 2 | Sabitri | Low | Late |
| 3 | Radha-7 | Low | Late |
| 4 | Radha Krishna-9 | Low | Late |
| 5 | Rampur Mansuli | Low | Medium |
| 6 | Masuli | Moderate | Late |
| 7 | Loktantra | Moderate | Medium |
| 8 | Mithila | Moderate | Late |
| 9 | Radha-4 | High | Medium |
| 10 | Barkhe 3004 | High | Late |
| 11 | Ghaiya-2 | High | Medium |
| 12 | IR-22 | | Late |
| 13 | IR-20 | | Late |
| 14 | IR-8 | | Late |
| 15 | Bharkhe-2 | | Late |
| 16 | Janaki | | Medium |
| 17 | Durga | | Medium |
| 18 | Jaya | | Medium |

*Source* Ministry of Agriculture and Cooperatives (2007)

climate change in mountains has not yet been specifically addressed by research (Regmi and Adhikari 2007).

Buckwheat is the major food of people living in the high mountainous regions of Nepal. Two species of buckwheat, sweet buckwheat (*Fagopyrum esculentum*), locally called mithe fapar, and bitter buckwheat (*Fagopyrum tataricum*), locally called tite fapar, are grown in Nepal. In lower Mustang, buckwheat is usually planted in April to June,

**Box 4** Indigenous knowledge of Lamas in Mustang (source: author's interview)

The inhabitants of Mustang or "Mustanges" are predominantly Buddhists. They strongly believe in their religious leaders or "Lamas". Farmers consult lamas before starting agricultural activities such as planting or harvesting of crops. Lamas fix the date and time of the day (morning, noon, afternoon, evening, late evening) for ploughing and give advice on the direction, which the Jhopa (hybrid between Yak and lowland cattle) should face while ploughing, and on who should be the first to start ploughing and sowing. The Lama's decision will be followed by all villagers

Farmers synchronize planting of crops in their fields to share risks. Insect pests and diseases attack crops at a specific age. If the crops are of different age then insect pests and diseases will completely destroy crops in one field and move to others. It will damage everyone's crop but when there is synchronization of crops there will be sharing of damage. Farmers' believe that when they perform farm activities according to the lama's instruction, weather and climate will favor them, there will not be the problem of pests and diseases, and the harvest will be good

and harvested in September/October. Bitter buckwheat takes 70 days and sweet buckwheat takes 90 days to mature. In past years, frost used to occur at the time of harvesting of sweet buckwheat and even 1 day of exposure to frost would damage all crops. Farmers used to harvest sweet buckwheat in a rush in order to prevent this damage. Bitter buckwheat has a longer growing period than sweet buckwheat and is thus more susceptible to frost damage. Farmers in lower Mustang, therefore, did not plant bitter buckwheat at all. But now that the occurrence of frost has been delayed by 1 month, i.e. from September to the 2nd week of October, farmers no longer need to rush the buckwheat harvest and can grow both bitter and sweet buckwheat. They are thus able to put more grain into storage. The case of corn is similar. In the past, farmers could not grow corn in the upper regions of lower Mustang and used to carry it up from lower elevations. But now, under more clement climatic conditions, farmers grow corn also in the upland areas.

Apart from cereals, farmers cultivate vegetables and fruits. The diversity of vegetables in the upper regions of Mustang district was very low in the past and residents used to bring vegetables from below. The changing climate, however, has gradually created more favorable conditions for the diversification of agriculture. Crop diversification as a potential farm-level response to climatic variability and change has been explained by Bradshaw et al. (2004). The cultivation of vegetables such as cucumber, bean, tomato, pumpkin and chili, both in the open and in greenhouses, has recently expanded into the upper regions of lower Mustang. Another innovation, peculiar to Marpha, where horticulture with apples has become popular, is to plant vegetables into the apple orchards. Changing climatic conditions in conjunction with expansion of markets have thus induced farmers to shift vegetable growing to higher altitudes and to further promote crop diversification.

Apples were introduced to Mustang in the 1960s. Apple is a perennial crop, which requires less labor and gives a higher profit than annual crops. Many farmers were thus attracted by it and converted cereal fields into apple orchards on a large scale. As of recently, however, apple production has declined in the lower reaches of lower Mustang on account of climatic changes and expanded into higher altitudes. The increasing number of rainy and foggy days has proven unfavorable for apple production in Kunjo, lower Mustang, as under the more humid conditions apple trees were infested by insects, pests and diseases, and eventually died. This has forced farmers to use chemical control, or to chop down the apple trees and go back to cereal farming. However, cereal crops may in the long run be similarly affected, and the use of chemicals may be unsustainable in the long run. Howden et al. (2007) suggested that pest, disease and weed problems due to projected climate changes should be dealt with more sustainably using integrated pest and pathogen management as well as by adopting pest and disease resistant varieties.

## Conclusion and recommendations

The research presented here provides insights into farmers' perception of and adaptation to changing climate in lowland and upland Nepal. It is apparent that Nepal is experiencing gradual changes in climate. Farmers in both lowland and upland Nepal are perceptive of climate change and possess a rich fund of indigenous knowledge relating to climate, which includes knowledge about weather forecasting. Farmers' capacity to observe and understand climate could provide the basis for a locally based monitoring system to supplement the network of weather stations, which is rather thinly spread in Nepal, especially at higher altitudes, where climate change impacts are most strongly felt.

This study indicates that farmers in both lowland and upland Nepal have been involved in farming since many generations and have thus acquired a long experience working the soil and coping with the vagaries of climate. Through their dependence on agriculture for their livelihood, they are greatly affected by climate change. The study found that farmers are capable of quickly responding to climate change, but that their adaptation measures are for the short term mainly, and may be inadequate to cope

**Table 10** Possible adaptation strategies to adapt to climate change in two different study areas

| S. no | Possible adaptation strategies for | |
|---|---|---|
| | Low-land region | Up land region |
| 1 | Development of early maturing drought and flood tolerating varieties | Diversification of crops |
| 2 | Dissemination of soil and water conservation technologies | Development of kitchen waste water harvesting technologies |
| 3 | Introducing fish farming in the flood-prone areas | Promotion of apple production from one elevation to other |
| 4 | Promotion of integrated insect, pest and disease management practices | |
| 5 | Building on indigenous knowledge to develop local specific long-term adaptation strategies | |

*Source* Field survey conducted in 2008

with the long-term effects of accelerating climate change, especially with the effects of rising temperatures and erratic rainfall patterns on agriculture.

The effects of climatic change are unevenly distributed. Research has provided evidence that upland farmers have to some extent benefitted from the changes, while lowland farmers lose out most of the times. On the other hand, because of differences in the topographical setting, dissemination and adoption of new technologies, agricultural inputs, information and innovations can be faster and easier in the accessible lowland than in the more rugged uplands.

Farmers' understanding of climate can be an important asset when it comes to adapting to climate change but is rarely taken into consideration in the design and implementation of modern mitigation and adaptation strategies in Nepal. However, farmers' local knowledge and initiatives alone cannot withstand the presumably increasing pressure of climate change impacts. Currently, climate change and adaptation issues are poorly integrated in national development plan and in sectoral policies and plans (Winrock international 2007). Adaptation options such as irrigation management and promotion of improved crop varieties are only viable if there is external support through government. Therefore, government and policy makers should support farmers to generate long-term and location-specific adaptation strategies. The statement by Fankhauser et al. (1999) that adaptation strategies may differ from situation to situation is particularly true for Nepal with its pronounced ecological and cultural diversity.

The focus should, therefore, be more on developing location specific adaptation strategies (see the summarized Table 10), encouraging sustainable farm management practices, and disseminating low cost technologies. Crop diversification should be supported in the upland region, while management of irrigation and drainage systems as well as development of rice cum fish farming systems into a profitable small enterprise business would be beneficial for farmers in the lowland region. Cheap and simple technologies such as reclaiming kitchen waste water and rain water harvesting can be easily handled by smallholder farmers. And, as in Africa, innovative micro-insurance schemes can be another tool to help Nepalese small-holder farmers to cope with climate variability and change (Patt et al. 2010). If climate change progresses in the same manner and if appropriate long-term adaptation strategies are not developed, agriculture will be at greater risk in the days to come.

**Acknowledgments** This research is supported by Norwegian government, Local Initiatives for Biodiversity Research and Development, Pokhara; Nepal Wheat Research Program, Bhairahawa; and District Agriculture Development Office, Mustang, Nepal. We would like to acknowledge Dr. S. L. Ranamukhaarachchi for his contribution in this study. Furthermore, we thank GCOE Program of University of Yamanashi and all others who have directly and indirectly helped us to successfully complete this research.

## References

Agriculture Diary (2008) Ministry of agriculture and cooperatives. Department of Agriculture, District Agriculture Development Office, Mustang

Alam M, Regmi, BR (2004) Adverse impacts of climate change on development of Nepal: integrating adaptation into policies and activities, capacity strengthening in the least developed countries (LDCs) for adaptation to climate change (CLACC). Working paper No. 3, Bangladesh Centre for advanced Studies (BCAS), Dhaka, Bangladesh

Arnell NW (1999) Climate change and global water resources. Global Environ Change 9:S31–S49

Baidya SK, Shrestha ML, Sheikh MM (2008) Trends in daily climatic extremes of temperature and precipitation in Nepal. J Hydrol Meteorol 5(1):38–51

Bradshaw B, Dolan H, Smit B (2004) Farm-level adaptation to climatic variability and change: crop diversification in the Canadian Praries. Clim Change 67(1):119–141

Chaulagain, NP (2006) Impacts of climate change on water resources of Nepal, the physical and socioeconomic dimensions. Unpublished master's thesis, University of Flensburg, Germany

Dey B, Kumar O (1983) Himalayan winter snow cover area and summer monsoon rainfall over India. J Geophys Res 88(C9):5471–5474

Fankhauser S, Smith JB, Tol RSJ (1999) Weathering climate change: some simple rules to guide adaptation decisions. Ecol Econ 30(1):67–78

Howden SM, Soussana J-F, Tubiello FN, Chhetri N, Dunlop M, Meinke H (2007) Adapting agriculture to climate change. PNAS 104(50):19691–19696

Huq S, Rahman A, Konate M, Sokona Y, Reid H (2003) Mainstreaming adaptation to climate change in least developed countries (LDCS). Retrieved on 16th April 2010, available online at http://www.un.org/special-rep/ohrlls/ldc/LDCsreport.pdf

Ichiyanagi K, Yamanaka MD, Muraji Y, Vaidya BK (2007) Precipitation in Nepal between 1987 and 1996. Int J Climatol 27(13):1753–1762

International Centre for Integrated Mountain Development (ICIMOD) (2009) Local responses to too much and too little water in the greater Himalayan region. ISBN 978 92 9115 129 5 (electronic version)

IPCC (2007) Summary for policymakers of the synthesis report of the IPCC fourth assessment report; Draft copy

Jones JW, Hansen JW, Royce FS, Messina CD (2000) Potential benefits of climate forecasting to agriculture. Agric Ecosyst Environ 82(1–3):169–184

Joshi GR, Pandey S (2006) Farmers perceptions and adoption of modern rice varieties in Nepal. Q J Int Agric 45(2):171–186

Malla G (2008) Climate change and its impact on Nepalese agriculture. J Agric Environ 9:62–71

Ministry of Agriculture and Cooperatives (2007) Statistical information on Nepalese agriculture 2006/2007, government of Nepal, ministry of agriculture and cooperatives, agri-business promotion and statistics division. Sigha Durbar, Kathmandu

Ministry of Population and Environment (2004) Initial national communication to the conference of the parties of the United Nations Framework convention on climate change, ministry of population and environment. Singha Durbar, Kathmandu

National Geographic Information Infrastructure Programme (NGIIP) (2010) Government of Nepal, Ministry of Land Reform and Management, Survey Department Complex, Min Bhawan, Baneshwor, Kathmandu

Nepal Trust for Nature Conservation (NTNC) (2008) Sustainable development plan of Mustang. NTNC/GoN/UNEP, Kathmandu

Nyong A, Adesina F, Elasha BO (2007) The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitig Adapt Strat Glob Change 12(5):787–797

Patt A, Pablo S, Hess U (2010) How do small-holder farmers understand insurance, and how much do they want it? Evidence from Africa. Global Environ Change 20:153–161

Regmi B, Adhikari A (2007) Human Development Report 2007/2008

Regmi BR, Thapa L, Sharma GB, Khadka S (2008) Climate change risk, vulnerability and adaptation strategies at community level, local initiatives for biodiversity research and development (LI-BIRD)

Salinger MJ, Stigter CJ, Das HP (2000) Agrometeorological adaptation strategies to increasing climate variability and climate change. Agric For Meteorol 103(1–2):167–184

Shrestha AB, Wake CP, Mayewski PA, Dibb JE (1999) Maximum temperature trends in the Himalaya and its vicinity: an analysis based on temperature records from Nepal for the period 1971–1994. J Clim 12(9):2775–2786

Shrestha AB, Wake CP, Mayewski PA, Dibb JE (2000) Precipitation fluctuations in the Nepal Himalaya and its vicinity and relationship with some large scale climatological parameters. Int J Climatol 20(3):317–327

Statistical Year Book of Nepal (2007) Government of Nepal, national planning commission secretariat, central bureau of statistics, ramshah path. Thapathali, Kathmandu

Winrock International (2007) Nepal country environmental analysis: part 1: environmental sector review; revised draft copy. Winrock International, Kathmandu