Indian Journal of Traditional Knowledge
Vol. 12 (4), October 2013, pp. 585-595

People's local knowledge of climate change in the Middle-Hills of Nepal

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Received 26.03.13, revised 31.07.13

In the Pokhare Khola watershed of Dhading district in the Middle-Hills of Nepal, almost all farmers perceived that summers are becoming hotter and longer while 81% of interviewed farmers responded that winters are becoming warmer and shorter. During the period of 1978 - 2008, the overall temperature has risen about 0.2^0C. Summer temperatures have fluctuated, but mean winter temperature has generally increased over this time. Meteorological data corroborates the farmers' perceptions. Annual and monsoon season rainfall was highly variable over the last 30 years, with the lowest mean monsoon rainfall (212 mm) in 1990 and the highest (646 mm) in 1999. Farmers observed that duration of the rainy season has decreased from four to two months. The reduction in wheat (*Triticum aestivum* L.) production due to shorter winters and insufficient post-monsoon rain was evident. Changes in annual rainfall pattern and resulting water shortages also lowered the millet [*Eleusine coracana* (L.) Gaertn.] production. The appearance of advancing phenological development in trees (flowering 10 - 25 days earlier), and earlier ripening of some crops were often cited as impacts of change in climate. Household survey and interview, group discussions, participatory rural appraisal (PRA) tools, viz. trend analysis, and problem ranking were conducted to gather the observations and experiences on climate change perceived by local people. Moreover, local meteorological data was analyzed to see the trend of changes in rainfall and temperature.

Keywords: Erratic rainfall, Impact, Meteorology, Phenology, Production, Monsoon

IPC Int. Cl.[8]: G01W 1/14, G01S 13/95, A01H 3/00, G08, G01L 5/00, E04H 9/16

Now a days, due to global warming, climate is changing rapidly, with adverse effects including excessive and uneven rainfall, flood, longer droughts, landslides and cyclones, with impacts on forests, agriculture, environment and human lives. Climate change[i] is therefore considered one of the main threats to the earth's environment and to humankind. Scientists generally concur that global climate change is occurring, that it is caused by human activities, and that it has wide ranging impacts at different scales[1]. In Asia, climate change is affecting many sectors. In agriculture, crop yields are expected to decline by 5 - 30% by the 2050s due to rising temperatures in the Himalayas, and this will lead to increased severe food insecurity at a local scale, including in Nepal[1,2]. Over the next 20 yrs a temperature increase of 0.2^0C per decade is expected[1.] In Nepal warming after the mid-1970s seems to be consistent and continuous, with an average annual temperature increase between 1977 and 1994 of 0.06^0C [1,3]. Warming in the Himalayas has been much higher than the global average of 0.74^0C over the last 100 yrs. Recent studies have shown that Nepal's temperature is rising at a particularly high rate, about 0.41ºC per decade[4], and that the mean annual temperature is expected to increase by 2.9^0C by the middle of the 21st century[5]. In reference to climate change at local scale, therefore, our study conducted in Nepal is relevant and important[1,6].

Five physiographic zones are recognized in Nepal. The Middle Mountains, or "Middle-Hills" (200–3000 masl), form the central belt, characterized as a network of ridges and valleys with less than 5% flat area. This zone occupies about 30% of Nepal's total land area, supports over 30% of the country's forests, and hosts about 44% of its population[7]. The close interrelationship between crops, livestock and forests fulfills the livelihood needs of resource-poor farmers and maintains ecological stability. This relationship is paramount to

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the ‘Nepalese Hill Farming System’, which offers the greatest diversity of species and ecosystems in the Middle-Hills and among the five physiographic zones of Nepal[8,9]. However, in Nepal climate warming has been much more pronounced in the Middle-Hills and the high Himalayas than in the Terai and Siwalik regions[4]. The Middle-Hills region is also where population density is highest and, consequently, where vulnerability to climate change is most pronounced. Notably, poor, marginalized and disadvantaged people are less resilient to climate change[10,11]. Hence, this study, assessing the observations, perceptions and knowledge of climate change and its effects amongst the people of Nepal’s Middle-Hills, is particularly relevant.

Furthermore, since farmers are the managers and ultimate users of a region’s agro-biodiversity and resources, farmers’ involvement in assessing climate change and its impacts is vital. Several studies have been carried out to enable a better understanding of climate change and its biophysical and social effects[12]. Farmers’ experiences and observations of climate change, including - increased temperatures, and changing rainfall and wind patterns, as well as year by year phenological changes, and changes in vegetation structure and patterns are also critically important in considering adaptation to climate change[5]. Integrating the “civic science” of farmers’ perceptions with “formal science” assessments in addressing climate change, impacts will provide the optimum tools to enable development of climate-resilient livelihoods[12]. “Perception” is the process of receiving information from the surrounding environment and transforming it into physiological awareness[13]. People’s knowledge, experiences, culture and other social factors are reflected in an actor’s behavior about a particular situation. Moreover, scientific study on climate change could be expensive and time consuming for rural people and their livelihoods that encourage local knowledge to be taken into consideration to predict, prevent catastrophes and adapt to climate change. Even though this varies with the individual’s past experiences, observations, and present attitudes, needs, values, moods, expectations and social circumstances[14,15].

While the importance of local knowledge has been recognized in the design and implementation of sustainable development projects, little has been done to incorporate this recognition into formal climate change situations. Climate change cannot be divorced from sustainable land and resource management as sustainable management is a crucial dimension of climate change adaptation and impacts and may be the most effective way to frame the mitigation question[16]. Incorporating local knowledge into climate change policies can lead to the development of effective, cost-effective, participatory, and sustainable adaptation strategies[17]. Nevertheless, incorporating local and indigenous knowledge into climate change concerns should not take the place of modern scientific knowledge. Indigenous knowledge should complement, rather than compete with global knowledge systems[18]. Therefore, this study aims to explore local perceptions and experiences of climate changes in conjunction with meteorological data and assessments of climate change impacts on physical and biological systems. Collectively, this knowledge represents a dynamic information base for the scientific community and for policy makers to develop strategies for adaptation to constantly changing and varying climate that will be supported by the general population.

Methodology

The study site

Our study site is located about 60 km west of the Kathmandu, between $27^{0}46'28''$ N and $27^{0}48'06''$ N latitude and $84^{0}53'32''$ E and $84^{0}55'11''$ E longitude[19]. The Pokhare Khola watershed encompasses Pida village of Dhading district in the Central Middle-Hills of Nepal, extending from the valley at 400 m bottom to 800 m on the hill slopes; this area constitutes the ‘middle mountain farming system’ (Fig. 1). The climate is sub-tropical with mean monthly temperatures ranging from 13 to 27^{0}C, mean monthly rainfall from 7 to 341 mm, and average annual rainfall of nearly 1700 mm, more than 80% of which occurs from June to September, as recorded at the nearest meteorological station of Dhunibeshi, 30 km away. There are three distinct seasons: rainy (wet); winter; and hot or humid summer[20]. Cambisols and Luvisols make up the dominant soils in the study area and the terrain is steeply sloping[21].

The major land uses in the study area are forestry and agriculture. Forest land covers about 55% of the watershed area and is an integral part of the farming system. Two main cultivation systems are *khet*, covering about 10% of the watershed area, and *bari*, covering 35%. The *khet* land consists of bounded and leveled terraces, which are generally located near streams and away from households.

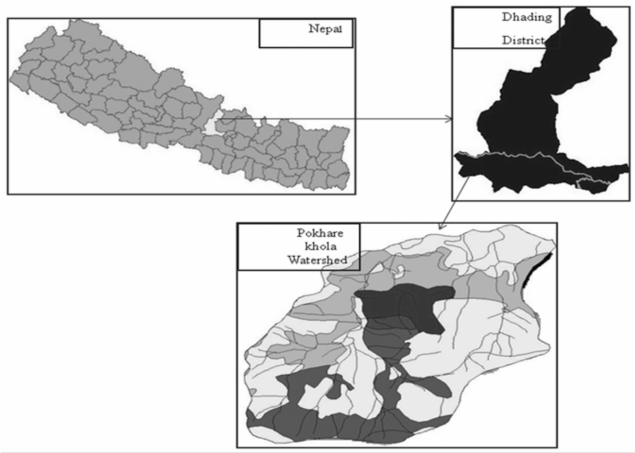

Fig. 1—Location map of Pokhare Khola watershed of Middle-Hill of Dhading district in Nepal

Source: Tiwari (2008)[20]

Bari land includes *bari* (around the homestead areas) and *pakhabari* (separate plots up to 30 minutes' walking distance)[21]. This farming system includes trees, food crops and livestock. Tree branches and grasses provide livestock fodder and bedding. The system also yields compost materials to enhance soil fertility, and the trees provide fuel wood and timber for household use. Farmers cultivate cereal and vegetables crops in their *bari* and *khet* lands. *Khet* is the most valuable land, as it yields two major cereal crops–rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) – annually with irrigation, as well as other crops such as maize (*Zea mays* subsp. *mays* syn. *Zea maiz* Vell.) and millet [*Eleusine coracana* (L.) Gaertn.]. *Bari* lands consist of outward sloping, rain fed terraces in which maize and/or millet are mainly grown. The *bari* lands have also been used intensively to produce several types of seasonal vegetables, including cauliflower (*Brassica oleracea* L.), beans (*Phaseolus vulgaris* L.), bitter gourds (*Momordica charantia* L.), pumpkins (*Cucurbita pepo* L.), and brinjal, or eggplant (*Solanum melongena* L.), for domestic and commercial use year-round. *Kharbari* lands are set aside for grass production, for roofing thatch and livestock feed[22].

Household survey and interview

A survey was conducted, stratified by villages at various altitudes (all over 400 m and six at 600 m and higher). Eight villages in Wards 2 and 3 in the Pokhare Khola watershed were selected, with random sampling of farm households within villages. A total of 148 farm households were selected, from 340 households. The head of the selected households (assumed to be the decision-maker in farming) or their spouse was interviewed using both structured and semi-structured questions. Sample households of each village were selected proportionately according to the number of total households, with information supplied by Village Development Committee (VDC) offices. Two trained enumerators conducted these personal interviews. Responses were recorded for questions on climate change, its impacts on agro-biodiversity, observations of changes in regular weather conditions, and changes in physical features. Moreover, a total of 40 interviews of which five from each village were carried out by asking closed and open ended questions to get in depth information with explanation on farmers' perceptions toward their comments. Since these interviews were part of an exploratory process, the sample was selected and interviewed from different villages based on snow balling techniques and respondents who were not considered for survey.

Group discussions

As well as personal interviews, group discussions were also held at 6 villages. The composition of the groups varied from 8 to 10 participants. Two groups were composed of only male, two groups were composed of only female and two others were composed of both male and female. The purpose of these group discussions was to focus on group perceptions of changing climate, particularly temperature increases, rainfall patterns, positive or negative impacts and changes in natural phenomena, and utilization and management patterns for crops, trees and livestock as affected by adverse climate.

Participatory rural appraisal (PRA)

Two PRA tools, viz. trend analysis of climate and farming, and problem ranking were used. Trend analysis is a visual representation which presented perceived trends in climate change, production, and other ecological and biophysical changes over the time since 1982-83, shown by different symbols. In the problem ranking tool, a given problem or impact was compared with other identified problems (pair wise), one after another, and after all problems have been systematically compared the sum scores for each problem are listed and the problems ranked from the most important problem (highest ranked) to the least important. To assist in our assessments, meteorological data obtained from nearest station, Dhunibeshi (30 km away), was synthesized and analyzed.

Results

Climate change and variability

Although about 60% of respondents of interviewees did not know the term “climate change”, but they could understand the concept, recognizing changes of temperature and rainfall and how this change has impacted their lives. The majority (84%) of the farmers interviewed perceived that temperatures have increased, while around 12% were uncertain and 2.7% perceived that temperatures have remained constant. Almost all the farmers interviewed perceived that summers are becoming hotter, and 81% responded that winters are becoming warmer than in the past.

The winter season in the region occurs from December to February, the pre-monsoon season from March to May, monsoon from June to September and post-monsoon falls in October to February. Analysis of 30 yrs of meteorological data showed a trend of increasing mean annual temperature of 1978 to 2008. During this 30-year period, temperatures have risen a total of around 0.2°C, with a maximum average temperature of 22.3°C in 1999 and lowest average temperature of 20.3°C in 1983 (Fig. 2). However, a nearly horizontal trend line for summers showed that there was no regular trend of temperature increase or decrease over these years; average summer temperatures fluctuated at times with a maximum of 24.9°C in 1999 and minimum of 21°C in 1983. However, the mean winter temperature in the study area seems to be on an increasing trend. Over the last 30 years, 1999 and 2006 mean winter temperatures were 16.2°C and 16.0°C respectively, whereas a minimum mean temperature was 13.0°C in 1983 (Fig. 3).

According to meteorological records, rainfall has fluctuated and generally decreased in the area over the last 30 yrs. Annual, monsoon and post-monsoon mean rainfall was found to be lower than perceived by the most of the farmers (Fig. 4). About 97% of the respondents observed greater unpredictability in rainfall over the past 30 yrs. Key informants also shared their observation that in recent years there was less or no rainfall in the monsoon season.

Precipitation records for the area showed no fixed trend; rainfall was erratic, but did not decrease during the monsoon season, or in overall annual rainfall

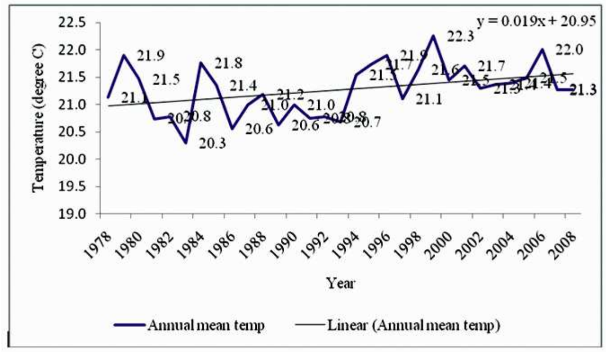

Fig. 2—Trend of mean annual temperature during 1978 – 2008

Source: Meteorological data (obtained from Dhunibesi station nearest to the study site) collection 2010

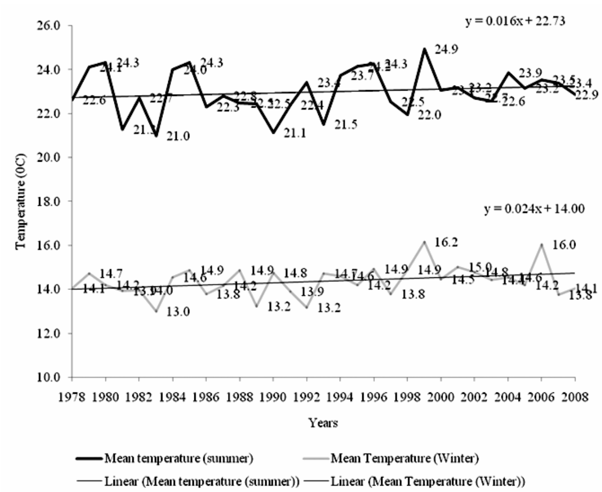

Fig. 3—Trend of mean summer and winter temperature during 1978 – 2008

Source: Meteorological data (data obtained from Dhunibesi station nearest to the study site) collection 2010

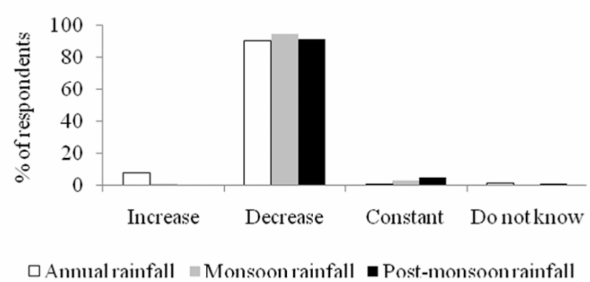

Fig. 4—Farmers’ perceptions on annual, monsoon and post-monsoon mean rainfall pattern

Source: Field data collection *Summer/Pre-monsoon: March to May; Winter: December to February

Monsoon: June to September; Post-monsoon: October to February. Source: Shrestha et al. 1999[3] between 1978 and 2008. Since, the maximum rainfall usually occurs in the monsoon season, and this amount supposedly represents the major portion of annual mean rainfall, the monsoon rainfall and yearly rainfall tend to mirror each other. The highest mean monsoon rainfall over the past 30 yrs was in 1999, at 646 mm, and the lowest, in 1990, at 212 mm. There was a trend of decreasing post-monsoon rainfall over these years, with highest, in 1999, at 118 mm. On the other hand, pre-monsoon rainfall fluctuated, although there was an increasing trend to some extent, with the lowest at 28 mm in 1996 and the highest in 1998 at 130 mm (Figs. 5 & 6).

Perceived impacts of climate change

Regarding weather conditions, the majority of farmers interviewed experienced longer summers, shorter winters, and shorter but heavy rainfalls on an annual basis, with a delay of monsoon breakout and a trend towards changing seasonal patterns. Most of the farmers had observed an earlier end to the monsoon season over the past few years, and, in particular, a decrease in the number of rainy days in winter. There was no strong evidence of hailstorms or strong wind occurring with greater frequency (Table 1).

Farmers have faced a drying up of water sources – springs, streams, and wells – and an overall decrease in soil moisture. There was no notable occurrence of flooding and landslides, although half of the respondents perceived soil erosion caused by exceptionally heavy rainfall (Table 1, Fig. 7).

Many farmers reported an increase in impacts on livestock, and increased outbreaks of pest and diseases in agricultural crops (e. g. pest attacks of lichi (*Litchi chinensis* Sonn.) and invasion of new plants and weeds, with grasslands in a critical condition, due to the changes in weather patterns. They observed invasive species like *nilgandhe* (*Ageratum* spp.), which is not edible for livestock, *kalo banmara* (*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.), and other local weeds *Gandhe Jhar* [*Ageratum conyzoides* (L.) L.] and these were considered as a major cause of reduction of cereal crops like rice and maize, and of vegetable production (Table 1, Fig. 8). New animal diseases were observed mainly in goat and chicken. Farmers also revealed that the different crops had changed in their fruiting and ripening times. For example, maize (*Zea mays* subsp. *mays* syn. *Zea maiz* Vell.) and rice (*Oryza sativa* L.) matured 10-20 days earlier. Flowering of different fruit trees like

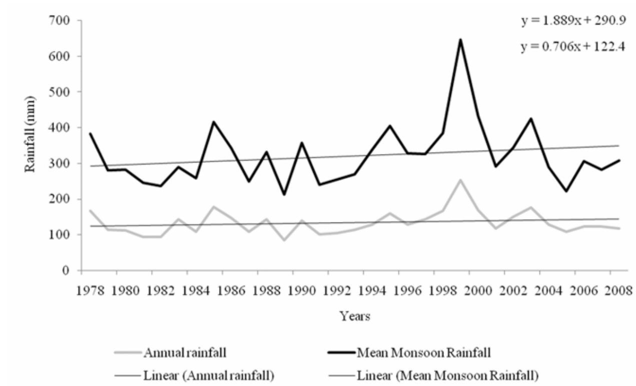

Fig. 5—Trend of mean monsoon and annual rainfall during 1978–2008

Source: Meteorological data (data obtained from Dhunibesi station nearest to the study site)

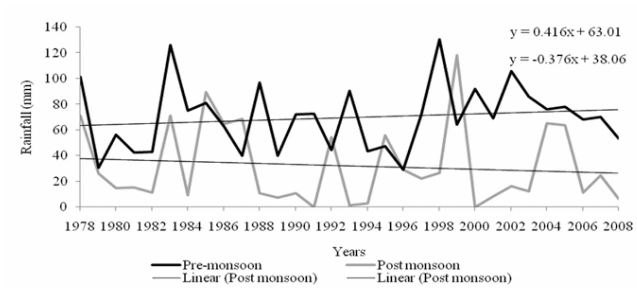

Fig. 6—Trend of rainfall (pre-monsoon, post -monsoon) during 1978–2008

Source: Secondary data (data obtained from Dhunibesi station nearest to the study site) *Summer/Pre-monsoon: March to May;

Post-monsoon: October to February. Source: Shrestha et al. 1999[3]

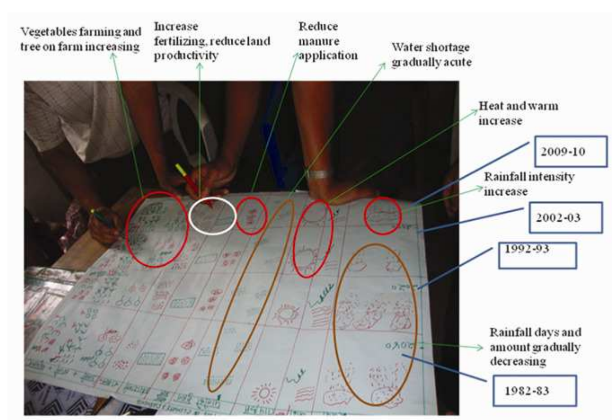

Fig. 7—Trend analysis of climate change and farming showing various changes of climate and farming

a: The trend from year 2040 (Nepali)/1982-83 to year 2067 (Nepali)/2009 -10 vertically arranged at left side of the sheet.

Table 1—Farmers' perceptions of the impacts of climate change on different areas of ecosystems

Particulars	Responses			
Major area of impact	Yes (%)	No (%)	Constant (%)	Do not know (%)
Regular weather phenomena				
Warm days increase/Longer summer	98	1	0	1
Shorter winter	78	16	4	2
Shorter but heavy rainfall	75	3	20	2
Rainy days in winter decrease	85	2	8	5
Delay of monsoon break out	69	31	0	0
Delay of monsoon break off	30	61	7	2
Strong wind increase	11	76	3	10
Hail storm increase	16	67	14	3
Physical changes				
Flooding in your field	1	98	0	1
Water spring/availability decrease	99	1	0	0
Soil moisture decrease	93	7	0	0
Landslides increase	2	98	0	0
Soil erosion increase	48	51	0	1
Biological changes				
Leaf fall, flowering and fruiting time change	59	36	0	5
Crop fruiting and ripening time change	65	32	0	3
Invasive plants and weeds seen in crops	73	26	0	1
New diseases, pests, insects in trees	32	67	0	1
New diseases, pests, insects in crops	93	7	0	0
New diseases in livestock	52	47	0	1
Grass shortage	62	33	5	0

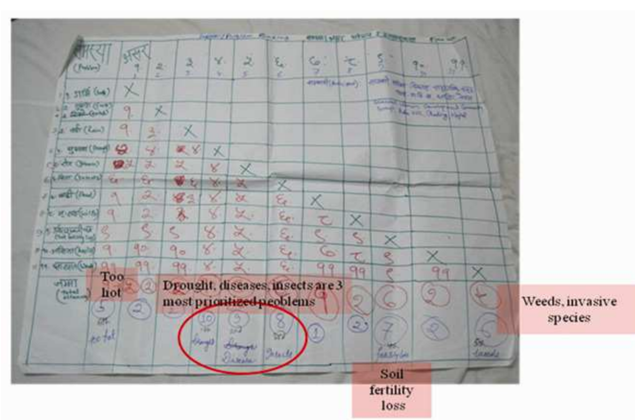

Fig. 8—Problem ranking by women group

Source: Field data collection (PRA)

peach (*Prunus persica* (L.) Batsch. syn. *Amygdalus persica* L.), guava (*Psidium guajava* L.), and mango (*Mangifera indica* L.) and leaf flushing of saal (*Shorea robusta* Gaertn.) was observed to be earlier by 10 - 25 days as compared to the past (Table 1; KI).

Discussion

Climate change and variability

Farmers in the study area might not understand the concept of the terms "global warming" or "climate change", but their understanding of the trend of temperatures increasing is very clear. They were well aware, from their long experience with the realities of the local environment, that the climate has changed a fact which is also reflected in local knowledge from other regions[23]. Farmers have observed an increase in annual temperature and a reduction in annual rainfall, with greater unpredictability in comparison to 30 years ago. The summers are getting hotter and the winters are becoming warmer. A similar result was also observed by Chapagain *et al.* (2009)[14], wherein local communities still appear to be unaware of the term "climate change," or of such a trend globally, but they well understand overall changes in temperature and rainfall over time.

The farmers' observations, except for the hotter intensity of temperatures in summer, corroborated with meteorological data that showed an increase in average annual temperatures of 0.2^0C from 1978 to 2008, especially in winter (rather than in summer). Our results agree with those of Gyampoh *et al.* (2007)[24] from rural Ghana, where farmers' perceptions were corroborated by a meteorological recording of a gradual rise in average temperature of 1.3°C between 1961 and 2006. In general, farmers' thoughts and experiences are in congruence with scientific studies (IPCC 2007)[1]. They also match with the studies conducted by Kansakar *et al.* (2004)[4] and Shrestha *et al.* (2000)[25] where an estimated rate of temperature increase of 0.41^0C per decade was predicted, based on meteorological data in Nepal.

The stable levels of annual rainfall over last 30 yrs, but with decreased post-monsoon rainfall, increased pre-monsoon rainfall, and a tendency of greater fluctuations in rainfall (i.e. higher intensity of rains but fewer rainy days and unusual rain patterns) were evident from meteorological data. Monsoon rains used to be of lower intensity and quantity than more recently. Farmers' observations were not reflected in meteorological data on rainfall patterns, but meteorological data from 1978 to 2008 supports local perceptions of post monsoon rainfall change. In some cases, local people's observations may be inconsistent with scientific findings[14]. For an instance, farmers' estimations of the intensity of rain and the number of rainy days in May 1990 were not supported by 20 yrs of daily rainfall data collected in Lumle station in Nepal[26]. However, in our study, erratic rainfall events with no decrease in the total amount of monsoon rainfall were also experienced over the entire country of Nepal, based on rainfall data of 1971 - 2005[27].

Impacts on regular weather condition and production

Weather pertains to atmospheric conditions at the surface, over a timescale from minutes to weeks, and has an important impact on agriculture[28]. Like other studies (e.g. Gyampoh *et al.* 2009)[23] our study documented that farmers who live close to natural resources often observe and feel the effects of decreased rainfall, increased air temperature and sunshine intensity, and seasonal changes in rainfall patterns; they monitor the activities around them and are the first to identify and adapt to any changes. Climate change causes disruption in normal weather patterns, changing the intensity and duration of the monsoon, summer and winter seasons. Within the past few decades, rainy days have decreased annually in the study area from four months to nearly two months, with delays in the monsoon breakout and early monsoon breakoff over the years and rain days has decreased in winter as well, while the intensity per rainfall period has increased. These overall rainfall patterns have resulted in a lowering of the water table, and consequent water scarcity for irrigation. Two major challenges – timing changes in rain-fed rice cultivation and irrigation problems with drying up the water sources – have been experienced which ultimately result in a reduction in yield and production of key crops such as rice, maize. Further, wheat (*Triticum aestivum* L.) production has decreased in the area owing to the shorter winter and insufficient post-monsoon (winter) rain. Changes in overall rainfall pattern and water shortages have also lowered millet [*Eleusine coracana* (L.) Gaertn.] production. Farmers are no longer able to grow barley (*Hordeum vulgare* L.), which they formerly grew, because of decreased rainfall. Thus, unpredictable rainfall, droughts and water scarcity are increasing in terms of both magnitude and frequency in Nepal, and this, in turn, is resulting in a reduction of agricultural productivity and loss of forests[29]. Notably, research by Chapagain *et al.* (2009)[14] showed a slightly different scenario – that rice and other summer crops have been less impacted because of often receiving irrigation during their growing season, whereas by contrast, winter crops such as wheat, which totally relies on winter rainfall, were more susceptible to the changes in rainfall patterns especially the decrease in post-monsoon rainfall. The IPCC (2007a)[30] concurred that higher temperature is also the reason for reduction in cereal (e.g. rice, wheat) production especially in South Asian countries. Although climatic parameters like rainfall and temperature strongly affect the growth and productivity of wheat, principally rains had favorable impacts on the wheat yield at all levels of temperature rise[27, 31]. The actual yield of wheat showed increased output in the Western region of Nepal with rise in temperature, but a decline in other regions[32].

Potential impacts on physical features and risks for local people

Water shortage has been identified as a key problem of recent years. Participants perceived that insufficient rain, unusual precipitation patterns, and increased temperatures cause drought. In the study area, drying up of wells, rivers, springs, ponds and lakes was found to be severe during the dry and hot season. If this trend continues, many biological and human systems dependent on sufficient available water will face challenges in the future as a consequence of drought and water shortage. Therefore, according to our group discussion and interviews, the farmers were forced to carry out mal-adaptive practices such as using machines to pump out and transport water from natural springs and groundwater Sources in order to meet their daily water requirements for household and farming activities. Drought and drying up of springs/rivers was identified as a climate change related risk in the entire Dhading district and elsewhere in Nepal, both from local people's perceptions and in scientific research[33]. Our informants also reported that agricultural ecosystems including *khet*, *bari* and *kharbari* in the study area are in critical condition, since low rainfall has reduced groundwater recharge and erratic rainfall events have accelerated runoff and caused loss of topsoil from *bari* and *khet* lands. To control the increasing diseases and pest attacks in crops, increased application of pesticides and intensive fertilizing has been required, further decreasing land productivity for the long term (Fig. 8).

There was no flooding or landslides in this watershed area within Pida VDC. However, SAGUN (2009)[33] presented the opposite result for the entire Dhading district; increased flooding and landslides were identified by farmers as two major climate-related hazards, whereas farmers participating in the same study did not perceive landslidse as an impact of climate change in Barida district.

Impacts on agro-biodiversity (vegetation and farming)

As temperature increases, cropping patterns as well as vector-born diseases and pests of crops, trees, humans and livestock can be expected to shift towards higher ecozones. Global climate change impacts can be tracked by biological indicators such as phenology of particular species[34]. As in other studies is the participants in our study noted signs of advancing phenological changes in trees, such as timing of leaf fall, flowering and budding, which they thought to be good indicators and results of climate change in the region. Flowering of different tree species such peach, guava, and mango, and leaf flushing of *saal* were observed to be earlier than in the past. Our participants in both interviews and group discussions noted that the ripening and harvesting of some crops had changed by as much as 10 - 20 days earlier, an observation also in agreement with the study of Sharma &Tsering (2009)[5] where these phonological changes were similarly reported as indicators. Throughout China, phonological development of many species has recently changed to as much as 2 - 4 days earlier than in the 1980s[35]. Thus, traditionally generated knowledge, wisdom, and experiences from generation to generation help in assessing and understanding climate variability due to their close proximity to natural resources and understanding local signals of temporal and seasonal change[23].

Changes in temperature and rainfall have resulted in more favorable environments for certain pests, diseases and invasive species to emerge, spread and encroach on agriculture. Diseases and insect pests and infestations in rice, maize, mustard and vegetables, mainly tomatoes, were ranked by farmers as the second and third main risks of climate change, were seen to decrease production significantly (Fig. 8). Most farmers were abandoning production of potatoes due to pests. Several new pests had appeared, as another major problem. Similar observations were made by Dahal (2006)[36] in Manang district, Nepal, and these perceptions are in agreement with a study in developing countries[37].

Although few studies on the spread of invasive species have been carried out, farmers have already experienced the emergence of invasive species they have never before seen. Weeds and other invasive species are spreading very fast, harming livestock in various ways and damaging agriculture crops. The emergence of these new invasive species links with increased temperatures as observed by the farmers participating in our study, and as documented by Sagun (2009)[33] in Dhading, Rasuwa and Barida districts of Nepal.

Kharbari is well known for grass production, but has now (Table 1) converted to barren wasteland due to prolonged drought. Moreover, *kharbari* is basically owned by rich farmers with larger area (> 1 ha) of farms[22]. Other farms also face heavy problems from grass shortage. Deforestation due to climate change and anthropogenic reasons appeared as a common problem in Nepal. Farmers, therefore, were prohibited from collecting fodder from forests, and hence, livestock production (mainly cattle and buffaloes) has been reduced due to the grass and fodder shortage. Farmers in our study perceived that, along with increased unpredictability in rainfall and intensity of climate hazards, intensive use of "improved" crop varieties had disrupted rain fed agricultural systems and caused loss of local crop varieties. Upreti & Upreti (2002)[38] also cited loss of agro-biodiversity due also to several factors such modern intensive cropping, population increase, etc. in six districts (except Dhading) in Nepal. This study observed the declination of genetic diversity, a problem which definitely needs further study.

Traditional significance of study to the farmers/ researchers/ society and some constructive recommendations

There is a wealth of local knowledge based on predicting weather and climate. A study of weather knowledge in Middle–Hill of Nepal reveals the wealth of knowledge that farmers possess. These farmers have developed intricate systems of gathering, prediction, interpretation and decision-making in relation to changing climate with impacts in different fields of dynamic ecosystems. To a very great extent, these systems of climate forecasts will be very helpful to the farmers in knowing the whole scenario and managing their vulnerability. Hence, farmers are known to make decisions on cropping patterns of cereal and vegetables crops based on local perceptions of climate, and decisions on planting dates based on complex cultural models of changed weather[39]. Obviously gathering and documentation of this scientific and indigenous knowledge explored by researchers, is vital for development practitioners and society, as if policy makers can make plan in order for adaptation strategies and providing extension and other services to such primary stakeholders who are at risk. We, as researchers, have responsibilities to find solutions coping with the environmental impacts, which include the development of monitoring systems with the changing environmental conditions. But most important, we wish to help local communities by promoting knowledge and new approaches that contribute to sustainable solutions in agriculture and use of resources.

Conclusion

Sometimes, people's observations and perceptions of climate change and related impacts vary. While the farmers may not have a full explanation of the reasons for what they are observing and experiencing, they can nevertheless help in designing adaptation strategies for climate change and its diverse impacts. Furthermore, local knowledge can reduce our sole reliance on climate change experts, and in many cases, can challenge or correct their analysis and interpretation, particularly at local scales. In this context, enhancing our understanding of climate change must combine the objectives, empirical information and people's observations, experiences and perceptions[18].

Farmer's observations are agreement with meteorological data regarding climatic variability. This can be sum up with farmers' observations and climatic data analysis that mean annual temperature is rising, winter is getting warmer and summer remained constant in temperature change and post-monsoon rainfall decreases with compared to 30 years back. However, farmers' perceptions do not coincide with the meteorological data in the point of annual and monsoon rainfall decrease. In general, farmers' thoughts, experiences on temperature changes support the scientific studies. Longer summer, shorter winter and shorter monsoon with erratic rainfall (few rainy days with heavy rain) have experienced with compared to last 30 yrs.

The impacts on weather, physical features, vegetation and farming were documented in this study. Drying of wells, rivers, springs, ponds and lakes was found to be severe during the dry and hot season, resulting in acute droughts in the area. Water scarcity for irrigation has decreased production of key crops such as rice and maize, as well as reduction of wheat and millet production due to insufficient post-monsoon rains, shorter winters and overall fluctuations in rainfall. Present conversion of *kharbari* to barren wasteland due to prolonged droughts has resulted in grass shortage and consequent reduction of big livestock production. The occurrence of exceptionally heavy rainfall events has caused topsoil erosion from *bari* and *khet* lands resulting in soil loss and reduction of soil fertility. The resulting increased application of fertilizers and pesticides against infestations of pests, insects and diseases, and decreased manure applications because of declines in production of big livestock, has ultimate resulting in a notable decline in land productivity over the long term.

Indicators of climate change were readily evident to our participants. Phenological changes (earlier leaf fall, earlier flowering of certain plants), emergence and spread of invasive species, pest infestation and spread of diseases affecting agricultural crops and trees in recent years are all important signals of changes in seasons and timing of weather events that are well understood in traditional knowledge systems.

Farmers' observations and perceptions of climate change and its impact correspond with findings of some scientific studies in the field. As the changes in natural ecosystems relating to climate change are dynamic, complex, and unpredictable, collection and interpretation of empirical facts alone cannot allow complete comprehension of the knowledge of the field. Therefore, meteorological data and objective scientific analysis must be combined with farmers' experiences and perceptions, which will ultimately help in understanding of the climate change and how people can adapt to it and mitigate its effects.

Acknowledgement

Authors are very greatly indebted Pida VDC community and enumerators, and local guide for their valuable time, co-operation during data collection in the field.

References

1 IPCC, Intergovernmental Panel on Climate Change; Climate change 2007: The physical science basis, In: Summary for policy makers, IPCC: 21, Geneva, 2007.

2 Dahal N, Understanding climate change adaptation issues in Nepal, National Trust for Nature Conservation, Kathmandu, Nepal, 2008

3 Shrestha AB, Wake CP, Mayewski PA & Dibb JE, Maximum temperature trends in the Himalaya and its vicinity: an analysis based on temperature records from Nepal for the period 1971–94', *J Climate*, (12) (1999) 2775–2787

4 Kansakar SR, Hannah DM, Gerrard J & Rees G, Spatial patterns in the precipitation regime of Nepal, *Int J Climae,* 24 (2004) 1645–1659

5 Sharma E & Tsering K, Climate change in the Himalayas: the vulnerability of biodiversity, In: *Biodiversity and climate change in the Himalayas Sustainable mountain development,* (ICIMOD, Kathmandu, Nepal) 2009, 55.

6 Du MY, Kawashima S, Yonemura S, Zhang XZ & Chen SB, Mutual influence between human activities and climate change in the Tibetan plateau during recent years, *Glob Plan Chan*, 41 (2004) 241–249

7 CBS, Central Bureau of Statistics; Population Census Main Report. Central Bureau of Statistics, Kathmandu, Nepal LRMP (1986) Summary report, Land resource mapping project, HMGN/Government of Canada, (Kenting Earth Sciences Limited, Kathmandu, Nepal), 2001.

8 Maharjan KL, Community participation in forest resource management in Nepal, *J Mount Sci*, 2(1) (2005) 32–41,

9 HMGN, Nepal Biodiversity Strategy, Ministry of Forests and Soil Conservation, Kathmandu, Nepal, 2002.

10 Regmi BR & Adhikari A, Climate risk and vulnerability in Nepal. Country case study, Human Development Report 2007/2008 Fighting climate change: Human solidarity in a divided world, (Human Development Report Office Occasional Paper, UNDP, Pokhara, Nepal), 2007.

11 Regmi BR, Thapa L, Suwal R, Khadka S, Sharma GB & Tamang BB, Agro-biodiversity Management: An opportunity for mainstreaming community-based adaptation to climate change, *J For Livel*, 8(1) (2009) 111–119.

12 Jianchu X, Shrestha A, Vaidya R, Eriksson M & Hewitt K, The melting Himalayas: Regional challenges and local impacts of climate change on mountain ecosystems and livelihoods, ICIMOD Technical Paper, (International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal), (2007).

13 Ban AW & van den Hawkins, HS, *Agricultural Extension,* 2nd Edition, (Blackwell Science UK), 2000.

14 Chapagain BK, Subedi R & Paudel NS, Exploring local knowledge of climate change: some reflections, *J For Livel*, 8(1) (2009) 106–110.

15 Banjade MR, *Local perception and use of information for Forest User Groups: Case studies from Dhankuta District, Nepal*, (MScThesis, Wageningen University, The Netherlands), 2003.

16 Swart R, Robinson J & Cohen S, Climate change and sustainable development: expanding the options, *Climate Policy*, 3S1 92003) S19–S40.

17 Robinson J & Herbert D, Integrating climate change and sustainable development, *Int J Global Environ Issues*, 1(2) (2001) 130–148.

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

19 CBS, Central Bureau of Statistics; Available at www.cbs.gov.np 2006; Accessed 4 December 2012

20 Tiwari KR, *Land management and soil conservation options for sustainable agricultural production in a middle mountain watershed of central Nepal*, (MSc Thesis, Norwegian University of Life Sciences, Ås, Norway), 2008.

21 Tiwari KR, Sitaula BK, Børresen T & Bajracharya RM, An assessment of soil quality in Pokhare Khola watershed of the Middle Mountains in Nepal, *J Food Agri Environ*, 4 (2006) 276–283.

22 Baul TK, Tiwari KR, Ullah KMA & McDonald MA, Exploring Agro-biodiversity on farm: A case from Middle–Hills of Nepal, *Small Scale For*, (2013). DOI 10.1007/s11842-012-9234-y

23 Gyampoh BA, Amisah S, Idinoba M & Nkem J, Using traditional knowledge to cope with climate change in rural Ghana, *Unasylva*, 60 (2009).

24 Gyampoh BA, Idinoba M, Nkem J & Amisah S, Adapting watersheds to climate change and variability in West Ghana, In: *Proceedings on 3rd International Conference on Climate and water*, (Helsinki, Finnish Environment Institute (SYKE)), 2007.

25 Shrestha AB, Wake CP, Dibb JE & Mayewski PA, Precipitation fluctuation in the Nepal Himalaya and its vicinity and relationship with some large scale climatological parameters, *Int J Climate*, 20 (2000) 317–327.

26 Chambers R, *Putting the first last*, (Intermediate Technology Publications', London), 1997.

27 Malla G, Climate change and its impact on Nepalese agriculture, *The J Agri Environ*, 9 (2008) 62–71.

28 ICIMOD/UNEP, Global climate change and retreat of Himalayan glaciers in China, India, Bhutan and Nepal, 2007, 7–19.

29 Rai KKS, Climate change and its impact on indigenous people in Nepal Himalaya, Indigenous Affairs–International

Work Group for Indigenous Affairs, No.1–2/08, pp 60–65, 13 ref. 2008.

30 IPCC, Intergovernmental Panel on Climate Change; Climate Change 2007: The physical science basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge and New York, (Cambridge University Press,UK), 2007a, 996.

31 Sherchand et al., Climate change and agriculture in Nepal, DSSAT, July 2007.

32 MoEST, Ministry of Environment Science and Technology; Initial National Communication report submitted to United Nations Framework Convention on Climate Change (UNFCCC), 2004.

33 SAGUN, Climate change impacts on livelihoods of poor and vulnerable communities and biodiversity conservation : A case study in Banke, Bardia, Dhading and Rasuwa districts of Nepal, Strengthened Actions for Governance in Utilization of Natural Resources (SAGUN) Program, CARE Nepal, Kathmandu, Nepal, 2009.

34 Menzel A, Sparks TH, Estrella, N & Koch E, European phenological response to climate change matches the warming pattern in global change, *Biology*, 12 (2006) 1969–1976.

35 Zheng JY, Ge QS & Hao ZX, Impact of climate warming on plant phenology during recent 40 years in China, *Sci Bull*, 47(20) (2002) 1582–1587.

36 Dahal N, Implications of climate change in Nepal; some observations and opportunities, In: Paper presented at the 23rd Warden Seminar, Pokhara, Nepal, November, 2006.

37 Stern N, Report of the Stern Review: The economics of climate change, (HM Treasury, London), 2006.

38 Upreti BR & Upreti YG, *Factors leading to agro-biodiversity los*s in developing countries: the case of Nepal, *Biodivers Conservat*, 1111 (2002) 1607–1621.

39 Baul TK, *Climate change and adaptation practices through agro-biodiversity on farm land in the Middle–Hills of Nepal: A case study in Pokhare Khola watershed in Pida village development committee (VDC) of Dhading district*, (Master Thesis, Bangor University, UK), 2010.

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