

Full Length Research Paper

Evaluating the changes in climate and its implications on peri-urban agriculture

*Anushiya Shrestha and Rajesh Sada

Abstract

Nepal Engineering College-Center for Postgraduate Studies, Balkhu, Nepal

*Corresponding Author E-mail: anushiyas@nec.edu.np; Tel: 00977-9841578432.

This paper provides an overview of changing climatic context in Kathmandu valley based on the analysis of temperature and rainfall data and perception of local people on key climatic variables. Perceived changes in climate, its impacts on peri-urban agriculture and adaptation strategies practiced by peri-urban farmers were assessed using participatory tools and household questionnaire survey at four peri-urban villages in Kathmandu valley. Temperature in Kathmandu showed an increasing trend while rainfall was erratic with no distinct pattern. The impacts of these changes on agriculture have been primarily negative with increase in crop pests and diseases and decline in the crop production. The adaptive strategies evolved include shifts in cropping dates, switch towards drought tolerant crop varieties and application of technological inputs to adapt against the increasing climatic stresses. The study found needs of communicating the knowledge and experiences, replicating the successful adaptive practices and intervening to control malpractices to strengthen the adaptive capacity and ensure resilient peri-urban agriculture.

Keywords: Peri-urban agriculture, rainfall, temperature, impacts, adaptation.

INTRODUCTION

Climate change is one of the major phenomena that have grabbed special global attention. Climate change is expected to cause an increase in mean annual temperature up to 5 °C in Asia by 2080 (Cruz et al., 2007). Chaulagain (2006) states the climate change in Nepal is going even faster than the global average. Between 1977 and 1994, the mean annual temperature in Nepal is estimated to have increased by 0.06°C, and is projected to increase by another 1.2°C by 2030, 1.7°C by 2050, and 3.0°C by 2100 (as cited in ADB, 2009). Baidya et al. (2008) found a strong increase in annual rainfall in wet days (> 1mm) and Joshi et al. (2011) found rainfall is continuously increasing in Kathmandu at a significant rate but majorities of literatures analyzing the rainfall

trend over Nepal (Shrestha et al., 2000; Practical Action, 2009) found a lack of long term definite trend in rainfall over Nepal.

A variety of sectors in Nepal are projected to be impacted by ongoing climate variability and change. Agriculture, which is the only available means of livelihood for many of the poor, is one of sector which is expected to be most vulnerable to climate change (WECS, 2011). Climate change will affect agriculture through effects on crops; soils; insects, weeds, and diseases; and livestock (IPCC, 1996). The report published by World Bank in 2007 mentioned that climate change will have far-reaching consequences for agriculture that will disproportionately affect poor and

marginalized groups who depend on agriculture for their livelihoods and have a lower capacity to adapt. The changes in the temperature and rainfall patterns are expected to bring major changes in the farming systems and practices. These are expected to produce far reaching implications to the rural economy and livelihood of the people. Increased water demand and decreased water availability as a result of climate change may adversely affect the society and economy (Brookes et al., 2010).

Food and Agricultural Organization in 2008 stated the increase in the variability in rainfall increases instability in rain-fed agricultural production. Nepalese agriculture is mainly rain-fed and agricultural productions in both rain-fed as well as irrigated areas are being badly affected due to droughts, flooding, erratic rainfall, and other extreme weather events (WECS, 2011). National Adaptation Programmes of Action (NAPA) prepared by Ministry of Environment of Nepal in 2010 has ranked Kathmandu as the most vulnerable place in Nepal. However, most of the climate change studies in Nepal deal broadly with rural areas (Chapagain et al., 2009; Practical Action, 2009; Chaudhary and Bawa, 2011; Tiwari et al., 2010; NCDC, 2010; Maharjan et al., 2011 and Piya et al., 2012). This necessitates studies focusing on the climate change and its impacts in Kathmandu valley. The urban expansion in the valley towards former rural lands adjacent to edges of urban lands has evolved dynamic peri-urban landscapes; characterized by mixed rural urban features. The agricultural lands in these urban fringes have traditionally been supplier of food to sustain urban livelihood in Kathmandu valley. In addition to ongoing landscape conversions, peri-urban areas in Kathmandu valley are exposed to the risk of unprecedented negative impacts of climate change.

The significance of agriculture in peri-urban Kathmandu is not only limited in maintaining food security for peri-urban residents but also for the rapidly expanding cities. In this context, this paper explores the changes in climate of Kathmandu valley both as shown by climatic records and as perceived by peri-urban inhabitants. Additionally, this paper brings forward the impacts on agriculture as experienced by the peri-urban farmers of Kathmandu valley. Further, it assesses the adaptive strategies that have been adopted by the peri-urban farmers in adapting against the implications of climatic variability.

MATERIALS AND METHODS

Study area

The study was conducted at four different peri-urban village development committees (VDCs) viz. Jhaukhel, Dadhikot, Matatirtha and Lubhu in Kathmandu valley. Jhaukhel covering an area of 5.41 km² is located at the

northern flange of Bhaktapur Municipality. The VDC has 7721 inhabitants in 1631 households (CBS, 2012). Dadhikot adjoining to the Thimi municipality in Bhaktapur district covers an area of 6.27 km². The population of this VDC increased from 7244 in 2001 to 11629 in 2011 (ibid) showing an increase by 60.53%. Matatirtha in western part of Kathmandu District is approximately 5 km away from the urban area. It covers an area of 6.19 km² and is inhabited by 1413 households, with total population size of 5982 people. Lubhu VDC is situated at the periphery of Lalitpur district covering an area of 4.76 km², has a population of Lubhu is 10374 (ibid). The four VDCs are on the process of rapid urbanization and represent the peri-urban context of Kathmandu valley in general. (Figure 1)

Method

A mixture of both quantitative and qualitative research approach was used in this study. Participatory research tools were used to gather the qualitative data. These data were collected at household and community level. Series of focus group discussions and household questionnaire survey were conducted to assess perception on climate change, its impacts on agriculture and the adaptation strategies. The multi-stage stratified random sampling technique was adopted during household survey. The aim was to ensure geographical representation from each of the VDCs. Ten percent of the total households were determined as the sample size while social stratification based on caste was followed as the sampling basis. Structured questionnaire was prepared and the survey was conducted with 1164 respondents (a male and a female) at 582 households across the study sites. The information collected was supplemented through reviewed secondary literatures and reports including those published at local level.

Rainfall data for seven (Godawari, TIA, Changu Narayan, Naikap, Sankhu, Panipokhari and Khumaltar) and temperature data for four stations (Khumaltar, TIA, Panipokhari and Godawari) within Kathmandu valley were analyzed to understand the long term climatic trends. These stations were selected based on their proximity to the study sites. All the stations except Naikap had data over 30 years and qualified the meteorological data analysis criteria as defined by World Meteorological Organization (WMO, 1966).

RESULTS

Temperature and rainfall trend

The analysis of temperature records of Kathmandu valley showed the long term average monsoon temperature in the valley ranged between 21.6°C and

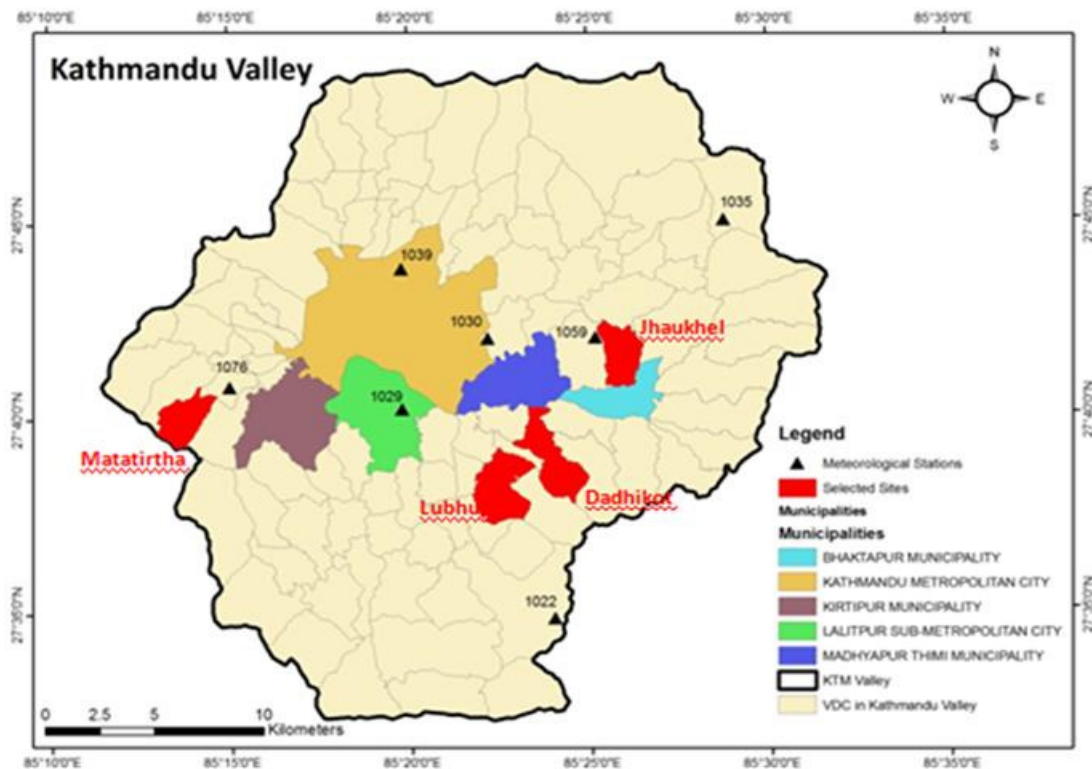


Figure 1. Hydro-Meteorological stations used in the analysis and the research sites. The black triangles represent the stations. These were selected based on their proximity to the selected peri-urban research sites.

23.9°C. Long term average winter temperatures varied between 11.2°C and 12.7°C. The numbers of days with maximum temperature above 30°C was increasing while the number of days with minimum temperature below 0°C was decreasing (Figure 2). The maximum temperature was increasing at 0.05°C per year and minimum temperature at 0.04°C annually. The increase of both maximum and minimum was highest in winter. Table 1 shows the four seasons in Nepal; adapted from those defined by Thapa and Joshi (2011).

Rainfall in Nepal is dominated by summer monsoon rainfall that extends from June to September. This makes monsoon the major cropping season in Nepal.

The analysis of rainfall data showed no clear increase in the number and length of dry spells, the number of rainy days and the daily intensity index. At most stations, an increase was found in the number of days in monsoon with rainfall exceeding 50mm per day. There were no significant (based on Seasonal and ordinary Mann-Kendall test) increasing or decreasing trends in total annual rainfall. Seasonal breakdown indicated rainfall decreased mainly in the months October to March which is the period for winter rainfall implying decrease in winter rainfall. Increase in rainfall took place from April to September, except for June. June is the month with the

onset of monsoon. This average decrease in June can imply that the onset of monsoon had shifted to later in the season.

Perceived temperature and rainfall trend

Increasing trend of temperature was dominant perception. It was expressed through increase in temperature related indicators such as summer and winter temperature, extreme hot summer days, less cold winter and hot days. Farmers noted decline in occurrence of fog and frost during peak winter mornings.

Rainfall was perceived to be declining and occurrence of dry spells was perceived to be increasing. The declining trend was perceived to have started since 1980s which increased progressively in 1990s and 2000s. Decline in number of rainy days and persistence was noted in monsoon rain. Winter and spring rainfall amount as well as number of rainy days were also perceived to be decreasing. Rather than the amount of rainfall, it was the unreliability and erratic rainfall trend perceived as major stress by the peri-urban farmers.

Figure 3 shows the perceived changes in different climatic indicators obtained from household survey.

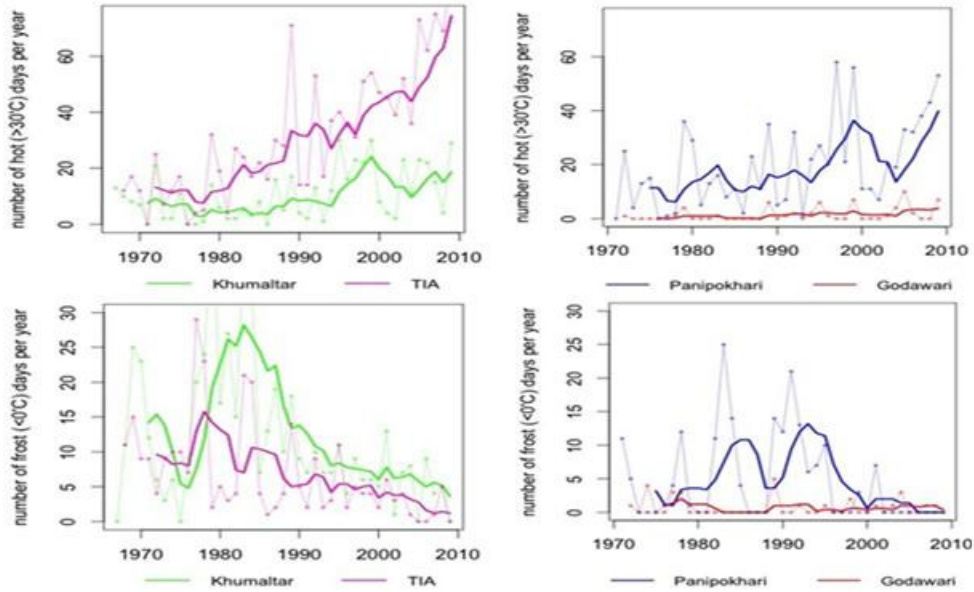


Figure 2. The figure shows five year moving average for the annual number of days with temperature above 30°C and number of days with temperature below 0°C. The increasing trend of former and decreasing trend of latter clearly shows increasing trend of hot days.

Table 1. Seasons in Nepal.

Seasons	Months
Winter	December - February
Spring/Pre-monsoon	March- May
Monsoon	June- September
Fall/Autumn	October - November

(Adapted from Thapa and Joshi, 2011)

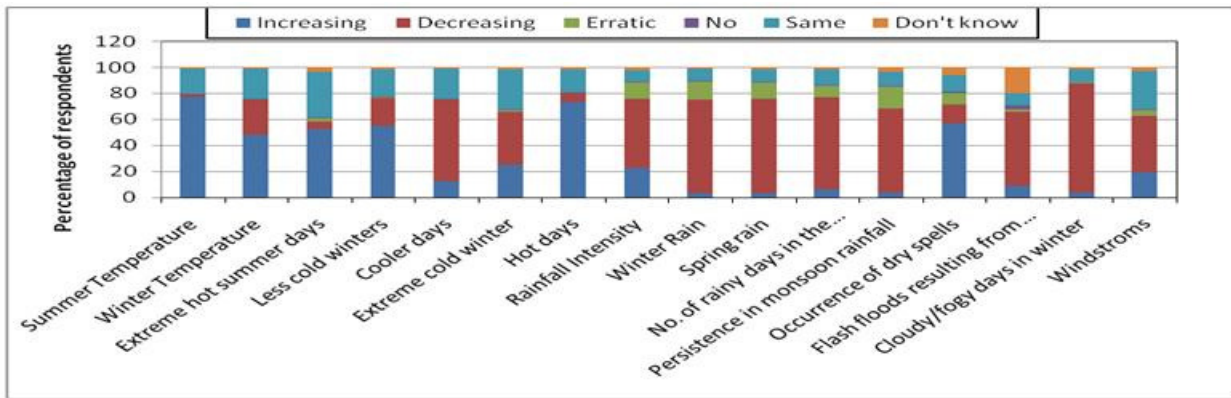


Figure 3. Changes in different climatic indicators as perceived by peri-urban farmers. Perceived changes in rainfall and temperature were captured using different attributes of temperature and rainfall. The farmers strongly perceived increasing trend in temperature and decreasing trend in rainfall.

Impacts on Agriculture

Paddy and wheat rotation was the most important

cropping pattern in the *khet* (irrigated farm land) and maize and beans in circulation with mustard as winter crop was common in *bari* (unirrigated terrace land)

across peri-urban Kathmandu. Other crops cultivated during winter included millet, barley, pea, lentil, fava bean. Potato was cultivated as winter crops by the farmers with dependable irrigation service. Other crops cultivated were pulses, garlic, onion, millet, radish and wide range of vegetables.

Shifting monsoon and effects on monsoon crops

Prior to 1980s, generally paddy transplantation used to be accomplished by the June with some exceptional years. Declining rainfall in June was resulting delay in the paddy transplanting. Over the years, July had become the peak season for paddy transplanting. In recent decade, peri-urban agriculture was increasingly being rain-fed. Consequently, paddy transplanting was found to be delayed more frequently. It was possible only after the monsoon started in full swing such that the delay of transplanting till August was being common. This delay in paddy transplanting affected ripening and harvesting especially for up-hill farmers which was further disturbing the sowing of winter crops. The ultimate impact was loss in quality and quantity of the potential yields.

Despite increasing rainfall in April and May the farmers commonly perceived the additional water stress for the protection of the nurseries. This was attributed to decline in the rainfall in June, the month of monsoon onset thereby affecting the newly germinated maize and the paddy seedlings in seed bed prepared utilizing pre-monsoon rain. Shift in the peak monsoon rainfall during August and September was further perceived to be the factors affecting the harvestable maize and the paddy growing in the field.

Declining winter rain and stresses for winter cropping

The winter crops in the valley were primarily cultivated in rain-fed condition which made them more prone to crop failure due to climatic conundrums. With declining irrigation facility as a result of poor management of irrigation canals, by mid to late 2000s the practice of irrigating wheat was possible only for the farmers along the river banks. Farmers depending on rain remained helpless against dry winter which resulted in the massive decline in wheat yield. Consequently, many farmers stopped cultivating wheat. The limited farmers continuing wheat cultivation were again stressed by increasing temperature and unexpected pre-monsoon rainfall. This was increasing the hardship during the wheat harvest and also reducing the harvestable wheat.

Besides rainless winters, the disturbed monsoon cropping cycle was causing moisture deficit for plantation of winter crops. The delayed paddy harvest led to

delayed sowing of winter crops. This caused additional problem for germination of winter crops as the temperature fell below the threshold temperature required for germinating winter crops. Therefore the farmers were left with no option besides leasing out lands or leaving the land fallow.

Increasing temperature and impacts on crops

Farmers noted both positive and negative impacts of increasing temperature. A positive impact of increasing temperature was noted by farmers in the lower belts of these peri-urban villages. In the recent decade, even when paddy was transplanted after second week of July, they stated paddy in the lower belts was ripening nearly by the same time (November second week). Likewise, decrease in the frost was resulting less frost damage to winter crops. However, the farmers perceived negative implications of increasing temperature undermining its possible positive effects. Despite ripening of paddy on time, the problem was with the decrease in its yield whereas pest attacks in winter crops were also increasing due to milder winter.

A negative impact of increasing temperature was also noted in the quality of agricultural products. They perceived decline in the occurrence of frost during winter which was causing loss of typical taste of the green leafy vegetables. They believed the taste was added by frost during winter.

Farmers observed mustard seeds were germinating within fewer days after sowing its seeds. They linked the change in crop phenology with milder winter. The newly germinated plants were less disease resistant and more prone to weather vagaries that followed during the crop growing period. Farmers perceived increasing drought stress as a result of increasing temperature and rainfall uncertainty was major cause of crop disease and crop damage.

Changes in crop weeds and pests

Farmers recalled the incidences of damaging insects, pests and weeds started in 1990s. 2000s onwards there were surge of pests. *Spilanthus iabadicensis*, *Cynodon dactylon*, *Ageratum conyzoides*, *Echinochloa colona*, *Eclipta prostrata* were weeds that occurred commonly in paddy prior to 2000s. *Polygonum barbatum*, *Cyperus difformis*, *Paspalum distichum*, *Commelina diffusa* invaded in 2000s. Similarly sterile spikelets and discoloration of the paddy leaves into yellow or rust color was increasing. Sheath blight in paddy caused by *Rhizoctonia solani* and attack by stem borer (*Chilo partellus*) in maize both were noted only in 2000s. These were being more destructive. Smut (*Sphacelotheca reilian*) on the above ground and white grubs

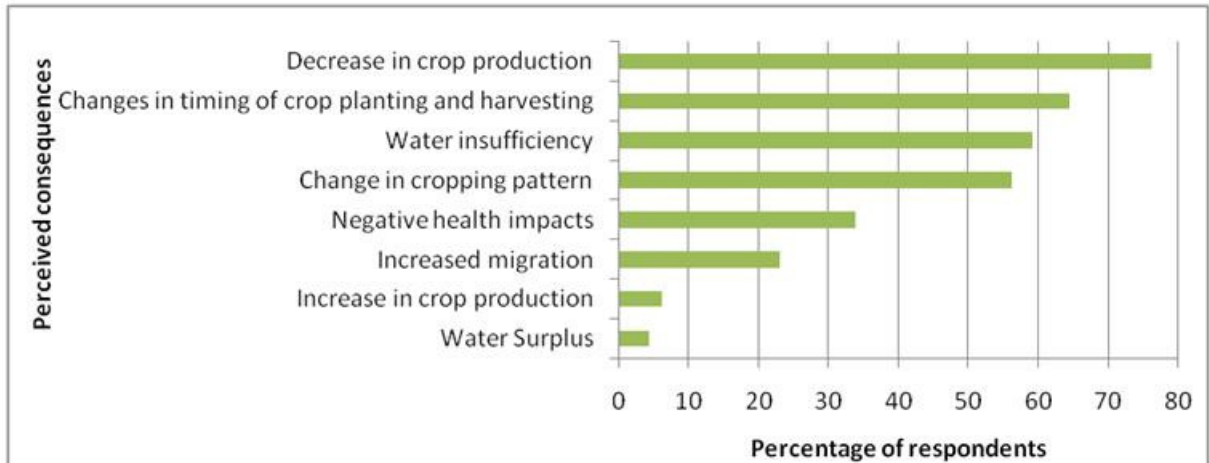


Figure 4. Perceived consequences of changes in climatic attributes. Decrease in crop production was commonly perceived and the most prioritized impact of climate change.

(*Phyllophaga spp.* and *Cyclocephala spp.*) attacking the roots were noticeable 1990s onwards and were widespread in 2000s.

Aphids (*Rhopalosiphum spp.*) affected a wide range of crops including mustards, different vegetables, maize, broad bean and other pulses and causing crop failure. The potato damages by leaf blight, white grub, red ant became frequent in 2000s. Though the occurrences of the insect pests were relatively lower during winter season, pest population was observed to be increasing every year. Furthermore, with rapidly rising trend in temperature in 2000s, the new pests had also emerged. Farmers related increase of pest in agricultural crops with the progressive decline in soil moisture; the most common was occurrence of aphids devastating mustard plants, pulses and vegetables that were cultivated as alternative to traditional winter crops.

Though farmers considered the disturbances in the natural pest predator cycle as a result of unbalanced use of chemical fertilizers initiated the emergence of pests, they realized the role of changing climate in increasing the severity of pest attacks. The increasing temperature, declining occurrence of frost and variation in the pattern and amount of rainfall were the climatic variations perceived as the major causes of pest surge in crops.

Climate change impacts on crop production

The study revealed negative impacts of climatic variability on crop productivity in peri-urban areas. Farmers reported three distinct stages of crop production. Prior to 1970s, traditional varieties of cereals were planted. The traditional varieties had much lower yield. Increase in the yield from period prior to 1970s to 1990s was considered the result of switch to high yielding varieties and the

application of chemical fertilizers. The decade of 2000 onwards, the production declined despite of cultivating high yielding varieties and fertilizers applications. Besides the major crops, alternative crops introduced at different times also showed declining trend in 2000s. The farmers considered several reasons behind the decrease in production; increasing rainfall uncertainty was perceived to be main culprit behind the declining annual crop yield. This was followed by low quality fertilizer, water scarcity, soil degradation due to extensive use of fertilizers and increase in pests and crop diseases. The apparent increase in the yield of some crops was attributed to extensive use of chemical inputs applied to the crops in the forms of fertilizers, pesticides and supplements such as vitamins.

In addition to increasing climatic pressure, increasing urban influence and declining labor for agriculture was also perceived to be negatively affecting peri-urban agriculture. (Figure 4)

Adaptive strategies

Switching towards less water demanding crops

Taichin-242 and Tainan- 176, the high yielding varieties of paddy were most preferred paddy varieties planted across peri-urban Kathmandu. However, these had high water requirements. Delayed and unreliable monsoon compelled the farmer to cultivate drought tolerant varieties like *Khumal-4*, *Khumal-8* and *Pokherili*. With declining irrigation service and changing rainfall pattern, preference over this less water demanding variety was increasing.

Farmers switched from wheat to barley, lentils, soya bean and pea was the latest preference in the process of

selecting less water requiring winter crops. Since mid 2000s, the farmers started shifting from traditional crops towards cash crops such as mushroom, vegetables and flowers. These could be irrigated using water extracted from the dug wells which were common across peri-urban households. Additionally, these crops were economically more productive and were increasing with expanding market opportunities in adjacent urban centres.

Leaving land fallow or leasing out

Peri-urban farmers left the land fallow particularly during winter after the incidences of crop failure and poor yield became regular phenomena. According to them, the winter crops were not getting favorable environment due to erratic rainfall pattern resulting poor soil moisture and disturbed seasonal cropping cycle. Therefore, the farmers are left with no option besides leaving the land fallow or lease out.

As a result of declining economic returns from agriculture, leasing out land was preferred lucrative alternative among peri-urban farmers. Brick factories were prominent leaseholders and scraped the top soil for brick production. The consequence on crop productivity due to removal of top soil by the growing brick factories had started emerging in form of degrading soil fertility and further declining crop production.

Strategies evolving to preserve moisture

In order to cope against decreasing soil moisture, farmers modified the practice of drying paddy straw and started using it in mulching winter crops. Likewise, farmers managed the fields immediately after the paddy harvest and the seeds of crops selected for the winter season were sown over the field before the residual soil moisture could escape into the air. The straw was then spread over the surface for drying. Simultaneous aim of the process was to prevent the loss of soil moisture so that water remained available for germination of the winter crops. In addition, the farmers started to sow pea prior to paddy harvest so that the pea germinates using the soil moisture of paddy field and grows to young plant by the time of paddy harvest.

Increasing use of pesticide

With increasing occurrence of pests, farmers were applying the pesticides more frequently and in larger amounts to control the pests. The volume of pesticide required for a plot of land was reported to have increased three times over a period of decade. In addition to insect pests, diseases caused by microbes were increasing

massively in such a way that the application of pesticides had been inevitable among the farmers. Furthermore, vegetables cultivated as alternative winter crops needed supplementary inputs so as to increase their resistance against increasing pests and diseases. As a result, the cost incurred for the production had increased thereby reducing the net gain for the farmers.

Occupational diversification

People were shifting to off-farm occupations, such as, weaving traditional textiles, jobs in the government and private firms and industries and off-farm wage earning. A very important reason for shift in occupation was declining economic returns from agriculture. The main reason for these losses was perceived to be changing climatic trend. Urban proximity was additional factor for growing deviation towards non-agricultural occupations.

The usual adaptive practice growing among peri-urban farmers was selling out land for non-agricultural investments and keeping small piece of land for cultivation of economically attractive crops, such as vegetables or shifting completely to non-farm occupations.

Technological support

Though the rivers in the peri-urban areas were polluted, farmers initiated use of electric water pumps for lifting water from river to agricultural lands. Such initiatives began in 2008 with the financial support of Micro irrigation support program under the Multiple Use Water System (MUS). It was implemented through International Development Enterprise's (IDE) Small Irrigation Market Initiative (SIMI) Project Nepal. The water users committees started collecting irrigation service fee from the farmers based on the location and area of field to be irrigated. This fund was used in operating and maintaining the pump sets. Drip irrigation though was introduced in the same period could not attract farmers.

Initiation of charging irrigation service fee

A positive change due to increasing rainfall variation was increasing social pressure for revival of traditional irrigation systems. Following the renovation of irrigation system, farmers improved the mechanism of irrigation system management. In the traditional practice of irrigation, water for irrigation was provided free of cost. Very recently, farmers evolved practice of collecting irrigation service fee. Water users were charged on the basis of area to be irrigated and the distance of the field from the canal. This new system helped farmers to manage the water based on the demand and hence

controlled free riding of the limited water resource.

Shifting to organic farming

Willingness to shift to organic farming was found among farmers across study sites. Alongside commercial organic farms were attracted to these peri-urban areas targeting the growing demand for organic products at the adjacent cities. Local farmers applied compost fertilizers and organic pesticides prepared at the household levels. However it was practiced by limited farmers. The major constraint was the limited knowledge on the process of preparing compost and organic pesticides. Application of compost increased recently after the local farmers were trained on compost and vermin-compost preparation at household level. This was provided by Nepal Engineering College in 2012 as a part of increasing adaptive capacity against negative impacts of climate change. However there were needs of expanding the knowledge of farmers on organic farming.

DISCUSSIONS

Several climate change studies (Dahal, 2005; Thomas et al., 2007; Byg and Salick, 2009; Mertz et al., 2009; Green and Raygorodetsky, 2010; Piya et al., 2012) underline the importance of local perception of climate change, impact assessment, and adaptation planning. Increasing temperature trend perceived by peri-urban farmers across the study sites was consistent with results obtained from analysis of temperature data. The finding was also supported by earlier studies (Shrestha et al., 2000; Cruz et al., 2007; Baidya et al., 2008; Practical Action, 2009; Joshi et al., 2011).

Paddy yield is optimal at 25°C (Luo, 2011) and for maize the temperature range is between 10°C and 35°C (Navaya and Gurung, 2010). Similarly the optimal temperature for wheat growth depends on the development stage, between 20.3°C and 22.0°C (Luo, 2011). Considering the average temperature range in Kathmandu valley, an increase in temperature could positively contribute both monsoon and winter crop yield for certain years. Alongside, it should not be neglected that the different development stages of crops demand their own particular optimal conditions. It can therefore be inferred; over years the continuous increase in temperature could itself limit the yield of these major crops of peri-urban Kathmandu. Extreme temperatures can significantly reduce yield (Porter and Gawith, 1999) and especially during flowering time, crops are sensitive to extreme temperatures (Wheeler et al., 2000). Studies also link increase in temperature with the increases in the risks of pests, invasion of new weeds and diseases in crops (Dukes and Mooney, 2000; Patz et al., 2000; Masters and Wiebe, 2000; Malla, 2003; Chakraborty et

al., 2008; Ziska et al., 2011). Chakraborty and Newton (2011) pointed the effects of drought-stress on the disease resistance of the crop, giving pests and pathogens more chance to succeed. The increasing pests and crop diseases were observed across the peri-urban areas. In Nepal, 70-80 percent of yield loss of rice in upland conditions and 20-40 percent yield loss in lowland conditions was reported by Upadhyaya (1998). The increasing weeds could therefore be a major biological constraint for the crops.

Peri-urban farmers perceived those as compounded effect of increasing temperature, erratic rainfall and degrading irrigation systems. Considering the changing climate and increasing rainfall dependency with degrading irrigation systems, the analysis made by farmers based on their understandings and experiences seem appropriate.

Most of the respondents had strong view of decrease in rainfall. This was not completely supported by the rainfall data analysis as some months showed decreasing while some showed increasing trend. This indistinct trend was increasing rainfall uncertainty making rainfall unpredictable and unreliable. Consequent water stress increasing for agriculture could be the possible cause of dominant perception of declining rainfall among the farmers across study area. The observed changes in seasonal rainfall pattern can have implications on existing process of water use in agriculture. The increase in pre-monsoon rainfall may lead to declining irrigation needs and provide possibility of additional crops in this season. Delayed onset of monsoon and decline in winter rain suggested the needs of exploring alternative water sources and improving irrigation systems. Nayava et al., (2009) pointed rainfall distribution in February and March had a very good impact on yield. They found most of the up and down in the cultivation of wheat was a result of October rainfall as it helped as residual moisture during sowing time. The declining wheat yield across the study areas could therefore be linked to the declining winter rainfall. Analysis of relation of pre-monsoon rainfall on maize yield and production by Nayava and Gurung (2010) recommended that maize planting needed to be adjusted according to the change in rainfall pattern in the recent decades. The findings of this study also emphasize on the need of readjustment of the cropping dates according to the changing rainfall patterns. This implies the need of joint action between the scientific communities and the farmer communities.

The adaptive strategies adopted by peri-urban farmers have to a certain extent been helpful to overcome the agricultural stresses added by climatic variations. Nevertheless, it should not be undermined that there are needs of improving the adaptive capacities and empowering farmers with better adaptive options specifically addressing activities such as leasing out the farm lands for brick factories and increasing

dependency on chemical pesticides and fertilizers. USDA (1993) clarifies the significance of topsoil to agricultural productivity as it is the part of the soil horizon with higher level of organic matter and nutrients and generally better structure. Thus scraping of top soil by brick factories creates persistent threat to peri-urban agricultural system. Intensive use of pesticides considerably affects the land and its biotic environment rendering most crops more susceptible to pest attack (Brader, 1987). It shows peri-urban farmers have to be acquainted with alternative techniques of pest control. Climatic uncertainty was perceived as a prime factor of increasing cost of production. This was distracting peri-urban farmers towards off-farm practices. Considering role of peri-urban agriculture, the negative impacts on peri-urban agriculture can be speculated to further expand adding vulnerability to both peri-urban and urban food security.

Manandhar et al. (2010) and Rai et al. (2011) have correctly stressed that climate change is not always the main driver behind the impacts on agriculture but it in many cases acts as a catalyst. Agriculture in peri-urban Kathmandu was influenced by several factors such as intensive use of chemical fertilizers, degrading irrigation system, degradation of soil and increasing urban influence. However, changing climate was further aggravating the situation. Both warmer temperatures and changing rainfall patterns presented economic challenges for peri-urban agriculture.

The study found the needs of communicating the knowledge and experiences to identify and replicate climate smart agricultural practices. Furthermore ensuring resilient peri-urban agriculture requires creative interventions to control malpractices and to strengthen the adaptive capacity of the farmers.

ACKNOWLEDGEMENT

This study has been supported by International Development Research Centre (IDRC), Canada (under IDRC Grant No. 106248-003).

REFERENCES

- ADB (2009). Strategy and Program Assessment NEP: Climate Change Assessment Asian Development Bank and International Center for Integrated Mountain Development, Kathmandu, Nepal
- Baidya SK, Shrestha ML, Sheikh MM (2008). Trends in daily climatic extremes of Temperature and Rainfall in Nepal, *J. Hydrol. and Meteorol.* 5: 38-51.
- Brader L (1987). Plant Protection and Land Transformation, Land Transformation in Agriculture.
- Brookes JD, Ainger CM, Howe C, Norton Jr JW, and Schladow G (2010). Water and Climate Change: Challenges for 21st Century, IWA Publishing 2010. *J. Water and Clim. Chang.* 01, 1.2010.
- Byg A, Salick J (2009). Local perspectives on a global phenomenon—climate change in eastern Tibetan villages. *J. Glob Environ Chang.* 19:156–166
- CBS (2012). National Population and Housing Census (Village Development Committee/ Municipality), Central Bureau of Statistics, Government of Nepal, Kathmandu, Nepal.
- Chakraborty S, Luck J, Hollaway G, Freeman A, Norton R, Garrett KA, Percy K, Hopkins A, Davis C, Karnosky DF (2008). Impacts of global change on diseases of agricultural crops and forest trees. *CAB Reviews: Perspect. in Agric, Vet. Sci., Nutr. and Nat Resour.* 3: 1-15
- Chakraborty S, Newton AC (2011). Climate change, plant diseases and food security: an overview. *Plant Pathol.* 60: 2-14.
- Chaudhary P, Bawa KS (2011). Local perception of climate change validated by scientific evidence in the Himalayas. *Biol. Lett.* 7: (2011) 767:770.
- Chaulagain NP (2006). Impacts of climate change on water resources of Nepal: The physical and socioeconomic dimensions. Master's thesis, University of Flensburg, Flensburg, Germany.
- climate changes and their adaptive intiations to withstand its impacts in western terai of Nepal.
- Dahal N (2005). Perceptions of Climate change in the Himalayas A Bull. in *Clim. and Dev.* 56: 19- 24.
- Development Center (NCDC). Research report submitted to World Wildlife Fund, Kathmandu,
- Dukes JS and Mooney HA (2000). Does global change increase the success of biological invaders? *Trends in Ecol. and Evol.* 14:135-139. Edited by M. G. Wolman and F. G. A. Fournier @ 1987 SCOPE. Published by John Wiley & Sons Ltd
- Europ. *J. Agron.* 10: 23-36.
- FAO (2008). Climate change water and food security, Technical Background Document from the Expert Consultation held on 28 to 28 February 2008 Food and Agriculture Organization, Rome.
- faunal species in the Kanchanjunga-Singaila complex, Eastern Nepal. Namsaling Community
- Green D, Raygorodetsky G (2010). Indigenous knowledge of a changing climate. *Clim. Chang.* 100: 239–242.
- Intl. *NGO J.Vol.* 6(2), pp. 35-42. Retrived from www.academicjournals.org/INGOJ.
- IPCC (1996). Climate change 1995: economic and social dimensions of climate change, Contribution of working group III of the Second Assessment Report of the Intergovernmental Panel on Climate Change edited by J.P. Bruce, H. Lee and E.F. Haites. Cambridge University Press, Cambridge.
- Joshi NP, Maharjan KL, Piya L (2011). Effect of Climate Variables on Yield of Major Food-crops in Nepal, *J. Contemp. India Stud.: Sp. and Soc.* 1:19-26.
- Lal M (2011). Implications of climate change in sustained agricultural productivity in South Asia. *Reg. Environ. Chang.* 11 (Suppl.1):79-94.
- Luo Q (2011). Temperature thresholds and crop production: a review, *Clim. Chang.* 109: (2011) 583-598.
- Maharjan SK, Sigdel ER, Sthapit BR and Regmi BR (2011). Tharu community's perception on
- Malla G (2003). Impact of climate change on water and soil health, *J. Agric. Environ.* 4: 63-71.
- Manandhar S, Schmidt VD, Perret RS, Kazama F (2010). Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices. *Reg Environ Chang.* 11:335–348
- Masters WA, Wiebe KD (2000). *Clim. and Agricl. Product.*
- Mertz O, Mbow C, Reenberg A, Diouf A (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environ. Manage.* 43: 804–816.
- Mo E (2010). National Adaptation Programme of Action. Ministry of Environment (MoE), Government of Nepal, Singhdurbar Kathmandu, Nepal.
- Nayava JL, Gurung DB (2010). Impact of Climate Change on Production and Productivity In Nepal: A Case Study of Maize Research And Development In Nepal, *J. Agric. Environ.* 11: 59-69.
- Nayava JL, Singh R, Bhatta MR (2009). Impact of climate, climate change and modern technology on Wheat production in Nepal: a case study at Bhairahawa. *J. Hydrol. Meteorol.* 6:1-14.
- NCDC (2010). Understanding indigenous people's perception on climate change impact on floral and Nepal.

- Patz, JA, McGeehin MA, Bernard SM, Ebi KL, Epstein PR, Grambsch A, Gubler DJ, Reiter P, Romieu I, Rose JB, Samet JM, Trtanj J (2000). The Potential Health Impacts of Climate Variability and Change for the United States: Executive Summary of the Report of the Health Sector of the U.S. National Assessment. *Environl. Health Perspect.* 108 (4): 367-376.
- Piya L, Maharjan KL, Joshi NP (2012). Perceptions and Realities of Climate Change among the Chepang Communities in Rural Mid-Hills of Nepal. *J. Contemp. India Stud.: Sp. and Soc.* 2: 35-50.
- Porter JR, Gawith M (1999). Temperatures and the growth and development of wheat: a review.
- Practical Action (2009). *Spatial and Temporal Variability of Climate Change Over Nepal (1976-2005)*
- Rai YK, Ale BB, Alam J (2011). Impact Assessment of Climate Change on Paddy Yield: A Case Study of Nepal Agriculture Research Council (NARC), Tarahara, Nepal. *J. Inst. Eng.*
- Shrestha AB, Wake CP, Dibb JE, Mayewski PA (2000). Rainfall fluctuations in the Nepal Himalaya and its vicinity and relationship with some large scale climatological parameters." *Intl. J. Climatol.* 20: 317-327.
- Thapa S, Joshi GR (2011). A Ricardian analysis of the climate change impact on Nepalese agriculture. Technical Report Paper No. 29785, Munich Personal RePEc Archive (MPRA).
- Thomas D, Twyman C, Osbahr H, Hewitson B (2007). Adaptation to climate change and variability: farmer responses to intra-seasonal rainfall trends in South Africa. *Clim. Chang.* 83: 301-322.
- Tiwari, KR, Awasthi KD, Balla MK, Sitaula BK (2010). Local people's perception on climate change, its impact and adaptation practices in Himalaya to Terai regions of Nepal. Retrieved on January 19, 2013, from <http://www.forestrynepal.org/publications/article/4837>.
- Upadhyaya HK (1998). Rice research in Nepal: current state and future priorities. In: Everson RE, Herdt RW and Hossain M (eds.) *Rice Research in Asia: Progress and Priorities*. CAB International. 61-68.
- USDA (1993). *West Virginia erosion and sediment control handbook for developing areas*. USDA. Soil conservation service: Morgantowa, W. V.
- West Virginia Division Highways (WVDOH) (2000). *Standard specifications for roads and bridges*, State Government, Charleston, W. V.
- WECS (2011). *Water Resources of Nepal in the context of climate Change 2011*, Government of Nepal Water and Energy Commission Secretariat Singha Durbar, Kathmandu, Nepal.
- Wheeler TR, Craufurd PQ, Ellis RH, Porter JR, Vara Prasad PV (2000). Temperature variability and the yield of annual crops. *Agric., Ecosyst. and Environ* 82: 159-167.
- WMO (1966). *Climate Change*. Technical Report 79, World Meteorological Organization, 1966.
- World Bank (2007). *Nepal Country Environmental Analysis Strengthening Institutions and Management Systems for Enhanced Environmental Governance, Environment and Water Resources Management Unit Sustainable Development Department South Asia Region*
- Ziska, LH, Blumenthal DM, Runion GB, Hunt Jr ER, Diaz-Soltero H (2011). Invasive species and climate change: an agronomic perspective. *Clim. Chang.* 105: 13-42. http://www.wmo.int/pages/mediacentre/press_releases/pr_904_en.html