

Climate change impacts in agriculture: A case of Makrahar Village, Rupandehi, Nepal

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Abstract

Nepal ranks fourth in the world with respect to climate change vulnerability. The country has been experiencing extreme climatic events causing crop failure and food deficiency. The extent of impact varies with location, production environment the quality of services, and crop plant species. The present study was conducted to assess the impacts of climate change on agriculture and food security in a village of Rupandehi district of South Western Tarai region of Nepal. The standard methods and tools were used to assess climate change impacts on agriculture, food security and farmers' practices. Peoples' perceptions were gathered through household surveys, focus group discussions and key informants interviews. Secondary information was garnered through the review of literature, official records and personal communications. The climatic data were further validated with people's perceptions. The analysis of climatic data record from 1984 to 2013 revealed a declined precipitation, but mean air temperature was consistently rising. Change in timing, intensity and distribution of rainfall also caused shifting of crop calendar. Such extreme climatic trends along with dry spells for extended period, lowering water sources and increased infestation of crop pest and diseases affected crop performance. Heat and cold waves also affected crops yields. Farmers still lack access to proper adaptation options and support to adapt the climate change impacts. Inadequate irrigation and drainage facilities, public services and policy supports unavailable in times of stress have made farmers and farming system more vulnerable in Makrahar. Institutional support to facilitate local vulnerable people should be increased for better adaptation.

Key words: Adaptation, climate change, food security

Introduction

The variation of climatic parameters lasting for an extended period of time may be termed as 'climate change'. Climate change encompasses changes on the patterns and behavior of temperature, solar radiation, precipitation or wind velocity that occur over decades. The cases of extreme heat events may now be inevitable as the Earth's warming is nearby 1.5 °C above pre-industrial levels by mid-century. Turbulent and uncertain consequences exist due to climate change for agriculture, water supply, transportation, economy, energy, ecosystems, coastal communities and national security. Consistent warming and rise in mean annual maximum temperature at the rate of 0.04 - 0.06 °C has been observed in Nepal.

Nepal ranks fourth with regard to relative vulnerability to climate change. The frequency of extreme climatic events such as rainfall, dry spell, heat and cold waves, hailstorms and snowfall have affected agriculture performance. Such events may cause crop failure and challenges food security (Regmi & Adhikari, 2007). The earlier study has revealed higher impact of climatic variability

and extremes on crop species of Tarai region compared to Hilly and Himalayan region of Nepal (NARC, 2007). The extent of impacts varies over the location, production environment and the quality of services available for the farmers as well as food crop species. The studies conducted in the recent past focused more on hilly areas and only a few studies have been conducted focusing on the Tarai regions. Therefore, this study was carried out to assess impacts of climate change on the agriculture in Tarai.

The specific objectives include:

- To study local perceptions on the climate change vis-à-vis meteorological data.
- To assess potential impacts of climatic extremes on household food security.
- To identify the initiatives taken and possible adaptation strategies on food security in the context of climate change.
- To explore links between climate change policy provisions & local adaptation.

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Materials and methods

Study area

Makrahar is a village located in Tilottama Municipality of Rupandehi District of Nepal (Fig. 1). On 18th May, 2014, Makrahar was merged to create a new municipality. The total population of the Makrahar is 16,514 and the total number of households is 3,479. Tharu are the major ethnic comprising a population of 4,554 whereas Brahmin, Magar and Chettri comprise population of 2,820, 2,624 and 1,818 respectively (CBS, 2012).

Hinduism is the major religion of the people residing in the study area. Agriculture is the major occupation along with animal husbandry, labor works, etc. Rice and wheat are the major food crops along with mustard and varieties of pulses, maize and millet. Varieties of vegetables are cultivated locally. In terms of education, 56.53% people are literate among which female comprises 48.09%, male comprises 65.8% (CBS, 2064).

Methods

The research methodology encompasses literature review and other widely used techniques and tools for gathering both primary and secondary information. Socio-economic data along with weather/climatic data were gathered from the department of hydrology and meteorology, government of Nepal (DHM).

Household surveys were conducted using simple random sampling method. The research was carried out primarily based on the quantitative data but secondary information was used while validating and analyzing the relationship. Key informants' interview (KII) and focus group discussion (FGD) were conducted to generate the field data. Though the results were examined based on quantitative data but these were further validated with qualitative data. A total of 65 households were chosen using the formula designed by Arkin and Colten (1963). It comes to some 33% to the total households of the ward number 13 of the study area. Some selected participatory tools like transect walks, focus group discussion and key informant interviews were conducted while collecting field data. Climatic data sets were obtained from the Department of Hydrology and Meteorology (DHM). Data analysis was done by using MS-Word, Excel 2007, Minitab17 and Minitab express softwares. Simple regression analysis was performed to observe the trends in rainfall and temperature over season. The results obtained were presented in the form of charts, table and graphs.

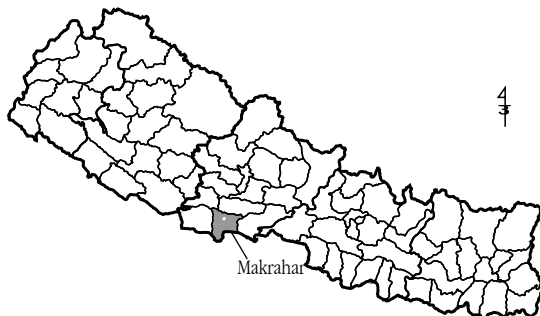


Fig 1 Makrahar village in Rupandehi district

Results and discussion

Climatic data recorded at Bhairahawa meteorological station were obtained for years between 1984 and 2013. Temperature records of the station were missing for September of 1989 and for the time period between June and November of 2013.

Temperature analysis

The analysis of temperature data for 29 years, from 1984 to 2012, recorded at Bhairahawa, close to the research site, revealed that annual mean maximum and minimum temperatures are increasing at the rate of 0.003 °C/year and 0.027 °C/year, respectively (Fig. 2, Table 1). The analysis of mean maximum and minimum monsoon temperature from 1984 to 2013 showed an increasing trend at the rate of 0.037 °C/year and 0.029 °C/year, respectively (Fig. 3). Likewise, the analysis of mean maximum and minimum summer temperature showed an increasing trend at the rate of 0.006 °C/year and 0.036 °C/year respectively (Fig. 4). The analysis of annual mean maximum and minimum temperature during winter season of the same period revealed that the former is declining at the rate of 0.067 °C/year, whereas average minimum temperature was found to be rising at the rate of 0.004 °C/year (Fig. 5, Table 1). The changes in temperature were found to be positively correlated.

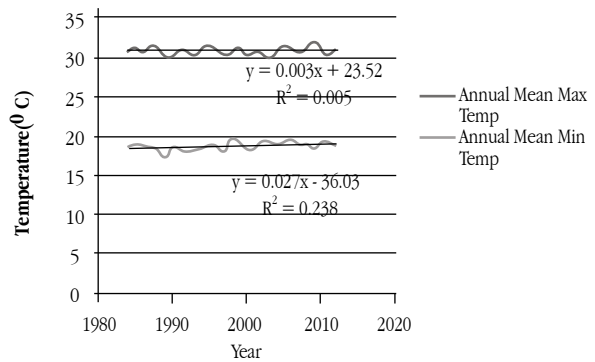


Fig. 2 Trend of mean annual temperature over time (1984-2012)
Source: DHM

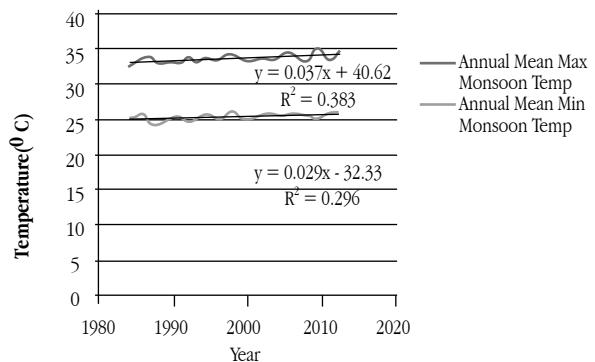


Fig. 3 Trend of mean monsoon temperature over time (1984-2012)
Source: DHM

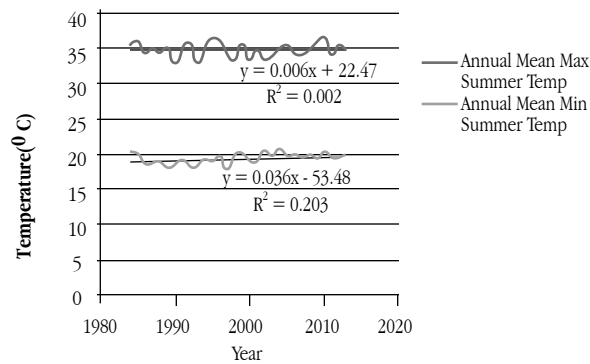


Fig. 4 Trend of mean summer temperature over time (1984-2013)
Source: DHM

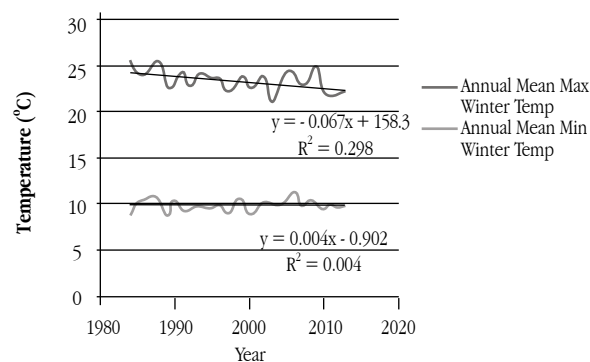


Fig. 5 Trend of mean winter temperature over time (1984-2013)
Source: DHM

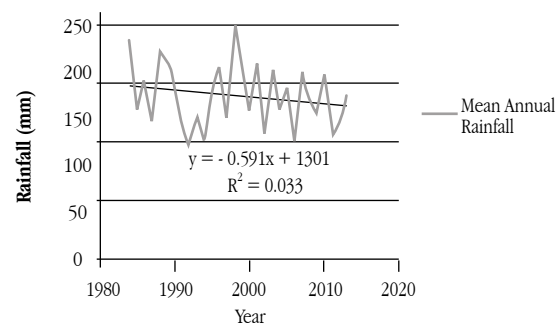


Fig. 6 Trend of mean annual rainfall over time (1984-2013)
Source: DHM

Rainfall analysis

The amount of rainfall varies within 30 years. The rain fall data revealed that the mean annual and mean monsoon rainfall has been declining at the rate of 0.581 mm/year (Fig. 6) and 1.684 mm /year (Fig. 7) respectively. The average summer rainfall was found to be rising at the rate of 0.393 mm/year (Fig. 8).

The annual mean winter rainfall from 1984 - 2013 revealed that winter rainfall is rising at a rate of 0.01 mm (Fig. 9). But, analysis till 2011 revealed decrease in rainfall at the rate of 0.2 mm per year, whereas from 2011, it was found to be decreasing at the rate of 5.6 mm /year ($R^2=1$) (Fig. 10), which implies strong correlation with time. Hence, erratic pattern of winter rainfall was observed.

The net rainfall, changes over time was found to be statistically significant, i.e. $p < 0.05$.

Table 1 Summary results of statistical (simple regression) analysis of temperature data from 1984 to 2013

Change in temp. per year	R ²	p value	Correlation Coefficient
Rise in mean annual min. temp.	0.238	0.007	r = 0.49
Rise in mean min. summer temp.	0.2031	0.0124	r = 0.45
Rise in mean max. monsoon temp.	0.383	0.00045	r = 0.62
Rise in mean min. monsoon temp.	0.2965	0.003	r = 0.54
Decline in max. winter temp.	0.29	0.002	r = -0.55

Source: Primary data

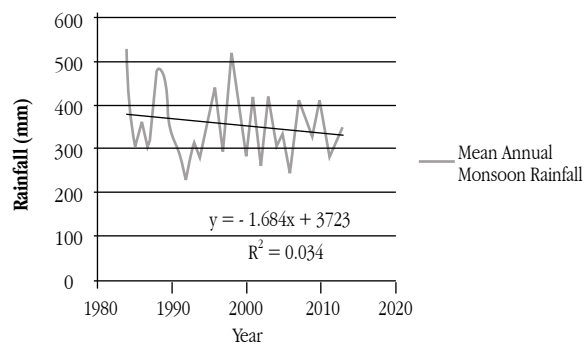


Fig. 7 Trend of mean monsoon rainfall over time (1984-2013)
Source: DHM

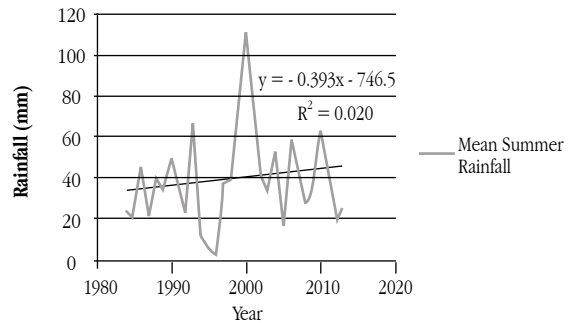


Fig. 8 Trend of mean summer rainfall over time (1984-2013)
Source: DHM

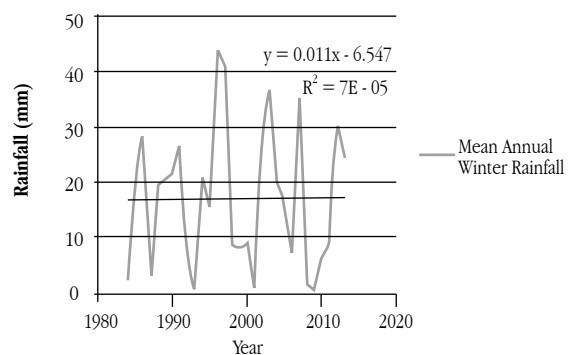


Fig. 9 Trend of mean winter rainfall over time (1984-2013)
Source: DHM

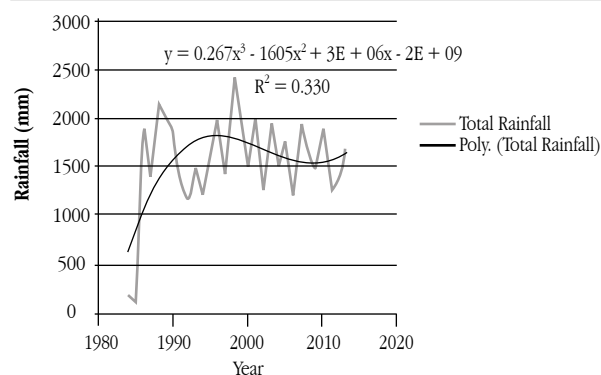


Fig. 10 Trend of total rainfall over time (1984-2013)
Source: DHM

Perception on climate change

Temperature

All 65 respondents felt that both the summer and winter temperature has been increasing over the period of 30 years. But 10 respondents out of 65, opined that there used to be less cold in the past 10 or 20 years, but winter has been colder since last four years.

Cold waves

Among the total, 77% respondents opined that both the volume and extreme cases of cold waves have been increasing since four years affecting their livelihoods along with agriculture.

Rainfall

All the respondents agreed that there has been shift in traditional rain fall patterns (June-September/October) which now has shifted to August-October/November. This is affecting agriculture practices thereby along with the livelihoods of the farmers who cultivate rain fed ecosystem. Majority of the respondents (66%) mentioned variability and uncertainty in both the amount and extreme cases of rainfall whereas others mentioned erratic nature only.

Perceived changes in rainfall pattern

All the respondents mentioned large decrease in total rainfall and number of rainy days along with amount of monsoon rainfall at present as compared to past. In case of winter rainfall, majority of the respondents, i.e. 94% respondents opined that there has been large decrease at present time as compared to past time periods. People mentioned that whenever they required rain for agriculture, they did not receive rain water and vice versa.

Correlation between people’s perception on climate change and meteorological data

People’s perceptions largely agree with the trend analysis carried out both for rainfall and temperature data recorded for 30 years. In other words, food security is very much linked with climatic favorability.

Changes in the productivity of the crops over time

People’s perception regarding changes in the productivity of rice, wheat, mustard, pulses and vegetables over time was known which revealed that there has been large increase in production of such crops and vegetables at present time as compared to the past due to the use of hybrid seeds. It was found that cold waves during winter season have been severely affecting potatoes’ production during recent years which caused farmers to stop cultivating potatoes during the winter season. The majority of the respondents i.e. 34, who grew vegetables, mentioned that there has been double production in recent years in vegetables as compared to past time periods.

Change in crop calendar

All the respondents showed consensus on shifting of planting time of some crops such as rice, wheat and maize, whereas some respondents responded shifting of even mustard, pulses, etc. (Table 2). Majority of the respondents who depend upon the rainfall responded that rice which used to be sown during June-August has been shifted to the time period of July -September (Table 2). Similarly, shift in planting time of other crops were found due to the change in timing, intensity and distribution of rainfall which affected both yield and productivity.

Table 2 Shift in cropping calendar over time at Makrahar

Crops	Earlier cropping time												Present cropping time											
	April/May	May/June	June/July	July/Aug	Aug/Sept	Sept/Oct	Oct/Nov	Nov/Dec	Dec/Jan	Jan/Feb	Feb/March	March/Apr	April/May	May/June	June/July	July/Aug	Aug/Sept	Sept/Oct	Oct/Nov	Nov/Dec	Dec/Jan	Jan/Feb	Feb/March	March/Apr
Rice																								
Wheat																								
Mustard																								
Maize																								
Flax seeds																								

Source: Field survey (2014)

Adoption of high yielding cultivars over time

The study reveals that longer dry spell has affected traditional crop varieties and therefore seeds of those varieties have almost vanished from Makrahar village. To address ever increasing food demand and to cope with climatic stresses, local communities have increasingly been growing high yielding modern and hybrid seeds with the use of external inputs.

Income made from crops at different time periods

The majority of the respondents (28) expressed large decrease, and 6 respondents mentioned small decrease in income through major crops (paddy, wheat and mustard) at present time as compared to past.

Status of food security

In the study area, only 41.54% respondents expressed food sufficiency for last 30 years, whereas 12.31% responded that they had food deficiency during the whole time. At present, 73.85% respondents mentioned that they are food sufficient whereas 26.15% respondents responded that they still face food deficiency. At present, the reasons for food sufficiency was attributed to the use of hybrid seeds, access to irrigation facilities, remittance and off farm jobs aiding in increasing income, double benefit from vegetable farming, etc.

The reason for food deficiency at the present time was attributed to changing climatic patterns like drought, erratic rainfall, unfavorable weather conditions, lack of irrigation facilities, occurrence of insects and the related damages, etc. In 2014, during rice plantation period, rainfall didn't even start until middle of July/August badly affecting rice production and its yield.

Food is accessed either through self production at fields or through local markets nearby. Those who cultivate paddy and wheat depend on markets for vegetables, oil and others, whereas those who cultivate only vegetables depend on market for rice, wheat, oil and others. As roads connect near by highway only, population of Makrahar lack access to big markets which are distant. They need to rely on local markets which opens only once a week at a specific location. So, this creates obstacles especially for daily wage dependent individuals who cannot afford buying stocks of commodities at once.

Due to lack of proper market of wheat, people are bound to shift towards mustard cultivation which ultimately has led to import of wheat from other areas. Only economically sound people were found to be food sufficient throughout the year either through their own production or through their higher purchasing capacity. But poor people, whose production could suffice for few months only, were found to be hampered by the soaring food prices which led them to consume meal only once a day (Table 3).

Regarding utilization of food on the basis of nutrients, it was revealed that the residents of Makrahar consume food with the sole purpose of pacifying their hunger instead of considering the nutritional contents. People were found to be directly consuming ground water without any treatment or boiling procedure.

Variability and uncertainty of weather events was found to be directly affecting the stability of food production at Makrahar ultimately raising question on the sustainability of livelihoods of the residents as majority of the population directly depend on agriculture for their subsistence. Along with it, the poor economic condition of the majority of Makrahar's residents and the problem of price hikes of commodities somehow pave the way for food insecurity especially for the poor population.

Period of food deficiency

Most of the respondents facing food deficiency or who faced food deficiency in the past cited the time period from April/May to September/October as the period of food deficiency; as people rely on rice production and the previous years' rice stocks last for only for short duration. On the basis of food security, FGD exercise revealed four categories of the village people; i. Population having food sufficiency for 12 months (10%), ii. Population having food sufficiency for 9 months (30%), iii. Population having food sufficiency for 6 months (50%) and, iv. Population having food sufficiency for 3 months (10%). Although Rupandehi district is considered food sufficient, in case of local level like Makrahar, the status of food security has not been revealed yet due to lack of studies hereby.

Perceived consequences to livelihoods

During the present time, large increase on scarcity of irrigating water and the need of increased inputs to maintain agricultural productivity was felt by majority of the respondents as compared to the past. Most of the farmers growing food crops were disappointed with the fact that the inputs to the farming encompassing fertilizers, insecticides, pesticides, labor costs, etc. were more expensive than the output. Regarding the number of month of food sufficiency from own farm produce along with return from farming per unit of land, significant number of respondents mentioned large decrease in such case as compared to past.

Table 3 Change in prices of major food crops over 20 years at Makrahar

Commodities	Price at past	Price at present
Rice	Rs. 10/Kg	Rs. 23/Kg
Wheat	Rs. 12/Kg	Rs. 25- Rs. 30/Kg
Pulses	Rs 70-80/Kg	Rs. 130-135/Kg
Oil	Rs. 40/Litre	Rs. 110/Litre

Source : FGD (2014)

Climatic hazards in agriculture

Rainfall hazards

Water logging was found to be one of the major problems in agriculture in Makrahar which damages crops like rice, beans, pulses, etc. through rotting their stalks during torrential rainfall. As there is no proper mechanism for excess water collected in farm during the heavy rainfall to get diverted, water logging and inundations become more severe. Some farmers try to cut off water through canals. Even water logging for short periods can have long term effects on the growth of young wheat plants (Malik et al., 2002).

Floods

During the monsoon season, the risk of flooding by the Rohini river keeps the residents of Makrahar in fear. In 2004, flood has swept away most of the houses and farmland in the Bhupusainik tole in Makrahar.

Drought/intermittent drought

Drought was found to be the major problem in agriculture in Makrahar, where rice and wheat are the major cereal crops for production. All the respondents claimed that it was the major factor affecting agriculture time and again. In 2006, adverse climatic conditions significantly affected cereal production in Nepal, especially in the Eastern and Central Tarai, which was badly affected by drought (Fang et al., 2007). The winter drought in 2009 caused a historic loss by reducing the production of the major winter crops, i.e. wheat and barley nationally by 14% and 17% respectively.

Pests and diseases

Being farmers, since longer generations, people were aware about the increasing incidences of pests and diseases, which have been troublesome as it has directly affected crop production and yield. The majority of respondents (63.1%) responded that there has been large increase of insect/pests infestation on crops compared to past. Malla (2008) indicated that the development and distribution of insects and pest infestation are influenced by rising temperature, rainfall and humidity. It was found that people of Makrahar use organic fertilizers, pesticides, chemical fertilizers etc to control pest problems. Bhandari (2014) revealed that Tarai region have the highest number of households using pesticides.

Cold waves

All the respondents mentioned increase in cold waves' effect on winter crops especially potato which has led most of the farmers to stop growing potatoes during winter. Extreme cold waves somehow drive potato dependent communities towards food insecurity. According to NARC's annual reports, cold waves have caused decline in the production of potato, toria, sarson, rayo, lentil and chickpea crops by 27.8%, 36.5%, 11.2%, 30%, 37.6% and 38% respectively in Nepal in 1997/98 (Malla, 2008).

Senescence

The senescence period of crops in Makrahar has been shortened due to rise in temperature which can be considered as the effect of climate change. People mentioned early ripening of major cereal crops, i.e. paddy and wheat, which were affected as their yield declined. Crop cycle is often accelerated due to heat stress which causes the reproductive phase to commence before adequate resources are stored (Zinn et al., 2010). Rice is one of the most sensitive crop to high temperature particularly during the heading and next sensitive nine days prior heading (Yoshida, 1981). This study also revealed that high temperature during anthesis plays a vital role on the sterility.

Impact on livelihoods

All the indicators of livelihood options revealed that the area is having unsustainable livelihood. The food production is affected directly by drought, water logging conditions and through pest infestation and spread or expansion of new or introduced diseases on food crop species. The lack of irrigation facilities has been one of the most striking factors especially for poor farmers who hardly have capacity to afford costly irrigation. The most of small holder households are bound to shift towards off farm activities. Along with the rising population's demand for more food, majority households are trapped into food insecurity which seems to create imbalance between population, production and food sufficiency. The external migration of the agricultural workers has put additional pressure in local farms production, leading to unsustainable farming.

Adaptation

Though farmers of Makrahar have been adjusting stresses in many ways but the coping strategies were found to be insufficient and inefficient as well in many cases. Many farmers shifted from cereal to vegetable farming, increasingly engaged in off farm activities, shifted their cropping calendar, started using improved high yielding stress tolerant crop varieties and seeds, built temporary water canals, used boring for irrigation in response to climate change impacts. It seems that proper adaptive measures haven't been undertaken by poor farmers especially due to their poor financial condition. The same hybrid seeds under proper irrigation facilities by rich farmers give higher yield whereas the same seeds under lack of proper irrigation give lower yield.

Conclusion

Trend analysis reveals that visible change observed in rainfall and temperature when measured in terms of variability, extremes and timing. The degree of climatic change, however, was found variable over years and seasons within the year. Dry spell and flooding, heat waves and cold waves are the major climatic stressors observed that directly impact livelihood assets and agriculture. This analysis largely agrees with results of peoples' perception data carried out through surveys and focus group discussion. This research results

broadly agree with similar studies carried out elsewhere. Scientists have claimed that climate change has been impacting lives and livelihoods in Nepal (Park, 2015) and so does this study. A shift in rain fall has many fold implications in traditional practices. Implications were seen on the selection of crop species, varieties, planting and harvesting time, quantity and quality of production and the infestation of the crop diseases and pests. Farmers have been using various lifelines to adjust additional stresses posed by climate change. In responses to such stresses farmers have been diversifying options that could be more resilient to stresses. It was noted that farmers have been gradually shifting from traditional cereal cultivation to vegetable farming, absorption of farm laborers in off-farm activities and modification of local practices. However, the response measures have not been proved best which was mainly due to inadequate support provided from the public services.

Among others, the most poor and vulnerable people are hit hardest from the additional stresses posed by climate change. Farmers with limited livelihood assets, poor access to services and lack of capacity to adopt improved or resilient practices are actually becoming more vulnerable. These people could be helped if the government agencies reach out with special adaptation packages as provisioned by several national policies, strategy and vision document and national commitments of alleviating poverty, community resilient development and basic needs. It is recommended to devise the strategy and acts to effectively implement the policy provision and government commitments that reduce poverty and climatic vulnerability.

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References

- Arkin, H., & Colton, R.R. (1963). *Tables for statisticians*. New York: Barnes & Noble.
- Bhakta, G. (2006). Flood threat haunts locals. Retrieved November 7, 2014 from <http://bloggingnepal.blogspot.com/2006/07/flood-threat-haunts-locals.html>
- Bhandari, G. (2014). An Overview of Agrochemicals and Their Effects on Environment in Nepal. *Applied Ecology and Environmental Sciences*, 2(2), 66-73.
- CBS (2012). National Population and Housing Census (2011) Rupandehi. Vol 06. NPHC 2011, Kathmandu, Nepal.
- CBS (2064). District Profile of Rupandehi, 2064.
- Fang, C., Sharma, R., Favre, R., & Hollema, S. (2007). *Special Report FAO/WFP Food Security Assessment Mission To Nepal*. Economic and Social Department. FAO.
- Fernandez-Cornejo, J. (2004). *The Seed Industry in U.S. Agriculture*. Agricultural Information Bulletins. Economic Research Service. Agricultural Information Bulletins. United States Department of Agriculture, Washington, DC.
- IPCC (2014). *Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
- Malik, A. I., Colmer, T. D., Lambers, H., Setter, T. L., & Schortemeyer, M. (2002). Short-term waterlogging has long-term effects on the growth and physiology of wheat. *New Phytologist*, 153 (2), 225-236.
- Malla, G. (2008). Climate Change and its Impact on Nepalese Agriculture. *The Journal of Agriculture and Environment*, 9, 62-71.
- Maplecroft (2010). *Big Economies of the Future*. Maplecroft.
- MoSTE (2012). Integrating Climate Change Concepts into the Science Curriculum for Secondary Level Education. Lalitpur, Nepal: MoSTE, GoN.
- Ministry of Education (2010). National Adaptation Programme of Action (NAPA), Government of Nepal, Kathmandu.
- NARC (2007). Climate change and agriculture in Nepal. Final Report, Environment Unit, Nepal Agriculture Research Council, Khumaltar, Lalitpur.
- Park, M. (2015). With climate change, Himalayas' future is warmer, not necessarily brighter. CNN. Retrieved; January 2, 2015 from <http://edition.cnn.com/2014/12/30/world/asia/nepal-climate-change-himalayas/>
- Regmi, B. R., & Adhikari, A. (2007). *Human Development Report 2007/2008 Fighting climate change: Human solidarity in a divided world*. Retrieved; September 7, 2014, from http://hdr.undp.org/sites/default/files/regmi_bimal_and_adhikari_anu_nepal.pdf.
- The World Bank Group (2014, November 23). "New Climate Normal" Poses Severe Risks to Development—World Bank Report. Retrieved; November 24, 2014, <http://www.worldbank.org/en/news/press-release/2014/11/23/new-climate-from-normal-poses-severe-risks>.
- Yoshida, S. (1981). *Fundamental of Rice Crop Science*. Manila, Phillipines: The International Rice Research Institute.
- Zinn, K. E., Tunc-Ozdemir, M., & Harper, J. F. (2010). Temperature stress and plant sexual reproduction: uncovering the weakest links. *Journal of Experimental Botany*, 61(7), 1959–1968. doi:10.1093/jxb/erq053