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Research Article

Assessment and prioritization of community soil and water conservation measures for adaptation to climatic stresses in Makawanpur district of Nepal

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Abstract

Climate change is the global concern of our sustainable development whose impact is of great concern to humanity. In Nepal, we are already starting to become aware of recent changes and developing the mechanism to adapt. A study was carried out in Bramha Thakur Community Forest User Group of Makawanpur district with an objective of assessing and prioritizing adaptation options by local community using soil and water conservation measures on climate change. Primary data were collected from direct observation, focus group discussion, key informant interview, preference ranking and transect walk. Meteorological data on temperature and rainfall of 30 years was collected from government sources and climatic trend was analyzed. Prioritization of adaptation options was done using Index of Usefulness of Practices to Adaptation (IUPA) tool developed by Debels et al. (2010). Monthly maximum value of daily maximum temperature and minimum temperature has increased by 0.0461^0C and 0.12^0C respectively. Numbers of warm days are increasing. Annual precipitation has increased steadily whereas maximum five days and monthly precipitation trend is increasing at high rate, alarming to hazards induced by climate change. Local people were found very resourceful in using various adaptation practices to deal with impacts of climate change. IUPA scoring provided important rankings on the adaptation options. Conservation pond was highly prioritized for drought management. To adapt with flood, engineering structures with or without vegetation were highly used as adaptation option. Bamboo plantation was highly preferred by local community to reduce the impacts of landslide and to prevent its occurrence. Bioengineering structures are highly recommended for long term stability in flooded and landslide affected areas. Further studies on adaptation options and their prioritization in more areas are recommended for comprehensive database and generalization.

***Key words**: Climate change, Adaptation, Prioritization, Drought, Flood, Landslides*

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INTRODUCTION

The scientific community by now agrees that climate change is real, it will become worse, and the already poor and vulnerable will be affected the most (IPCC, 2007). There is also evidence of more intense precipitation events and an increase in the number of flood days in some rivers while other rivers show reduction in flows in the dry season, with implications for both water supply and energy generation (Shakya, 2003).

In Nepal, observed data indicate consistent warming and rise in the maximum temperatures at an annual rate of 0.04-0.06 degree Celsius. Studies also indicate that the observed warming trend is not uniform across the country. Annual precipitation data show a general decline in pre-monsoon precipitation in far-and mid-western Nepal, with a few pockets of declining rainfall in the western, central and eastern regions. In contrast, there is a general trend of increasing pre-monsoon precipitation in the rest of the country (MoE, 2010). Significant and consistent increases in temperatures and annual precipitation rates are predicted for Nepal in the years 2030, 2050 and 2100 across various climate models (Agrawala et al., 2003). About 80% of the precipitation in Nepal falls within four months of the year; and much of this falls during a few extremely intense rainfall events. The result is too much water during a very short time period, making it very difficult for both humans and plants to benefit from it. Most of it flows quickly through the watersheds and basins of the high mountains and middle hills, causing floods and havoc without much replenishment of groundwater and other natural reservoirs. During the rest of the year, the population struggles to support household needs, agriculture, and industrial demands with too little water (ICIMOD, 2009).

Siwaliks, commonly referred as *Churia*, is the range gradually elevated from Terai plains up to 1,800 metres from the sea level, stretched almost the entire length of the country from east to west. The *Churia* range crosscuts the 33 districts of the country (Oli, 2000).Varied in height and breadth across the length, *Churia* range, however, shares common morphological features: coarse-grained, loose rocks and thin layer of soil, resulting into a fragile topography and, therefore, unsuitable for farming. The land-use data of the Churia hills for 2001 show that, out of the total 1.349 million ha, 8.5 per cent was cultivated, 74.3 per cent forest, 13 per cent degraded or degrading forest, 2.9 per cent exposed forest, 1.2 per cent riverbed, 0.1 per cent river channels and 0.01 per cent wetland. Also, between 1975 and 2001, cultivated land increased by 52.3 per cent (79,813 ha in 1975 to 121,591 ha in 2001), whereas forest area decreased by 3.1 per cent (1,247,129 ha in 1975 to 1,208,813 ha in 2001) in the Churia hills (MFSC, 2008). *Churia* hills generally suffer from the problems of degradation and over exploitation. Degradation is broadly natural and anthropogenic. Soil erosion, flood and landslides caused by torrential rain, forest fire, slash-and burn cultivation, inappropriate agriculture practices, uncontrolled and over grazing, encroachment and unplanned settlements, etc., are the common problems of the *Churia* hills in general. Further, these problems give rise to and manifested in several other problems, viz. loss of biomass and biodiversity, reduced crown coverage of the forest, flash floods, sedimentation and desertification of agricultural land in *Bhabar* and Terai, flooding of settlements. Similarly, losses of lives, landlessness, limited opportunity for livelihood, and further deprivation of the people, are among other problems. Also underlined problems are inadequate understanding of the complexities of the problem, for e.g., treating *Churia* conservation as a standalone problem, disregard of the questions of livelihood of the people depending on *Churia* resources (NPC, 2004).

Human adaptation remains an insufficiently studied part of the subject of climate change (Brooks and Adger, 2003). Emerging evidence indicates that adaptation and coping strategies by the poor in developing countries are highly varied and local-level studies are needed for development policies to be effective (Smit et al., 2007). In Nepal, a few studies have indicated that people do experience increased temperatures and changed rainfall patterns (e.g. Chapagain et al., 2009; Regmi et al., 2009), and that adaptive capacities of poor and marginalized households, and especially women, are low (Oxfam 2009). Vulnerability assessments are useful when, for example, deciding what regions or villages to target for with development programmes.

Over the last couple of years, the global climate change debate has made a noteworthy shift from focussing on mitigation of greenhouse gas emissions to increasing awareness of the importance of adaptation to unfavourable impacts from changes in climate and its variability (Schipper and Burton, 2009). In the context of impact from ongoing and future climate change, it is increasingly important to understand the broad spectrum of adaptation. Historically, most work on climate adaptation has taken a global, large-scale, or sector-based perspective. There is a gap in research on local adaptation processes, and the factors enabling or constraining them (ISET 2008) and a need for studies based on evidence of local adaptation practices.

Adaptation is necessary if we are to manage the risks posed by climate change (New et al., 2011; Smith, 2011). What we know about adaptation, however, is limited. Few studies have systematically examined actual adaptation actions at local, national or regional level. While adaptation is being thought about widely, examples of actual intervention reported in the literature are limited, raising concerns about the likelihood of effective adaptation given the speed of climate change and limited window of opportunity for action (Adger and Barnett, 2009). The majority of the data and studies on climate change vulnerability, adaptation and mitigation are from developed countries—in particular, in temperate climates. There is thus a need to expand the observational series in developing countries and tropical and subtropical climates. Such studies might also increase the knowledge base on vulnerability and adaptive responses in subsistence agricultural systems and rural populations in developing countries (Mertz et al 2009). This need for a better understanding of the actual and potential adaptation needs in developing countries has spurred an increasing interest in adaptation and development policy (Halsnæs et al., 2008; Michaelowa and Michaelowa, 2007; O'Brien et al., 2008).

In order to reduce vulnerabilities, a timely adaptation to probable new environmental conditions under climate change becomes imperative. Climate adaptation refers to a wide range of behavioural adjustments (involuntary or planned) that households and institutions take—including practices, processes, legislation, regulations and incentives—to mandate or facilitate changes in socioeconomic systems, aimed at reducing vulnerability to climatic variability and change (Burton et al., 2002; Leary, 1999). Many of these actions require the formulation and implementation of one or a group of adaptation practices, policies and strategies (Smit and Wandel, 2006). Adaptation practices may vary considerably among regions, countries and social groups: all of these may react to climatic variability and change in different forms. Effective adaptation practices are responsive to a wide variety of economic, social, political, geographic and environmental conditions, so criteria for success may be context specific (Dessai and Hulme, 2007). It is also well established that people are generally resourceful in responding and adapting to climate variability and other external disturbances (Mortimore and Adams, 2001; Thomas and Twyman, 2005).

In this context, this research is designed to filling these research gaps, with an aim to document, assess and prioritize the adaptation of forest dependent communities with soil and water conservation practices to the stresses induced by climate change, and the focus is on the Churia hills region of Eastern Nepal.

MATERIAL AND METHODS

Study area

The study was conducted in Bramha Thakur community forest sub-watershed (fig. 1) in Churia range of Makawanpur district of Nepal. The district is bordered by Dhading and Kathmandu district in the north, Bara and Parsa in the south, Lalitpur and Sindhuli in the east and Chitwan in the west. The subwatershed covers an area of 192.33 hectares, with altitudinal variation from 250m to 500m from mean sea level. It holds 396 households with 2368 human population. The majority of the people are from indigenous community: Rai and Majhi. The main occupation of the people in the subwatershed is agriculture. Simat khola, Ajimgare khola and Tama khola are the major water channels/streams in the area. Drought, flood and landslide are the major natural hazards in the subwatershed, causing local people vulnerable to climatic stresses.

Data collection and analysis

Out of 396 households in total, 60 households (in total 60 respondents) were purposively chosen for key informant interview. Key informant interviews were conducted with village leaders, forest dependent people, individuals affiliated to local non governmental organizations, Community Forest User Group (CFUG)'s committee members and women group members using open ended questionnaire. They were interviewed about their perception on climatic trends, change in occurrence and impacts of flood, landslide and water stress related to climate change and people's adaptation measures to those impacts. Major focus was given to the adaptation options and their effectiveness.

Three focus group discussions (FGDs) were conducted to gather information on past natural disaster events in the area, get people's view on climate change in recent years, its impacts and adaptation measures adopted by local people. The major stakeholders involved in FGD include the mother grous, father groups, pro-poor groups, CFUG members as well as local political leaders.

Direct field observation was conducted along transect in Churiya hills of Brahma Thakur Community Forestry to observe the local adaptation options inside and outside the community forest, and agricultural lands. The research team was supported with two committee members of the community forest.

Monthly temperature and monthly rainfall data of Makawanpur district for 30 years were obtained from Department of Hydrology and Metrology, Kathmandu, Nepal. Trend analysis was carried out using the climatic data for 30 years.

Index of Usefulness of Practices to Adaptation (IUPA) tool developed by Debels *et al*. (2010) was used for the evaluation of the general usefulness of practices for prioritization of adaptation strategies to climate change and variability. Indicators were used for listing and ranking adaptation practices at community level and later, the scores were adjusted with expert opinion. An integrated index value for the IUPA is obtained by multiplying individual variable scores with the assigned variable weight and consequently summing the weighted individual parameter scores (weighted sum).

$$IUPA = \{\sum_{i=n}^{n} (Ci * Pi)\} / \sum_{i=1}^{n} Pi \quad \text{.......(i)}$$

Where,

n represents the total number of criteria (variables),

Ci is the score (value between 0 and 10) assigned to criterion i,

Pi is the weight of the ith criterion in the total index score (value between 0 and 10; an indicator of its' relative importance in the global evaluation of the practice's usefulness.

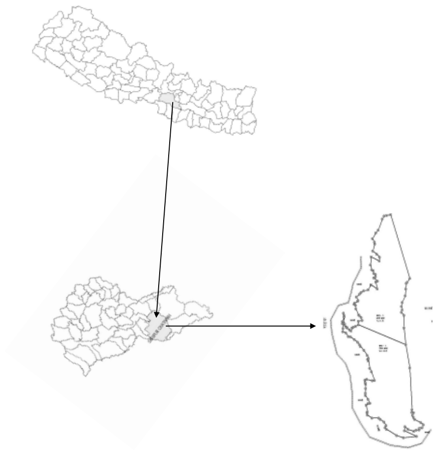

Fig 1: Map of Nepal showing Makawanpur district and study area – The Bramha Thakur Community Forest

RESULTS AND DISCUSSION

Climatic trend

The mean average maximum temperature was found to be around 38.50^0C for the period of 30 years in Makawanpur district. The year 2009 was recorded to be the hottest year with maximum temperature of 39.90^0C in this decade. The year 2004 was recorded to have highest minimum temperature with 26.98^0C in this decade. The maximum valve of daily minimum temperature has been gradually decreasing. The minimum value of daily maximum temperature has declined in year 1993, 1996 and 2002. Despite of this, average minimum value of daily maximum temperature was found to be increasing. The study area had the significant increase in warm days for last 30 years of Makawanpur district. Here fluctuation in number of warm days is seen more in between 1990 and 2010. The number of warm days were maximum (similar to present) in 1996 but it declined rapidly till 2003 again it has risen dramatically to reach maximum. A number of warm days were below 5 in 1980's whereas it reached to more than 20 at present. The number of cool days is decreasing in significantly. Number of cool day were maximum in early 1980's i.e. nearly 25 then after no recording more than 10 has been done so far. After 2006 cool days are always less than five in a year.

Maximum one day precipitation fluctuates regularly in between 1980 and 2008. It reaches to maximum in year 2001. Similarly it was recorded lowest in early 1980's, however there was significant increase in maximum one day precipitation in Hetauda. Maximum five days precipitation has reached to maximum in year 2001 and hited to the lowest in 1991. Even though it fluctated regulary throuh out 30 years the precipation has increased significantly. The study site has the slight increasing trend of number of heavy precipation days in Hetauda. The highest number of precipitation days was around 75 in year 2001, but after this, days were found to be declined. The study area shows the increasing trend of one month highest precipation in hetauda. One month highest precipitation fluctuated significantly with 1600mm being highest recorded in this decade where as trend increases more rapidly in last 15 years. There is increasing trend of total annual precipitation in Hetauda. Annual total precipitation fluctuates regularly in last 30 years. In year 2003, highest amount of rainfall was recorded i.e. 3300 mm. There is increasing trend of consecutive dry days in Hetauda. Consecutive dry days had gone up to 75 days in year 2001. These days were around 60 in 1980's. There is a slight decrease in number of consecutive wet days in Hetauda. The numbers of consultative wet days were recorded to be 22 in last decade whereas it was just 18 in this decade. Year 1989 was recorded to have lowest number of consecutive wet days in last 30 years.

Adaptation practices to water shortage in agricultural lands

Water shortage for drinking and irrigation due to drought was a major issue in local community. The major adaptation practices to too little water in agricultural lands include conservation pond construction, water source protection, construction of irrigation channel and modification of cropping practices. The ranking of the adaptation practices is summarized using IUPA index as below:

Table 1: Preference for adaptation practices to water shortage in agricultural lands

S.N.	Adaptation practices to water shortage	IUPA score	Preference
1	Conservation pond construction	8.30	First
2	Water source protection	8.00	Second
3	Modification of cropping practices	7.45	Third
4	Construction of irrigation channel	7.19	Fourth

Two conservation ponds were constructed in the subwatershed to store water. The stored water was used for irrigation in agricultural lands. Local people depend on only one source of water inside community forest. They have adapted to this water shortage by proper protection of this water source. Local community had developed a punishment policy for the persons who conduct any activities towards degradation of the water sources. The vegetation around the water source was protected, and cultivation of grasses was observed. Generally protection of forest is the main way to conserve the sources of water. The local people informed that the vegetation cover helped to maintain water level, reduce runoff and sediments in the water and maintains landscape intact. Protections through sub-committee, control grazing and daily visit of forest by forest guard (*daily Laure Palo*) were successful.

Local people had adapted water shortage in irrigation by constructing one large irrigation channel connecting to the nearby stream. Most part of the channel is cemented and some parts still need to be cemented, which directly helped to reduce the drought impact. Even though it does this, cost of maintenance was high as well as water supply was still insufficient. Similarly second one was under the way of construction but due to limited fund it has not been completed yet. Farmers have practiced rotational irrigation, 7 days rotation, for each farmer. Hand pumps are also used as coping measures to water stress to lift water from ground water storage.

Farmers have adapted to climatic stresses by altering the cropping pattern. Farmers have gradually shifted perennial crops towards the vegetable and fruit species cultivation. Similarly plantations of drought resistance species were also practiced by local community as adaptive measures against drought. Plantation of maize in late march or early April, plantation of hybrid species of paddy *(Ghorakhnath, Champion)* etc. were common.

Farmers used late cultivation- January cultivation was shifted to April to catch the rains. Legumes were integrated much than previous to improve soil productivity. Minimum tillage with mulching was adapted to conserve soil moisture and reduce erosion. Bunds have been developed in the agricultural lands/terraces to improve rainwater retention in the field.

Adaptation practices to soil degradation in landslide areas

There were about 7 small landslides in the subwatershed. The scale of damage was different in different areas. Last year there was large landslide near to higher secondary school which was immediately treated by local people by engineering structures and bamboo plantation. Adaptation measures were more seen effective to reduce the incidence and effect of landslides. The ranking of the adaptation practices is summarized using IUPA index as below:

Table 2: Preference for adaptation practices to soil degradation in landslide areas

S.N.	Adaptation practices to soil degradation in landslide areas	IUPA score	Ranking
1	Bamboo plantation	8.70	First
2	Bio engineering measures	8.56	Second
3	Construction of engineering structures	7.27	Third
4	Control grazing	6.30	Fourth

According to farmers, bamboo can grow in diverse soil types. It grows fast to catch the soil and generates fodder as well as the income sources for local people. In this subwatershed, plantation of bamboo was carried out in river banks, open sloppy land, landslide base and frequently flooded area. After the plantation of bamboo, number of flood and landslide damage incidents has been reduced.

Construction of engineering structures such as spurs, embankment, gabion/loose stone check dam was one of the effective tool to adapt with landslides. Area where soil was available for plantation of bamboo, vegetable, amliso etc. bio engineering was practiced. Plantation of bamboos, amliso, fruit species in combinations with spurs, embankments etc. were seen frequently inside and outside community forest.

Grazing was totally controlled in this community forest by general assembly of the members. When grazing was controlled, trampling and channel erosion was significantly controlled, so now they are adapting this tool as adaptive measures against landslides.

Adaptation practices to land degradation in flooded areas

Churia range contains high number of seasonal rivers that flood quickly form north to south carrying gravels and sand. In this Community forest also, there are more than 4 seasonal streams that flow from forest along amidst settlement and agriculture field. People were more affected by flood prior to establishment of this community forest. But now impacts of this hazard seem to be reduced. The ranking of the adaptation practices is summarized using IUPA index as below:

Table 3: Preference for adaptation practices to land degradation in flooded areas

S.N	Adaptation practices to land degradation in flooded areas	IUPA Scoring	Ranking
1	Construction of engineering structures	8.39	First
2	Bio engineering	7.96	Second
3	Bamboo plantation	7.88	Third

Areas near to river of side of river were mostly affected by flood. Constructions of Spurs, embankment, gabion check dam etc. were mostly seen in study area. Area where river velocity was required to break there was gabion check dam, area where river need to be diverted there was spur and protection of wings of river was done with spurs.

Bamboos were planted in area where sail was collected after successful establishment of engineering structure. Plantation of bamboo in area where intensity of flood was high resulted in failure of bamboo even though it survived. But after 4-5 years of establishment of bamboo flood velocity was highly broke down.

Plantation of bamboo, fruit species, amliso etc. was seen common practice for poor and marginalized people. This option directly reduces the flood velocity as well as income was also possible through this measure. But in this process only small engineering structure where flood velocity was not much great were seen. Among the measures plantation of bamboos with gabions check dam and amliso with spurs were frequently seen during field observation.

Diversion of flood by planks, timber and loose stone in other direction is major practice to reduce streambank cutting by the flooder stream. Brushwood check dam was constructed with the use of local woody materials and stone to prevent channel scouring. Extraction of all obstructing object/material on flood way was also practiced so it could drain as fast as possible.

Different types of adaptation practices are found in Himalaya and Terai region of Nepal. In Himalayan regions people have reduced the livestock numbers as well as practiced rotational grazing and changed the occupation such as hotel business or migration from that place in adapting to adverse impacts of climate change on their livelihood assets. Furthermore, in Mountain and Siwalik region, local people have been managing forest as a community forest, Sloping Agriculture Land Technology (SALT) as an agroforestry (Horti-Silviculture) practices in their steep land and vegetable farming instead of cereal crops as crop diversification, livelihood diversification, modifying the practices to better adapt in context of changing climate. Utilization of marginal land by plantation of fodder trees, fruit trees and other grasses etc. is common in mid hills of Nepal. People have been using rainwater harvesting, conservation pond and utilization of excess drinking water for vegetable production. There is trend of replacing local varieties of crops with hybrids, which in long run can threat to the agro-biodiversity, though may provide short term good outcomes compared to local races. Additionally, those affected from loss of land from flooding and river bank erosion in the last downpour rainfall events (1986 and 1993) were moved to encroach nearby forest land for agricultural cultivation and settlement in the foothills of the Siwalik region. Moreover, communities have formed many groups such as Mothers' group, Community Forest User groups, Buffer zone User Groups, Community Managed Cooperatives, Vegetable farmer's group for community level works such as, natural resource management, awareness rising, and cleaning and fund collection to improve their livelihood assets in context of changing climate. These local groups can become potential institutions to community as well as local level adaptation measures in the future. The presence of many institutions influencing each and every aspect of the community works is critically important in the design of adaptation projects (Tiwari *et al*., 2010; Agrawal et al. 2003). This study has explored similar adaptation practices at local sub watershed level.

Coping strategies like encouraging short rotation commercial crops to annual crops, seed storing mechanism, mixed cropping practices, use of chemical fertilizers to enhance productivity etc. have been adopted to combat with the risk of drought. Change in crop planting time, type of crop, plantation of various plants in home garden, using improved stove, collection of rain water, protection of forest, construction of irrigation channel from nearly torrent and soil conservation through embankment construction are the adaptation measures in western part of Nepal (Bhatta, 2011).

In Nepal very urgent need is to reduce the problem faced by smaller farmers through drought & food, pest & diseases & hail, such as construction of rain water harvesting structures, change in crop pattern etc. which is followed by reduction of climate disasters (flood, landslide, hailstorm etc.) by construction of check dam, spurs, reforestation of denuded hills. The third priority should focus on providing early warning and forecasting of weather, seasons & providing the information to community so that they can make decision in advance to minimize or avoid disasters (Gurung, 2009). It is reported that activities such as awareness on climate change causes, impacts and adaptation, drought resistant varieties of seedlings should be distributed and reforestation and afforestation programs should be distributed to adapt with climate change have got more priorities in hilly area (Khadka, 2011).

This study is in line with the previous findings mentioned before, and the adaptation practices have been prioritized as new initiative.

CONCLUSION AND RECOMMENDATIONS

Analysis of temperature for last 30 years showed that there was an increase in Monthly maximum value of Daily Maximum temperature, Monthly minimum value of daily maximum temperature and number of warm days in Makawanpur district. In contrast, Monthly maximum value of daily minimum temperature and number of cool days were found to have declined. Similarly temperature after 1995 had increased more than compared to past years. So drought impacts were more severe after 1995. Analysis of precipitation data for last 30 years showed that there was alteration in precipitation pattern. The numbers of consecutive drought days had increased and maximum one day and five days precipitation had also increased along with increase in annual precipitation, which caused increase in floods and landslides events in recent 10 years than during past 20 years.

Local people used local techniques in adapting to adverse impacts of climatic stresses. Soil and water conservation measures using local available materials were used with community volunteer effort. Adaptation measures adopted for drought were conservation pond, conservation of water resources, construction of irrigation channels, and change in cropping pattern. Among these measures, local community highly prioritized for conservation pond for conservation of water due to limited availability of water resources. Adaptation measures for floods were construction of engineering structures, bamboo plantation and bio-engineering measures. Among these adaptation measures construction of engineering structures with or without vegetation was more preferred by local villagers. Adaptation measures for landslides with preference ranking were bamboo plantation, bio engineering measures protection of forest, construction of engineering structures were seems to have impacts. Local people have immense knowledge on coping and adaptation to climate change impacts using soil and water conservation measures. Further studies on effectiveness of the measures adopted by the community at local level in various sites will provide more comprehensive information for selecting appropriate adaptation measures at community level.

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