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Integrated Approach to Climate Change Adaptation

Gehendra Bahadur Gurung
Practical Action Nepal
Dinanath Bhandari
Practical Action Nepal

Satdobato, Lalitpur
PO Box: 12207, Kathmandu, Nepal
Contact number: +977 1 5552924; 5550631 **Fax:** +977 1 5535190
Email: forestaction@wlink.com.np; **URL:** www.forestaction.org

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Gehendra Bahadur Gurung* and Dinanath Bhandari*
Practical Action Nepal
Corresponding author: gehendra.gurung@practicalaction.org.np

Abstract: Nepal's temperature is rising faster than the global average, with a higher rate in the Himalayas. Precipitation is becoming unpredictable, resulting in extremities. Poor people, who are dependent on the nature for their livelihoods, suffer from the impact of climate change and have to struggle hard to cope with it more than others. This paper summarizes the key insights drawn from a project carried out by Practical Action Nepal. The project appraised the community perception of climate change, its impact, the coping strategies adopted by the communities and the need for adaptation through participatory approach. Community-based adaptation activities were implemented to respond to the climate change and its impact. The lessons from the project indicated that climate change adaptation requires an integrated approach, including socio-economic development, environmental conservation and disaster risk reduction.

Key words: Climate change, adaptation, vulnerability, watershed, sustainable development, integrated approach, disaster risk reduction, resilience

INTRODUCTION

Between 1977 and 1994, Nepal's average temperature rose at a rate of 0.03-0.06 Celsius per annum, with a higher rate in the mountains than in lowlands (Shrestha *et al*. 1999). Another report of the Government of Nepal (GoN), based on an analysis of the temperatures recorded between 1981 and 1998, shows an increase of 0.41^{o} Celsius per decade, (HMGN 2004). Although the analysis is based on data for a relatively short period, it shows that Nepal is warming at a significantly higher rate compared to the global average of 0.74^{o} Celsius, recorded in the twentieth century (IPCC 2007). In addition to increase in annual averages, extreme temperatures have been observed in recent years. Both days and nights are becoming warmer, while cool days and nights are becoming less frequent (Baidya *et al*. 2008). In December 2005, Dadeldhura and Dang in western Nepal recorded the ever highest temperatures for the month, while Taplejung, Dhankuta and Biratnagar in east Nepal and Nepalgunj and Dang in west recorded the ever lowest temperatures for the month of December (Rajbahak 2006). Dang recorded its ever highest and lowest temperatures for the same month, signifying a shift towards extreme temperatures (ibid).

On the other hand, there is no distinct trend regarding precipitation changes in Nepal. There are, however, regional and seasonal variations in annual precipitation (Shrestha *et al.* 2000). Observations show that high rainfall regions and seasons are recording increases in precipitation and becoming wetter, whereas low rainfall regions and seasons are recording decreases in precipitation and becoming drier (HMGN 2004). Both the number of monsoon days, with early onset and late withdrawal, and the intensity of monsoon rain have shown an increasing trend (Sharma 2006). The non-monsoon season of November 2005–May 2006 was the driest period during 1968–2006 (ibid). Monsoon extremes have been observed in recent years. Nepalgunj in western Nepal recorded the ever highest rainfall of 336.9 millimetres (mm) in twenty-four hours, on August 27, 2006 (SOHAM 2006). The 2006 monsoon record showed the wettest for Nepalgunj for the last 123 years (Sharma 2006). The precipitation extremes show increasing trend in intense precipitation events at most of the stations (Baidya *et al.* 2008).

IMPACT OF CLIMATE CHANGE IN NEPAL

The climate is changing in Nepal, like elsewhere in the world. Climate variability is natural. However, the current change is not natural, but due to human activities. The average temperature and the rainfall pattern have changed, which is not variability, that is to say, it is not natural but induced by human activities. The Intergovernmental Panel on Climate Change (IPCC) has confirmed global climate change, including in Nepal, and Nepal's reports cited above corroborate climate change in Nepal. Climate change impacts every aspect of nature and human life, and is predicted to continue. This section will highlight the impact of climate change in Nepal on: a) glaciers and water resources, b) agriculture, c) biodiversity and natural resources, and d) water-induced disasters.

Glacier is a much highlighted subject when discussing the impact of climate change in Nepal. Compared to other aspects, several studies have been carried out on glaciers in Nepal. Studies show that Nepal's glaciers are retreating faster than the world average (Dyurgerov and Meier 2005), and the number and size of glacier lakes are increasing along with increase in temperature. Glacier AX010 in Shorong Himal retreated by 30 m between 1978 and 1989 (Fujita *et al.* 2001), and most of the glaciers in Khumbu region retreated by 30 to 60 m between 1970 and 1989 (Yamada *et al.* 1992). Glacial Lake Outburst Flood (GLOF) is the most likely and serious hazard because of the increasing size and number of glacial lakes following a glacier melt. Nepal experienced disasters from GLOFs in 1985: from Dig Cho Glacial Lake, which washed away Namche Hydropower

Plant, several hectares of cultivated land, bridges and houses, and caused human and livestock deaths (WWF 2005). The flood lasted for six hours, surged 10–15 m deep, and affected more than 90 km downstream (ibid). In addition to formation and outburst of glacier lakes, there are evidences of disastrous avalanches and icefalls, which could be associated with increasing temperatures. A massive icefall in August 2003 blocked the Madi river in Kaski district at its source for several hours, damaged agricultural lands and crops, and killed livestock. It reached more than 50 km downstream, killing one person when the blockade burst1.

The climate change has impact on both quality and quantity of water resources. The discharges of snow-fed rivers have fluctuated in the past. The analysis of the discharge of the Koshi river in eastern Nepal during 1947–1994 showed a decreasing trend during low flow season (Sharma *et al,* 2000), whereas the discharge of the Kali Gandaki river in western Nepal increased by about 1% annually during 1964-2000 (Shrestha 2004). The discharge of glacier-fed rivers is projected to increase for some time in the future, as glaciers melt and subsequently decrease after the snow and glacier become smaller and smaller (ibid). The increase and subsequent decrease will have serious impact on hydropower plants, groundwater recharge and agriculture in downstream areas, together with disturbing the local hydrology and aquatic life. The decrease in reservoir water volume in some hydroelectric power stations in Nepal might have been a result of the observed changes in the precipitation behaviour, which resulted in less net water percolation and storage in the ground. Less water is reaching groundwater reservoirs due to erratic rainfall and increase in evaporation despite the increase in total annual precipitation.

The water springs in the mid-hills of Nepal have been drying up in the recent past. The GoN publicly announced a 45% decrease in spring flows, which are the sources of drinking water for Kathmandu valley.2 The intensive monsoon does not provide adequate recharge to groundwater reservoirs, despite high total precipitation as most of the precipitation ,leaves the site through surface runoff. On the other hand, the decrease in precipitation during the dry season has an adverse impact on groundwater recharge.

Agriculture, the mainstay of over 80% of the Nepalese population (CBS 2001), has been affected by both warming and uncertainty of monsoon. The increase in temperature has both negative and positive impact on agriculture. As the climate warms, farmers living in high altitudes, such as Jumla district (2,700 masl), can now grow two crops, rice and barley, a year. There is also potential for bringing new land under cultivation in higher elevations. The warming in higher elevations has also created climate conducive to increasing crop intensity. However, thinning snow deposition and retreating snowline have awakened the farmers to the threat of future water scarcity in the region. The prospects of bringing new land under cultivation by clearing the vegetation have also threatened biodiversity conservation in high altitude areas through habitat destruction, degradation, fragmentation and loss. Important habitats will be displaced by croplands. The relationship between crop yield and climate change has yet to be investigated. However, it is worth noting that statistical models predict increase in the yields of C4 crops and decrease in the yields of C3 crops with increase in atmospheric CO2 concentration through potential carbon fertilization effect and warming.

Out of the 2.64 million hectares (ha) of cultivated land in Nepal, only 43% has access to irrigation facilities, of which only 70%, 20% and 10% get irrigation water in monsoon, winter and spring seasons respectively (ADB 2004). The remaining land completely depends on natural precipitation. The crop yield has strong relationship with the amount of precipitation at the right time. The yields of wheat and rice in Kaski district declined over three consecutive years, 2003 to 2005, because of decrease in precipitation (Regmi and Adhikari 2007). But excessive rainfall causes floods and affects crop yields adversely (Gharti Chhetri 2005).

Studies have shown early onset and late withdrawal of monsoon (HMGN 2004). But the actual monsoon month and the main rice planting months are becoming erratic. Farmers of Kabilash VDC in Chitwan could not transplant rice for two consecutive monsoons of 2004 and 2005 because of dry months.3 Some farmers shifted from paddy to banana cultivation, as banana is more resilient to erratic precipitation (Gurung 2007). The late withdrawal of monsoon is affecting the crops at harvesting stage. In 2006, rains in October destroyed paddy at harvesting stage. The farmers are experiencing an increase in such incidents.

No study has been conducted in Nepal on the impact of climate change on biodiversity. However, local people have observed some anomalies in the growth pattern of plants, such as sprouting and onset of flowers. Aita Bahadur Lama, a farmer from Kabilash, Chitwan district, observed early sprouting and flowering of *Pipal (Ficus religiosa)* and *Simal (Bombax ceiba*) compared to their normal seasons.4 Gyalpo Gurung, a local resident of Humde, Manang district observed greening of pastures in high altitudes (3,000–4,000 masl) much earlier than the normal season.5 Furthermore, Gurung also observed shifting of alpine grassland towards higher altitudes and emerging of new pine forests on de-glaciated and glacial retreated areas. The impact of such phenomena on human life has yet to be understood. However, the biodiversity in high altitude areas is likely to be significantly affected by climate change as the soil productivity there is too poor to support plant growth and there is limited space for further upward shifting. Such vertical shifting of ecological zones will negatively affect both flora and fauna.

The changed intensity and amount of monsoon rains positively correlate with the increase in water-induced disasters like floods and landslides (Ministry of Home, quoted in DWIDP 2006). Extreme precipitation events account for increase in hazards. Intensive rainfall was the main cause of landslides in Laprak, Gorkha district, in 1999 and Nepane, Kaski district, in 2006. Laprak received 341.8 mm of precipitation between 4 pm and 7 am on July 3, 1999 and Nepane received 128 mm between 11 pm and 12.30 am on July 15, 2006 (Gurung 2006). On August 26–27, 2006, a heavy downpour exceeding 300 mm within twenty-four hours induced massive flooding in Nepalgunj, costing millions of rupees in relief and rescue activities (SOHAM 2006). Although anthropogenic activities might have contributed to some extent, the incidence of water-induced disasters is increasing despite the increasing efforts of the government, communities and development organizations to minimize such disasters. Local people have also perceived an increase in the frequency of intensive rainfalls, which is substantiated more by increasing climatic extreme events in recent years.

Frequent floods and landslides due to intensive rainfall affect the quality of water. On August 26–27, 2006, in western Nepal heavy floods were followed by outbreaks of diseases, including gastroenteritis, eye infection and pneumonia (SOHAM 2006). As the wet season is becoming wetter, water quality is likely to worsen. Human health will be affected adversely in the dry season because of lack of water for sanitation as the dry season becomes drier, where as there is already lack of water for sanitation (Erickson 2006).

A plant disease vector, *Citrus Scylla*, has been recorded above its normal habitat range, which is usually below 1,000 masl.6 Although the vector might have developed new genetic characteristics for cold tolerance, warming in higher altitude could be a strong factor. This has increased the probability of occurrence of vector-borne plant diseases in higher ecological zones, which were once free of such diseases.

The First Communication Report of Nepal to the IPCC showed increasing evidence of malaria, *Kalajar* and Japanese Encephalitis (HMGN 2004). However, their correlation with global warming is yet to be established.

THE PROJECT AREA

Chitwan district in Central Nepal was selected for the project as the district's total annual precipitation has been above the national average in the last few years (Koirala and Thapa 2005), showing extreme precipitation events, which exceeded 300 mm in twenty-four hours. Jugedi Khola watershed was selected for the implementation of the project based on the following factors: a) severity of climate-induced disasters, b) vulnerability of the community to disasters, c) priority of Chitwan District Development Committee (DDC), and d) ability of the project to address the community's expectations (Koirala and Thapa 2005).

The watershed is located at 270 45' 31" to 270 47' 41" N and 840 29' 03" to 840 30' 45" E with an area of 12.21 sq km (Shrestha *et al*. 2007) in the lower Mahabharat zone. The climate of the area is subtropical monsoon. The meteorological records at Rampur, the nearest station, approximately 19 km south-west, show an annual average maximum temperature between 29^{o} and 32^{o} C and minimum temperature between 16 and 19^{o} C (DHM data 1971-1986). Extreme highest and lowest 24 hour temperatures have been recorded at the station to be 43^{o} C and 1.6^{o} C between 1987 and 2000. The average annual rainfall of the area for 24 hours was 1,995.5 mm for the period 1971-2000. The watershed includes parts of ward no. 1, 7 and 9 of Kabilash VDC in the district. There were 183 households in 2005 (Gharti Chhetri 2005), 185 in 2006 (Practical Action Nepal 2006) and 187 in 2007 (Shrestha *et al.* 2007), showing a rising population trend.

Crop farming and livestock keeping are the mainstays of the majority of the Nepalese people. Daily wage labour, vegetable farming, off-farm employment, fruit farming and pension are the main complementary income generating activities (Table 1). Although liquor-making and selling was not reported during the discussions with the communities, field observation showed this activity to be a major income-generating activity of the communities. Only 31% of the households in the area produced sufficient food grains to meet their whole year need (Practical Action Nepal 2006). The rest of the households had to purchase food either from the local market or from their neighbours to supplement their on-farm production.

Table 1: Livelihood Options in the Project Area

S.N.	Livelihood options	No. of households
1	Agriculture (crop farming)	183
2	Livestock (excluding poultry)	173
3	Daily wages	46
4	Vegetable farming	42
5	Off-farm employment	36
6	Fruit farming	16
7	Pension	8

Source: Gurung 2005

A vulnerability context analysis of the area indicates that 99% of the respondents had reported landslides and floods as major hazards in the area (ibid 2006). The communities believed that the erratic rain pattern in the area had induced landslides. Floods had affected over twenty-five households in the area since 1966 (Table 2). Soil erosion, landslides, floods, lack of irrigation facility and seasonal droughts could be attributed to climate change. These vulnerability contexts have significant importance for the wellbeing of the communities.

Table 2 indicates that the return period of the flood is becoming shorter. Local people reported of an increasing trend in the incidence of floods. There are some direct anthropogenic activities that make the area prone to floods, including deforestation and cultivation of marginal lands, to meet the growing food demand. However, local people perceived erratic rainfall as equally responsible for intensifying the flood problem. Destruction of land by floods and landslides and subsequent decline in land productivity had forced people to occupy forest land, cultivate steep lands and seek alternative means of living.

A baseline study carried out by Practical Action Nepal in 2006 shows that over the past decades, local people have experienced hotter summers. Winter is slowly becoming shorter. The rainfall is erratic and there is an increasing trend of intensive rainfalls, inducing landslides and floods. Ninety-eight per cent of the people have perceived a change in climate, of whom 95% have perceived increasing droughts and erratic rainfall as the main indicators. Although people have experienced change in climate and its impact, they lack awareness of climate change, its causes and impact on different aspects of life and ecosystem and, therefore, need for adaptation.

Despite various vulnerability contexts, the communities were adopting a number of coping strategies. The first preference of coping or adaptation strategies was short-term in nature, which give immediate relief. Because of lack of resources and awareness of chronic impact of climate change, the communities had not been able to undertake long-term strategies.

MAJOR IMPACT OF CLIMATE CHANGE AND ADAPTATION STRATEGIES

Nepal is highly vulnerable to climate change impact due to a number of factors, including: a) higher rate of temperature increase compared to global average, b) exposure to all types of climatic conditions, c) high dependence on nature-based livelihood and economic activities, d) steep topography, e) fragile geology, f) inadequate human resources, and g) poor economy.

Impact of climate change in a locality is a product of diverse factors, including the intensity of climate change, geological conditions, geographical location, socio-political and economic factors. Climate change affects all aspects of human life and natural system. The coping and adaptation strategies to climate change, therefore, demand integrated approaches, both within and between the natural ecosystem and the socioeconomic system. In a hill area, integration can be carried out more effectively with watershed-based approach at grass roots level. In this paper, lessons learnt will be discussed based on the activities carried out in a watershed with integrated approach.

Table 2: Occurrence of Flash Floods in the Project Area

Year	Return period	Events	Effect	Response
1966		Flood	Flood on Jugedi river swept away people	No support from any organization
1983	17 years	Flood	Productive irrigated lands and watermill damaged by floods on Kholaghari river	No support from any organization
1993	10 years	Flood	Productive irrigated land damaged and three people killed by Jugedi river	No support from any organization
2003	10 years	Flood	5 people, 25 goats and some buffaloes killed by floods on Isti river 8 people, 55 goats, 3 buffaloes and 3 oxen killed, and 5 houses and about 2.6 ha of cultivated land destroyed by flood on Jugedi river About 7.8 ha of cultivated land destroyed by flood on Bharlang river	DDC and Red Cross supported the victims
2006	3 years	Flood and landslides	Loss of 12.33 ha of land with a minimum value of NRs 5.55 million by flood and landslides* Destruction of 5 irrigation channels	Rehabilitation of irrigation channels by Practical Action Nepal

Source: Practical Action Nepal 2006

* US$1.00 = NRs 66.00 (approximate)

In the adaptation process, coping strategies constitute the short-term activities, while adaptation strategies constitute the long term activities. As the first step, communities try to modify their existing practices to better respond to the impact of climate change. At the second step, they seek alternative livelihoods. In order to address the community needs for adaptation, programmes and activities also need to be designed accordingly. The following is a list of major activities for both coping and adaptation programmes: a) agriculture and livestock development; b) water resources management; c) forest, land and soil conservation; d) income and livelihood diversification; e) local infrastructure reconstruction; f) awareness and education; and g) institutional development.

The ultimate strategy is to develop the capacity of the community to cope with the impact of, and adapt to, climate change by building their livelihood resilience, diversifying of their livelihood options, conserving resources and reducing in disaster risks associated with climate change.

Agriculture and Livestock Development

Coping with erratic rains

The erratic rainfall pattern had affected regular rice cultivation. Farmers were looking for alternative crops that could be produced under erratic rainfall conditions. Some farmers had replaced rice with maize because that was the best alternative in hand. The main reason for such a replacement was not for the value of the maize produce, but to prevent their farmlands from lying fallow. However, some farmers wanted to grow fruits and vegetables, which generated good income, with which they could meet their needs. Certain factors were considered separately by each farmer in deciding what fruits to grow. Those factors included ability of the fruit tree to thrive under erratic rainfall condition, provide early fruits and having a good market value. Banana was identified as the most suitable species on account of its performance on each of these three factors. For instance, in terms of monetary value, banana has an edge on cereal crops like rice, maize and wheat. The type of best species, however, depends on the local climate change and socio-economic conditions.

Coping with shrinking land

Shrinking cropland calls for intensive farming of the remaining land by increasing the number of crops with high-yielding and fast-growing varieties in a year or shifting to high value crops. However, the number of crops in a year can be increased only if there is improvement in water management, as the rainfall had become erratic and irrigation facilities had been destroyed by floods and fallen debris.

Enterprising agriculture

Local people were encouraged, trained and supported by Practical Action towards commercial agriculture by producing cash crops for the market. The community was also supported by Practical Action in the marketing of crops. Such support had helped enhance the accessibility of households to income-generating activities, thereby improving their resilience to the impact of climate change.

Diversifying agriculture

Farmers had also been supported by Practical Action in livestock-keeping. Training was provided to the local people in livestock health management. Communities noted an increase in evidences of endo-parasites in the livestock in the village, which used to occur only in lowlands in the past. Although no systematic study has been done on the relationship between climate warming and increase in parasites in higher altitude, climate warming could be a strong basis of this evidence.

Practical Action had also supported farmers in training and goat farming. A 'transfer of ownership' scheme had been introduced in goat farming. Under this system, as soon as a 'seed' goat gave birth to a kid goat, it was handed over to another household. Communities were provided twenty-four seed goats to initiate the programme. A community livestock insurance scheme had been introduced, in which replacements were provided for goats dying accidentally. In this system, the household receiving a goat deposited NRs 100.00 (US$1.50) to the committee for insurance. If there was no need to reimburse the cost for the goats, the community could use the accumulated fund for the implementation of climate change or adaptation activities. Goat-rearing was linked with the promotion of Sloping Land Agriculture Technique (SALT) and fodder plantation to minimize the dependence on natural forest for fodder.

Local people were also encouraged to sell their surplus milk in the market for earning additional income, which was successful. The diversification of agriculture and livestock had diversified the income sources of the community, which had strengthened their capacity to cope with, and adapt to, climate change and its impact.

Water Resources Management

Changes in precipitation patterns had affected the sources of irrigation water. Landslides and flash floods caused by the increase in the events of intensive rains had destroyed irrigation channels and affected the water discharge in the streams. The streambeds had risen because of deposition of debris, which had covered up the stream water, making it inaccessible for irrigation. Local people had switched from irrigated crops like paddy to less water-requiring crops like maize when such irrigation channels were destroyed. In some cases, they left the land fallow. During dry season, it was not possible to cultivate any crop on these lands where

irrigation channels had been destroyed. Wherever possible, farmers had tried to use alternative techniques, such as wooden conveyers or pumps for lifting water for irrigation. According to the local communities, rehabilitation of irrigation channels was one of their priority demands.

Based on the needs of the communities, irrigation channels were rehabilitated. Communities were provided with high density polythene pipes and plastered concrete cement for the rehabilitation of six irrigation channels, which benefited thirty ha of land. Farmers could now grow three crops a year, including vegetables, in areas where previously they could hardly grow only one crop, viz. rice, the harvest of which was uncertain because of farmers' complete dependence on unpredictable rainwater for irrigation. This helped the beneficiary households to increase the total crop production in the area, thereby helping in food security and income generation. Increased food security and household income had strengthened their resilience to the impact of climate change and likely disasters. Based on site and preference, the farmers had now more options for different cropping patterns such as maize–rice–wheat or lentil or vegetables–maize –rice, etc.

Forest, Land and Soil Conservation

In the past, increased frequency and intensity of floods used to destroy large areas of cultivated land in the area. In 2006 alone, over eight ha of land was destroyed by landslides and floods. One of the demands of the communities was, therefore, protection of their land from future floods and landslides. In some cases, the houses located close to streams where floods occur frequently needed to be protected.

Based on the needs of the communities, gabion wire boxes were filled with rocks and on the riverbanks to divert the stream flow during flood periods. It helped protect the intakes of irrigation channels, lands and houses located at vulnerable sites. However, the flood of 2006 was several times bigger than the communities had anticipated. Most of the gabion wire boxes were destroyed and buried under the debris. There was, of course, need for some technical improvements. There could be further larger and intensive events of landslides and floods, for which the communities must be prepared and protected. The investment this time was too small to enable the riverbanks to withstand the impact of intensive rainfall and flash floods.

Interventions had now been made to erect check dams in upstream micro-catchments, together with afforestation and forest management, to reduce the deepening of gullies, occurrence of landslides and debris flow to minimize damage in downstream areas.

Tree planting had been done on both community and private lands. The preferred trees included fodder, timber and fruit species. The community members had also promoted grass species in plantations, which had effectively checked soil erosion. A community-managed forest nursery had been established to produce seedlings that were suitable to the local environment and economy. Communities had identified tree planting in upstream areas as an integral activity for coping and adaptation to prevent soil erosion and landslides in the future. They had formed Community Forest User Groups (CFUGs) to manage the existing forest, which didn't exist before the project intervention. They had controlled the intrusion by outsiders and locals to collect forest products illegally. Training had been organized for the local people in nursery production and weaving and filling of gabion wire boxes.

SALT was being promoted in the area. This technique was appropriate to the area as a large number of households were practising slash and burn farming system on non-terrace slope lands. Under this system, the land is exposed to droughts when there is no rain for long periods and to heavy soil erosion or landslides when there is intensive rainfall. Through the use of SALT, farmers were producing multipurpose crop species, including fodder, while arresting the top soil from erosion and minimizing the possibility of landslides.

Diversifying the Income and Livelihoods

Once the impact of climate change narrows down the scope of traditional livelihoods, people seek alternatives. They give first priority to making the existing livelihoods like agriculture more resilient. The second priority is to seek alternative livelihoods like income generation from the available resources and opportunities. Local resources and market opportunities are the enabling environments for alternative livelihoods. Goat rearing, vegetable growing and fruit farming are activities that make the agriculture more resilient, as well as diversifying the livelihood options to reduce the potential risks due to climate change and its impact.

New enterprises such as collection and sale of milk to the local market were also good income sources for the local people. In order to link the communities with the market system for both inputs and output, Village Livestock Health Workers' training was provided. One of the trainees had established a service centre, from where the communities receive services for livestock health and agri-inputs such as seeds and fertilizers. At the same time, these trainees had played a vital role in linking local producers and bigger markets elsewhere by acting as middlemen, thus contributing to increasing the income of the local people.

Rehabilitation of Local Infrastructure

Destruction of important local infrastructures such as bridges, trails and community buildings as a result of landslides and floods is also an impact of extreme rains and floods. More of such infrastructures are likely to be affected in the future from erratic rains, floods and

landslides. The communities are to be prepared for such events. There is a need for projecting and predicting future climate change and its impact and incorporate such factors in the planning, construction and rehabilitation of infrastructures. Although the communities in the project area needed help in a number of areas, including rehabilitation of infrastructures, only a local bridge was repaired with the help of the project of Practical Action Nepal, which was at the most strategic location. The bridge provided safe passage to the local people, especially students, during floods.

Awareness and Education to Local People and School Students

Awareness of local communities and stakeholders about climate change and its expected impact was very low. Their views on climate change were only related to their geographic boundaries. However, the area of coverage of climate is wide and beyond the local environment (Gurung 2005). A number of awareness activities, such as slide shows, interactions, educational visits, visual documentaries, etc., are required to increase the awareness of the communities and local stakeholders. The local people, especially school students, need to be aware of local weather and climate. In order to make them aware of local weather and climate, a meteorological station has been established in the project area, where school students take records of temperature and rainfall. Information materials such as booklets and posters on climate change and its global and local impact were also produced and disseminated.

Institutional Development

Climate change is a new factor that has to be recognized and mainstreamed into development and conservation endeavours. A Climate Change Impacts and Disaster Management Group (CCIDMG) had been formed in the project area. All households within the watershed were general members of this group. An executive committee of selected general members had been formed. The Group had been registered with the District Administration Office. It prepareed plans and raised funds from internal and external sources to implement climate change adaptation activities. The executive members had been trained by Practical Action in administrative and financial management. They had also been trained in planning, implementation, monitoring and reporting of activities. The Group also coordinated with the local government and service providers to access resources and services locally. The community members had been trained by Practical Action and made aware of climate change, its impact and need for adaptation. A watershed management plan in respect of adaptation to climate change had been prepared through community participation, which is expected to promote community's skills and resources to make them resilient to the impact of climate change.

IMPLEMENTATION STRATEGY OF THE PROJECT

The project was implemented in partnership with the CCIDMG, the local communities and Ecological Services Centre (ECOSCENTRE), which is a local non-governmental organization. The local communities mobilized local resources, including human resources, for community-level activities such as protection of riverbanks, afforestation, rehabilitation of irrigation channels, reconstruction of local bridges, etc. They were made responsible for various activities related to the project such as identifying, prioritizing and proposing appropriate activities to respond to observed as well as expected impact of climate change; and coordinating with local-level formal and informal organizations to share the resources and responsibilities. In addition, they had the overall responsibility for sustaining the climate change adaptation activities into the future. The local committees identified the right persons for participating in different training and awareness-raising activities.

ECOSCENTRE provided technical support to the local communities in agriculture and nursery establishment and management through training, technical advice and inputs supply. Involvement of the local NGO had helped the community develop linkages with local service providers to sustain activities after the termination of the project. It had also strengthened the capacity of local NGOs in climate change adaptation.

Besides ECOSCENTRE, agriculture experts, veterinary and livestock experts, forestry officers, sociologists and other individuals and institutions were also involved in the project for their specific inputs in training and socio-economic survey, data analysis and preparation of management plan for the area.

CONCLUSION AND RECOMMENDATION

Climate change has several local-level impact. In Nepal, the most studied subject on the impact of climate change is retreating of glacier and snowline and its subsequent impact on the formation of glacial lakes. There is inadequate information on the relationship of climate change with droughts, landslides, floods, and cold and heat waves. Studies are also lacking on the impact of climate change on agriculture, biodiversity and other sectors. Nevertheless, poor local communities are the ones most affected by the impact of climate change. Poor communities have low awareness of global climate change and its impact. There is inadequate awareness even among the professionals working in governmental and non-governmental organizations, both at grass roots and at national level. There is a need to raise the awareness of climate change and its impact among all types of stakeholders.

The communities have experienced the impact of climate change and are adopting different survival strategies. Nevertheless, most of such practices are focused on short-term coping strategies. The long-term adaptation strategies are lacking because of lack of understanding of climate change and its impact in addition to the lack of resources in the communities' control and hand. The impact of climate change is very much localized; therefore, it has to be systematically understood and subsequent coping and adaptation strategies developed and implemented locally. Although climate change has multiple effects in a given locality, the most affected sector should be taken as the entry point for developing and promoting an integrated programme.

The experience from this project suggests that the climate change adaptation approach should include a diverse range of conservation and development activities, including strategies for disaster risk reduction. The approaches might be promoted as 'Integrated Conservation and Development Approach' with ultimate goal to achieve sustainable development.

The impact of climate change has already become severe, with more severe impact likely to come. The adaptation to any climate change programme should keep the future projection in mind. If the likely future impact not taken into account, any investment in coping strategies will be a waste of resources, as they are likely to be destroyed by bigger disasters in the future. Therefore, disaster risk reduction should be an integral part of all climate change adaptation programmes.

Nepal is extremely vulnerable to the impact of climate change because of its poor economy, inadequate capacity of human resources, fragile geology, steep topography and high scale of change in temperature and precipitation. Nepal should give high priority and importance to adaptation to climate change while planning for development programmes. Improperly planned development can also amplify the impact of climate change (Gurung 2006, Pant *et al.* 2006).

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REFERENCES

Asian Development Bank 2004. Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the Kingdom of Nepal for Community-managed Irrigated Agriculture Sector Project. October 2004.

CBS 2001. *Population Census*. Kathmandu: Central Bureau of Statistics.

Dahal, R.K., Hasewaga, S., Nonomura, A., Yamakana, M., Masuda, T., Nishino, K., Bhandari, N.P. & Yatabe, R. 2006. Landslide Disaster in Shikoku Region of Japan During Typhoons of 2004. *Proceedings of International Symposium on Geo-disaster, Infrastructure Management and Protection of World Heritage Sites*. Bhaktapur: Nepal Engineering College. [pp 101–119]

Department of Hydrology and Meteorology (DHM) 1977, 1982, 1984, 1986, 1988, 1995, 1997, 1999, 2001, 2002. *Climatological Records of Nepal*, 1981 – 2000. Kathmandu, Nepal: Ministry of Water Resources, Government of Nepal

DWIDP 2006. *Disaster Review 2005. Series XIII*, July 2006. Kathmandu, Nepal: Department of Water Induced Disaster Prevention, Government of Nepal

Dyurgerov, M.D. & Meier, M.F. 2005. *Glaciers and Changing Earth System: A 2004 Snapshot*. Colorado, USA: Institute of Arctic and Alpine Research, University of Colorado.

Erickson, M. 2006. Climate Change and its Implications for Human Health in the Himalaya. *Sustainable Mountain Development in the Greater Himalaya*, **50**: 11–23.

Fujita, K., Kadota, T., Rana, B., Shrestha, R.B. & Ageta, Y. 2001. Shrinkage of Glacier AX010 in Shorong Region, Nepal Himalaya in the 1990s. *Bulletin of Glaciological Research, **18***: 51–54.

Gharti Chhetri, G. 2005. Report on PRA in Kabilash VDC ward 1 and 9, Chitwan Nepal. Kathmandu: Practical Action Nepal.

HMGN 2004. *Initial National Communication to the COP of UNFCCC*. Kathmandu: Ministry of Population and Environment, Government of Nepal.

Gurung, G.B. 2005. A Report on Vulnerability Assessment of Kabilas VDC in Ward no. 1 and 9, Chitwan, Nepal, in Respect to Climate Change Impacts, 10 - 11 December 2005. Kathmandu: Practical Action Nepal.

Gurung, G.B. 2007. *Pushkar is Now More Resilient to Impacts of Climate Change: a Personal Case Study*. Kathmandu: Practical Action Nepal.

Gurung, N. 2006. Cause of Laprak Landslide in Gorkha District and Nepane Landslide in Kaski District of Nepal and Their Remedial Measures. In *Proceedings of International Symposium on Geo-disaster, Infrastructure Management and Protection of World Heritage Sites*. November 2006. Bhaktapur: Nepal Engineering College. [pp 25 – 26].

IPCC 2007. Climate Change 2007: *The Physical Sciences Basis. In Summary for Policy Makers.* Geneva: IPCC.

Koirala, R.B. & Thapa, P.B. 2005. Field Visit Report of Chitwan and Makawanpur Districts. February 2005. Kathmandu: Practical Action Nepal

Pant, P., Hirota, K., Bhandari, N.P. & Yatabe, R. 2006. Geological and Geomorphological Analysis for Road Slopes Stability: a Case Study of Prithvi and Narayanghat – Mugling highway Sections Near Mugling. *In Proceedings of International Symposium on Geo-disaster, Infrastructure Management and Protection of World Heritage Sites. November 2006.* [pp 120–126].Bhaktapur: Nepal Engineering College.

Poudel, P.P., Joshi, J. & Devkota, B. 2006. Disastrous Landslide and its Mitigation in Matatirtha, Kathmandu. *Proceedings of International Symposium on Geo-disaster, Infrastructure Management and Protection of World Heritage Sites. November 2006* [pp 94–100]. Bhaktapur: Nepal Engineering College.

Practical Action Nepal 2006. Report on Baseline Information: Jugedi Khola Watershed. Kabilash VDC ward no. 1 and 9. Kathmandu: Practical Action Nepal.

Rajbahak, M. 2006. Weak Rainfall Activity in 2005 over Nepal. Disaster Review 2005. Series XIII, Department of Water Induced Disaster Prevention, GoN. [pp 26–28]

Regmi, B.R. & Adhikari, A. 2007. Climate Change and Human Development – Risk and Vulnerability in a Warming World – Country Case Study, Nepal. A Report Submitted to Local Initiative for Biodiversity, Research and Development, Pokhara, Kaski, Nepal.

Sharma, K.P., Moore, B. & Vorosmarty, C.J. 2000. Anthropogenic, Climatic and Hydrologic Trends in Koshi Basin, Himalaya. In: *Climate Change 4,* Dordrecht, The Netherlands: Kluwer Academic Publisher. [pp 141–165]

Sharma, K. 2006. Hydrologic Extremities of South-West Nepal in 2006. In *Proceedings of International Symposium on Geo-disaster, Infrastructure Management and Protection of World Heritage Sites*. November 2006. Nepal Engineering College, Changunarayan, Bhaktapur, Nepal. [pp 224–230]

Shrestha, A.B., Cameron, P.W., Paul, A.M. & Jack, E.D. 1999. Maximum Temperature Trend in the Himalaya and Its Vicinity: An Analysis Based on Temperature Record from Nepal for the Period 1971 – 94. *Journal of Climate, **12***: 2775–2787.

Shrestha A.B., Cameron, P.W., Jack, E.D. & Paul, A.M. 2000. Precipitation Fluctuation in the Nepal Himalaya and Its Vicinity and Relationship with Some Large Scale Climatological Parameters. *International Journal of Climatology,* **20:** 317–327.

Shrestha, B.D., Dhakal, B. & Rai, M.R. 2007. *Disaster Preparedness and Integrated Watershed Management Plan of Jugedi Stream, Kabilas VDC, Chitwan District Nepal (2007 – 2012)*. Kathmandu: Practical Action Nepal.

Shrestha, K.L. 2004. Global Change Impact Assessment for Himalayan Mountain Region: Resources Management and Sustainable Development. In Final Report. Lalitpur, Nepal: Institute for Development and Innovation.

Shrestha, O.M. 2006. Landslide Hazard Zonation Mapping in Some Parts of Kaski, Parbat, Syangja and Tanahun districts of Western Nepal. In *Proceedings of International Symposium on Geo-disaster, Infrastructure Management and Protection of World Heritage Sites.* [pp 86–93]

SOHAM 2006. *News Letter*. SOHAM – Nepal (Society of Hydrologists and Meteorologists – Nepal). **6**(2).

WWF Nepal Program 2005. *An Overview of Glaciers, Glacier's Retreat and Its Subsequent Impacts in Nepal, India and China,* Kathmandu: WWF Nepal Program.

Yamada, T., Shiraiwa, T., Kadota, T., Watanabe, T., Rana, B., Yageta, Y. & Fushimi, H. 1992. Fluctuation of Glaciers from the 1970s to 1989 in Khumbu, Sharong and Langtang Regions in Nepal Himalaya. *Bulletin of Lacier Research,* **10***:* 11-19.

[1] Field observations by the authors in 2008.

[2] Nepal Drinking Water Supply Corporation, Public Notice in *Annapurna Post*, April 15, 2007.

[3] Personal interaction with the local communities.

[4] Personal communication.

[5] Personal communication.

[6] Personal communication with Dr. Suresh Pokhrel, Agriculture Development Officer, Chitwan, Nepal, 2006.